Adaptive Server® Anywhere SQL User's Guide

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Contents

About This Manual ix
SQL Anywhere Studio documentation x
Documentation conventions xiii
The Adaptive Server Anywhere sample database xv
Finding out more and providing feedback xvi

I Designing and Creating Databases 1

1 Designing Your Database 3
Introduction 4
Database design concepts 5
The design process 11
Designing the database table properties 23

2 Working with Database Objects 25
Introduction 26
Working with databases 27
Working with tables 37
Working with views 50
Working with indexes 58
Working with temporary tables 72
Copying database objects in Sybase Central 73

3 Ensuring Data Integrity 75
Data integrity overview 76
Using column defaults 79
Using table and column constraints 85
Using domains 89
Enforcing entity and referential integrity 92
Integrity rules in the system tables 97

4 Using Transactions and Isolation Levels 99
Introduction to transactions 100
Isolation levels and consistency 104
Transaction blocking and deadlock 110
Choosing isolation levels 112
Isolation level tutorials 116
How locking works 131

Particular concurrency issues 145
Replication and concurrency 148
Summary 151

5 Monitoring and Improving Performance 153
Performance analysis tools 154
Top performance tips 161
Using the cache to improve performance 176
Using indexes to improve performance 181
Using keys to improve query performance 182
Sorting query results 184
Use of work tables in query processing 185
Monitoring database performance 187
Fragmentation 193
Profiling database procedures 197

II Querying and Modifying Data 205

6 Queries: Selecting Data from a Table 207
Query overview 208
The SELECT list: specifying columns 211
The FROM clause: specifying tables 218
The WHERE clause: specifying rows 219

7 Summarizing, Grouping and Sorting Query Results 231
Summarizing query results using aggregate functions 232
The GROUP BY clause: organizing query results into groups 237
Understanding GROUP BY 238
The HAVING clause: selecting groups of data 242
The ORDER BY clause: sorting query results 244
The ROLLUP operation: adding summary information to GROUP BY queries 247
Performing set operations on query results with UNION, INTERSECT, and EXCEPT 251
Standards and compatibility 258

8 Joins: Retrieving Data from Several Tables 261
Sample database schema 262
How joins work 263
Joins overview 264
Explicit join conditions (the ON phrase) 269
Cross joins 272
Inner and outer joins 274

Specialized joins 281
Natural joins 288
Key joins 292

9 Common Table Expressions **305**
About common table expressions 306
Typical applications of common table expressions 310
Recursive common table expressions 314
Parts explosion problems 317
Datatype declarations in recursive common table expressions 320
Least distance problem 322
Using multiple recursive common table expressions 325

10 Using Subqueries **327**
Introduction to subqueries 328
Using subqueries in the WHERE clause 329
Subqueries in the HAVING clause 330
Subquery comparison test 332
Quantified comparison tests with ANY and ALL 333
Testing set membership with IN conditions 336
Existence test 338
Outer references 340
Subqueries and joins 341
Nested subqueries 343
How subqueries work 345

11 Adding, Changing, and Deleting Data **355**
Data modification statements 356
Adding data using INSERT 357
Changing data using UPDATE 362
Changing data using INSERT 364
Deleting data using DELETE 365

12 Query Optimization and Execution **367**
The role of the optimizer 368
How the optimizer works 369
Query execution algorithms 379
Physical data organization and access 392
Indexes 395
Semantic query transformations 404
Subquery and function caching 418
Reading access plans 420

III SQL Dialects and Compatibility 437

13 Transact-SQL Compatibility 439
An overview of Transact-SQL support 440
Adaptive Server architectures 443
Configuring databases for Transact-SQL compatibility 449
Writing compatible SQL statements 458
Transact-SQL procedure language overview 463
Automatic translation of stored procedures 466
Returning result sets from Transact-SQL procedures 467
Variables in Transact-SQL procedures 468
Error handling in Transact-SQL procedures 469

14 Differences from Other SQL Dialects 473
Adaptive Server Anywhere SQL features 474

IV XML in the Database 477

15 Using XML in the Database 479
What is XML? 480
Storing XML documents in relational databases 481
Exporting relational data as XML 482
Importing XML documents as relational data 483
Obtaining query results as XML 490
Using SQL/XML to obtain query results as XML 510

V Remote Data and Bulk Operations 519

16 Importing and Exporting Data 521
Introduction to import and export 522
Importing and exporting data 524
Importing 528
Exporting 532
Rebuilding databases 539
Extracting data 547
Migrating databases to Adaptive Server Anywhere 548
Running SQL command files 553
Adaptive Server Enterprise compatibility 556

17 Accessing Remote Data 557
Introduction 558
Basic concepts to access remote data 560

Working with remote servers 562
Working with external logins 567
Working with proxy tables 569
Joining remote tables 574
Joining tables from multiple local databases 576
Sending native statements to remote servers 577
Using remote procedure calls (RPCs) 578
Transaction management and remote data 581
Internal operations 583
Troubleshooting remote data access 587

18 Server Classes for Remote Data Access **589**
Overview 590
JDBC-based server classes 591
ODBC-based server classes 594

VI Stored Procedures and Triggers 607

19 Using Procedures, Triggers, and Batches **609**
Procedure and trigger overview 611
Benefits of procedures and triggers 612
Introduction to procedures 613
Introduction to user-defined functions 620
Introduction to triggers 624
Introduction to batches 631
Control statements 633
The structure of procedures and triggers 636
Returning results from procedures 640
Using cursors in procedures and triggers 646
Errors and warnings in procedures and triggers 649
Using the EXECUTE IMMEDIATE statement in procedures 658
Transactions and savepoints in procedures and triggers 660
Tips for writing procedures 661
Statements allowed in batches 663
Calling external libraries from procedures 664

20 Debugging Logic in the Database **673**
Introduction to debugging in the database 674
Tutorial: Getting started with the debugger 676
Working with breakpoints 685
Working with variables 688
Working with connections 689

Index 691

About This Manual

Subject

This book describes how to design and create databases; how to import, export, and modify data; how to retrieve data; and how to build stored procedures and triggers.

Audience

This manual is for all users of Adaptive Server Anywhere.

Before you begin

This manual assumes that you have an elementary familiarity with database-management systems and Adaptive Server Anywhere in particular. If you do not have such a familiarity, you should consider reading *Adaptive Server Anywhere Getting Started* before reading this manual.

SQL Anywhere Studio documentation

This book is part of the SQL Anywhere documentation set. This section describes the books in the documentation set and how you can use them.

The SQL Anywhere Studio documentation

The SQL Anywhere Studio documentation is available in a variety of forms: in an online form that combines all books in one large help file; as separate PDF files for each book; and as printed books that you can purchase. The documentation consists of the following books:

- **Introducing SQL Anywhere Studio** This book provides an overview of the SQL Anywhere Studio database management and synchronization technologies. It includes tutorials to introduce you to each of the pieces that make up SQL Anywhere Studio.

- **What's New in SQL Anywhere Studio** This book is for users of previous versions of the software. It lists new features in this and previous releases of the product and describes upgrade procedures.

- **Adaptive Server Anywhere Getting Started** This book is for people new to relational databases or new to Adaptive Server Anywhere. It provides a quick start to using the Adaptive Server Anywhere database-management system and introductory material on designing, building, and working with databases.

- **Adaptive Server Anywhere Database Administration Guide** This book covers material related to running, managing, and configuring databases and database servers.

- **Adaptive Server Anywhere SQL User's Guide** This book describes how to design and create databases; how to import, export, and modify data; how to retrieve data; and how to build stored procedures and triggers.

- **Adaptive Server Anywhere SQL Reference Manual** This book provides a complete reference for the SQL language used by Adaptive Server Anywhere. It also describes the Adaptive Server Anywhere system tables and procedures.

- **Adaptive Server Anywhere Programming Guide** This book describes how to build and deploy database applications using the C, C++, and Java programming languages. Users of tools such as Visual Basic and PowerBuilder can use the programming interfaces provided by those tools. It also describes the Adaptive Server Anywhere ADO.NET data provider.

- **Adaptive Server Anywhere Error Messages** This book provides a complete listing of Adaptive Server Anywhere error messages together with diagnostic information.
- **SQL Anywhere Studio Security Guide** This book provides information about security features in Adaptive Server Anywhere databases. Adaptive Server Anywhere 7.0 was awarded a TCSEC (Trusted Computer System Evaluation Criteria) C2 security rating from the U.S. Government. This book may be of interest to those who wish to run the current version of Adaptive Server Anywhere in a manner equivalent to the C2-certified environment.
- **MobiLink Synchronization User's Guide** This book describes how to use the MobiLink data synchronization system for mobile computing, which enables sharing of data between a single Oracle, Sybase, Microsoft or IBM database and many Adaptive Server Anywhere or UltraLite databases.
- **MobiLink Synchronization Reference** This book is a reference guide to MobiLink command line options, synchronization scripts, SQL statements, stored procedures, utilities, system tables, and error messages.
- **iAnywhere Solutions ODBC Drivers** This book describes how to set up ODBC drivers to access consolidated databases other than Adaptive Server Anywhere from the MobiLink synchronization server and from Adaptive Server Anywhere remote data access.
- **SQL Remote User's Guide** This book describes all aspects of the SQL Remote data replication system for mobile computing, which enables sharing of data between a single Adaptive Server Anywhere or Adaptive Server Enterprise database and many Adaptive Server Anywhere databases using an indirect link such as e-mail or file transfer.
- **SQL Anywhere Studio Help** This book includes the context-sensitive help for Sybase Central, Interactive SQL, and other graphical tools. It is not included in the printed documentation set.
- **UltraLite Database User's Guide** This book is intended for all UltraLite developers. It introduces the UltraLite database system and provides information common to all UltraLite programming interfaces.
- **UltraLite Interface Guides** A separate book is provided for each UltraLite programming interface. Some of these interfaces are provided as UltraLite components for rapid application development, and others are provided as static interfaces for C, C++, and Java development.

In addition to this documentation set, PowerDesigner and InfoMaker include their own online documentation.

Documentation formats

SQL Anywhere Studio provides documentation in the following formats:

- **Online documentation** The online documentation contains the complete SQL Anywhere Studio documentation, including both the books and the context-sensitive help for SQL Anywhere tools. The online documentation is updated with each maintenance release of the product, and is the most complete and up-to-date source of documentation.

  To access the online documentation on Windows operating systems, choose Start ➤ Programs ➤ SQL Anywhere 9 ➤ Online Books. You can navigate the online documentation using the HTML Help table of contents, index, and search facility in the left pane, as well as using the links and menus in the right pane.

  To access the online documentation on UNIX operating systems, see the HTML documentation under your SQL Anywhere installation.

- **Printable books** The SQL Anywhere books are provided as a set of PDF files, viewable with Adobe Acrobat Reader.

  The PDF files are available on the CD ROM in the *pdf_docs* directory. You can choose to install them when running the setup program.

- **Printed books** The complete set of books is available from Sybase sales or from eShop, the Sybase online store. You can access eShop by clicking How to Buy ➤ eShop at *http://www.ianywhere.com*.

Documentation conventions

This section lists the typographic and graphical conventions used in this documentation.

Syntax conventions

The following conventions are used in the SQL syntax descriptions:

- **Keywords** All SQL keywords appear in upper case, like the words ALTER TABLE in the following example:

  ALTER TABLE [*owner*.]*table-name*

- **Placeholders** Items that must be replaced with appropriate identifiers or expressions are shown like the words *owner* and *table-name* in the following example:

  ALTER TABLE [*owner*.]*table-name*

- **Repeating items** Lists of repeating items are shown with an element of the list followed by an ellipsis (three dots), like *column-constraint* in the following example:

  ADD *column-definition* [*column-constraint*, . . .]

  One or more list elements are allowed. In this example, if more than one is specified, they must be separated by commas.

- **Optional portions** Optional portions of a statement are enclosed by square brackets.

  RELEASE SAVEPOINT [*savepoint-name*]

  These square brackets indicate that the *savepoint-name* is optional. The square brackets should not be typed.

- **Options** When none or only one of a list of items can be chosen, vertical bars separate the items and the list is enclosed in square brackets.

  [**ASC** | **DESC**]

  For example, you can choose one of ASC, DESC, or neither. The square brackets should not be typed.

- **Alternatives** When precisely one of the options must be chosen, the alternatives are enclosed in curly braces and a bar is used to separate the options.

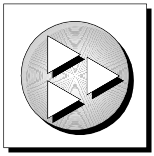
  [**QUOTES** { **ON** | **OFF** }]

  If the QUOTES option is used, one of ON or OFF must be provided. The brackets and braces should not be typed.

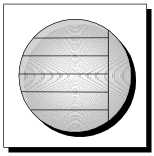
Graphic icons

The following icons are used in this documentation.

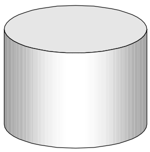
- A client application.



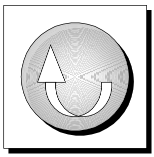
- A database server, such as Sybase Adaptive Server Anywhere.



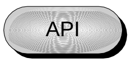
- A database. In some high-level diagrams, the icon may be used to represent both the database and the database server that manages it.



- Replication or synchronization middleware. These assist in sharing data among databases. Examples are the MobiLink Synchronization Server and the SQL Remote Message Agent.



- A programming interface.



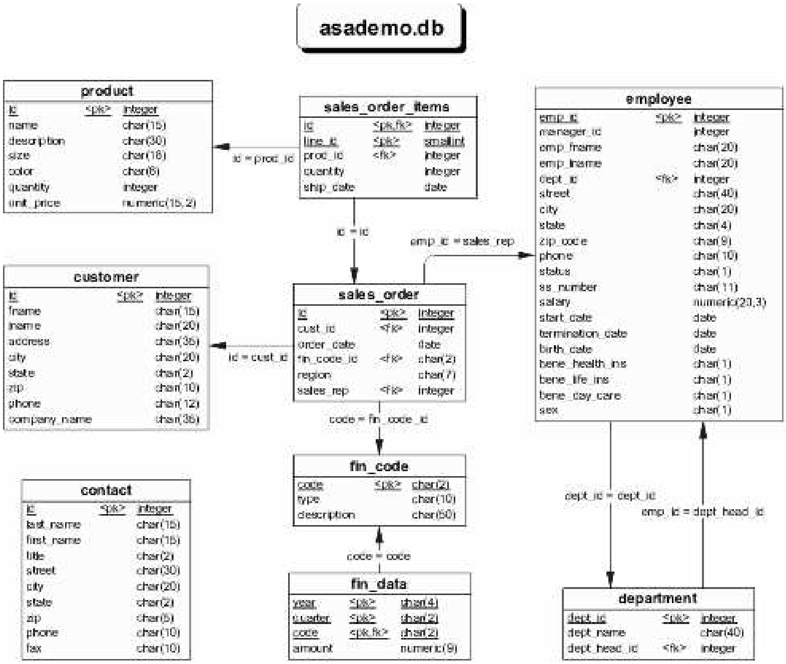
The Adaptive Server Anywhere sample database

Many of the examples throughout the documentation use the Adaptive Server Anywhere sample database.

The sample database is held in a file named *asademo.db*, and is located in your SQL Anywhere directory.

The sample database represents a small company. It contains internal information about the company (employees, departments, and finances) as well as product information and sales information (sales orders, customers, and contacts). All information in the database is fictional.

The following figure shows the tables in the sample database and how they relate to each other.



Finding out more and providing feedback

We would like to receive your opinions, suggestions, and feedback on this documentation.

You can provide feedback on this documentation and on the software through newsgroups set up to discuss SQL Anywhere technologies. These newsgroups can be found on the *forums.sybase.com* news server.

The newsgroups include the following:

- sybase.public.sqlanywhere.general.
- sybase.public.sqlanywhere.linux.
- sybase.public.sqlanywhere.mobilink.
- sybase.public.sqlanywhere.product_futures_discussion.
- sybase.public.sqlanywhere.replication.
- sybase.public.sqlanywhere.ultralite.

Newsgroup disclaimer

iAnywhere Solutions has no obligation to provide solutions, information or ideas on its newsgroups, nor is iAnywhere Solutions obliged to provide anything other than a systems operator to monitor the service and insure its operation and availability.

iAnywhere Solutions Technical Advisors as well as other staff assist on the newsgroup service when they have time available. They offer their help on a volunteer basis and may not be available on a regular basis to provide solutions and information. Their ability to help is based on their workload.

Part I

Designing and Creating Databases

This part describes key concepts and strategies for designing and building databases. It covers issues of database design as well as the mechanics of working with tables, views, and indexes. It also includes material on referential integrity and transactions.

CHAPTER 1

Designing Your Database

About this chapter

This chapter introduces the basic concepts of relational database design and gives you step-by-step suggestions for designing your own databases. It uses the expedient technique known as conceptual data modeling, which focuses on entities and the relationships between them.

Contents

Topic:	page
Introduction	4
Database design concepts	5
The design process	11
Designing the database table properties	23

Introduction

While designing a database is not a difficult task for small and medium sized databases, it is an important one. Bad database design can lead to an inefficient and possibly unreliable database system. Because client applications are built to work on specific parts of a database, and rely on the database design, a bad design can be difficult to revise at a later date.

For more information, you may also wish to consult an introductory book such as *A Database Primer* by C. J. Date. If you are interested in pursuing database theory, C. J. Date's *An Introduction to Database Systems* is an excellent textbook on the subject.

Database design concepts

In designing a database, you plan what things you want to store information about, and what information you will keep about each one. You also determine how these things are related. In the common language of database design, what you are creating during this step is a **conceptual database model**.

Entities and relationships

The distinguishable objects or things that you want to store information about are called **entities**. The associations between them are called **relationships**. In the language of database description, you can think of entities as nouns and relationships as verbs.

Conceptual models are useful because they make a clean distinction between the entities and relationships. These models hide the details involved in implementing a design in any particular database-management system. They allow you to focus on fundamental database structure. Hence, they also form a common language for the discussion of database design.

Entity-relationship diagrams

The main component of a conceptual database model is a diagram that shows the entities and relationships. This diagram is commonly called an **entity-relationship diagram**. In consequence, many people use the name entity-relationship modeling to refer to the task of creating a conceptual database model.

Conceptual database design is a top-down design method. There are now sophisticated tools such as Sybase PowerDesigner that help you pursue this method, or other approaches. This chapter is an introductory chapter only, but it does contain enough information for the design of straightforward databases.

Entities

An entity is the database equivalent of a noun. Distinguishable objects such as employees, order items, departments and products are all examples of entities. In a database, a table represents each entity. The entities that you build into your database arise from the activities for which you will be using the database, such as tracking sales calls and maintaining employee information.

Attributes

Each entity contains a number of **attributes**. Attributes are particular characteristics of the things that you would like to store. For example, in an employee entity, you might want to store an employee ID number, first and last names, an address, and other particular information that pertains to a particular employee. Attributes are also known as properties.

You depict an entity using a rectangular box. Inside, you list the attributes associated with that entity.

An identifier is one or more attributes on which all the other attributes depend. It uniquely identifies an item in the entity. Underline the names of attributes that you wish to form part of an identifier.

In the Employee entity, above, the Employee Number uniquely identifies an employee. All the other attributes store information that pertains only to that one employee. For example, an employee number uniquely determines an employee's name and address. Two employees might have the same name or the same address, but you can make sure that they don't have the same employee number. Employee Number is underlined to show that it is an identifier.

It is good practice to create an identifier for each entity. As will be explained later, these identifiers become primary keys within your tables. Primary key values must be unique and cannot be null or undefined. They identify each row in a table uniquely and improve the performance of the database server.

Relationships

A relationship between entities is the database equivalent of a verb. An employee is a member of a department, or an office is located in a city. Relationships in a database may appear as foreign key relationships between tables, or may appear as separate tables themselves. You will see examples of each in this chapter.

The relationships in the database are an encoding of rules or practices that govern the data in the entities. If each department has one department head, you can create a one-to-one relationship between departments and employees to identify the department head.

Once a relationship is built into the structure of the database, there is no provision for exceptions. There is nowhere to put a second department head. Duplicating the department entry would involve duplicating the department ID, which is the identifier. Duplicate identifiers are not allowed.

> **Tip**
> Strict database structure can benefit you, because it can eliminate inconsistencies, such as a department with two managers. On the other hand, you as the designer should make your design flexible enough to allow some expansion for unforeseen uses. Extending a well-designed database is usually not too difficult, but modifying the existing table structure can render an entire database and its client applications obsolete.

Cardinality of relationships

There are three kinds of relationships between tables. These correspond to the **cardinality** (number) of the entities involved in the relationship.

- **One-to-one relationships** You depict a relationship by drawing a line between two entities. The line may have other markings on it such as the two little circles shown. Later sections explain the purpose of these marks. In the following diagram, one employee manages one department.

- **One-to-many relationships** The fact that one item contained in Entity 1 can be associated with multiple entities in Entity 2 is denoted by the multiple lines forming the attachment to Entity 2. In the following diagram, one office can have many phones.

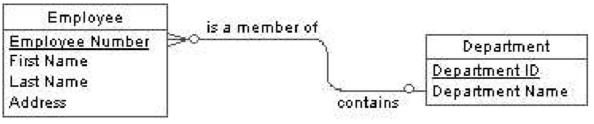
- **Many-to-many relationships** In this case, draw multiple lines for the connections to both entities. This means that one warehouse can hold many different parts, and one type of part can be stored at many warehouses.

Roles

You can describe each relationship with two **roles**. Roles are verbs or phrases that describe the relationship from each point of view. For example, a relationship between employees and departments might be described by the following two roles.

1. An employee *is a member of* a department.

2. A department *contains* an employee.



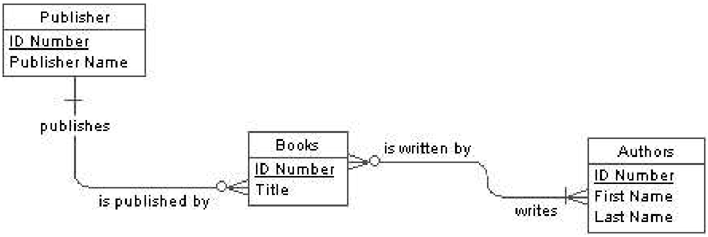
Roles are very important because they afford you a convenient and effective means of verifying your work.

> **Tip**
> Whether reading from left-to-right or from right-to-left, the following rule makes it easy to read these diagrams:Read the 1 name of the first entity, 2 role next to the *first entity* , 3 cardinality from the connection to the *second entity* , and 4 name of the second entity.

Mandatory elements

The little circles just before the end of the line that denotes the relation serve an important purpose. A circle means that an element can exist in the one entity without a corresponding element in the other entity.

If a cross bar appears in place of the circle, that entity must contain *at least* one element for each element in the other entity. An example will clarify these statements.



This diagram corresponds to the following four statements.

1. A publisher publishes *zero or more* books.

2. A book is published by *exactly one* publisher.

3. A book is written by *one or more* authors.

4. An author writes *zero or more* books.

> **Tip**
> Think of the little circle as the digit 0 and the cross bar as the number one. The circle means *at least zero* . The cross bar means *at least one* .

Reflexive relationships

Sometimes, a relationship will exist between entries in a single entity. In this case, the relationship is said to be **reflexive**. Both ends of the relationship attach to a single entity.

This diagram corresponds to the following two statements.

1. An employee reports to at most one other employee.

2. An employee manages zero or more employees.

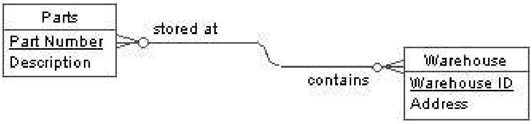
Notice that in the case of this relation, it is essential that the relation be optional in both directions. Some employees are not managers. Similarly, at least one employee should head the organization and hence report to no one.

☞ Naturally, you would also like to specify that an employee cannot be his or her own manager. This restriction is a type of *business rule* . Business rules are discussed later as part of "The design process" on page 11.

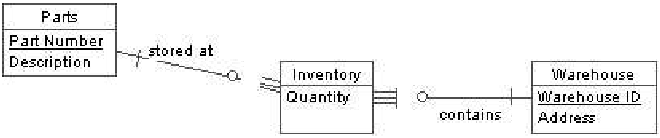
Changing many-to-many relationships into entities

When you have attributes associated with a *relationship* , rather than an entity, you can change the relationship into an entity. This situation sometimes arises with many-to-many relationships, when you have attributes that are particular to the relationship and so you cannot reasonably add them to either entity.

Suppose that your parts inventory is located at a number of different warehouses. You have drawn the following diagram.



But you wish to record the quantity of each part stored at each location. This attribute can only be associated with the relationship. Each quantity depends on both the parts and the warehouse involved. To represent this situation, you can redraw the diagram as follows:



Notice the following details of the transformation:

1. Two new relations join the relation entity with each of the two original entities. They inherit their names from the two roles of the original relationship: *stored at* and *contains* , respectively.

2. Each entry in the Inventory entity demands one mandatory entry in the Parts entity and one mandatory entry in the Warehouse entity. These relationships are mandatory because a storage relationship only makes

sense if it is associated with one particular part and one particular warehouse.

3. The new entity is dependent on both the Parts entity and on the Warehouse entity, meaning that the new entity is identified by the identifiers of both of these entities. In this new diagram, one identifier from the Parts entity and one identifier from the Warehouse entity uniquely identify an entry in the Inventory entity. The triangles that appear between the circles and the multiple lines that join the two new relationships to the new Inventory entity denote the dependencies.

Do not add either a Part Number or Warehouse ID attribute to the Inventory entity. Each entry in the Inventory entity does depend on both a particular part and a particular warehouse, but the triangles denote this dependence more clearly.

The design process

There are five major steps in the design process.

- "Step 1: Identify entities and relationships" on page 11.
- "Step 2: Identify the required data" on page 14.
- "Step 3: Normalize the data" on page 15.
- "Step 4: Resolve the relationships" on page 19.
- "Step 5: Verify the design" on page 21.

☞ For more information about implementing the database design, see "Working with Database Objects" on page 25.

Step 1:Identify entities and relationships

❖ To identify the entities in your design and their relationship to each other

1. **Define high-level activities** Identify the general activities for which you will use this database. For example, you may want to keep track of information about employees.

2. **Identify entities** For the list of activities, identify the subject areas you need to maintain information about. These subjects will become entities. For example, hire *employees* , assign to a *department* , and determine a *skill* level.

3. **Identify relationships** Look at the activities and determine what the relationships will be between the entities. For example, there is a relationship between parts and warehouses. Define two roles to describe each relationship.

4. **Break down the activities** You started out with high-level activities. Now, examine these activities more carefully to see if some of them can be broken down into lower-level activities. For example, a high-level activity such as *maintain employee information* can be broken down into:
   - Add new employees.
   - Change existing employee information.
   - Delete terminated employees.

5. **Identify business rules** Look at your business description and see what rules you follow. For example, one business rule might be that a department has one and only one department head. These rules will be built into the structure of the database.

Entity and relationship example

Example

ACME Corporation is a small company with offices in five locations. Currently, 75 employees work for ACME. The company is preparing for rapid growth and has identified nine departments, each with its own department head.

To help in its search for new employees, the personnel department has identified 68 skills that it believes the company will need in its future employee base. When an employee is hired, the employee's level of expertise for each skill is identified.

Define high-level activities

Some of the high-level activities for ACME Corporation are:

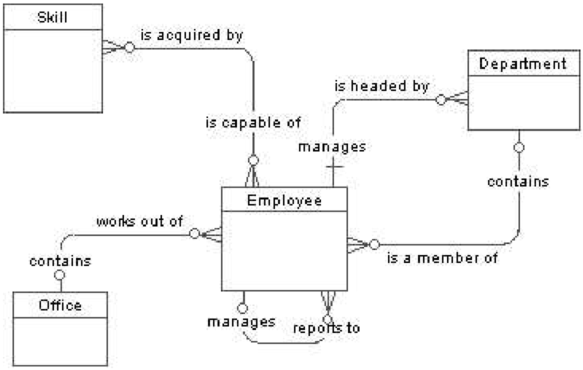
- Hire employees.
- Terminate employees.
- Maintain personal employee information.
- Maintain information on skills required for the company.
- Maintain information on which employees have which skills.
- Maintain information on departments.
- Maintain information on offices.

Identify the entities and relationships

Identify the entities (subjects) and the relationships (roles) that connect them. Create a diagram based on the description and high-level activities.

Use boxes to show entities and lines to show relationships. Use the two roles to label each relationship. You should also identify those relationships that are one-to-many, one-to-one, and many-to-many using the appropriate annotation.

Following is a rough entity-relationship diagram. It will be refined throughout the chapter.



Break down the high-level activities

The following lower-level activities below are based on the high-level activities listed above:

- Add or delete an employee.
- Add or delete an office.
- List employees for a department.
- Add a skill to the skill list.
- Identify the skills of an employee.
- Identify an employee's skill level for each skill.
- Identify all employees that have the same skill level for a particular skill.
- Change an employee's skill level.

These lower-level activities can be used to identify if any new tables or relationships are needed.

Identify business rules

Business rules often identify one-to-many, one-to-one, and many-to-many relationships.

The kind of business rules that may be relevant include the following:

- There are now five offices; expansion plans allow for a maximum of ten.
- Employees can change department or office.
- Each department has one department head.
- Each office has a maximum of three telephone numbers.
- Each telephone number has one or more extensions.
- When an employee is hired, the level of expertise in each of several skills is identified.

- Each employee can have from three to twenty skills.
- An employee may or may not be assigned to an office.

Step 2:Identify the required data

❖ To identify the required data

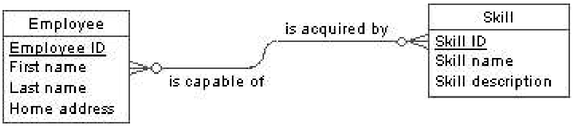
1. Identify supporting data.
2. List all the data you need to track.
3. Set up data for each entity.
4. List the available data for each entity. The data that describes an entity (subject) answers the questions who, what, where, when, and why.
5. List any data required for each relationship (verb).
6. List the data, if any, that applies to each relationship.

Identify supporting data

The supporting data you identify will become the names of the attributes of the entity. For example, the data below might apply to the Employee entity, the Skill entity, and the Expert In relationship.

Employee	Skill	Expert In
Employee ID	Skill ID	Skill level
Employee first name	Skill name	Date skill was acquired
Employee last name	Description of skill	
Employee department		
Employee office		
Employee address		

If you make a diagram of this data, it will look something like this picture:



Observe that not all of the attributes you listed appear in this diagram. The missing items fall into two categories:

1. Some are contained implicitly in other relationships; for example, Employee department and Employee office are denoted by the relations to the Department and Office entities, respectively.

2. Others are not present because they are associated not with either of these entities, but rather the relationship between them. The above diagram is inadequate.

The first category of items will fall naturally into place when you draw the entire entity-relationship diagram.

You can add the second category by converting this many-to-many relationship into an entity.

The new entity depends on both the Employee and the Skill entities. It borrows its identifiers from these entities because it depends on both of them.

Notes

- When you are identifying the supporting data, be sure to refer to the activities you identified earlier to see how you will access the data.

  For example, you may need to list employees by first name in some situations and by last name in others. To accommodate this requirement, create a First Name attribute and a Last Name attribute, rather than a single attribute that contains both names. With the names separate, you can later create two indexes, one suited to each task.

- Choose consistent names. Consistency makes it easier to maintain your database and easier to read reports and output windows.

  For example, if you choose to use an abbreviated name such as Emp_status for one attribute, you should not use a full name, such as Employee_ID, for another attribute. Instead, the names should be Emp_status and Emp_ID.

- At this stage, it is not crucial that the data be associated with the correct entity. You can use your intuition. In the next section, you'll apply tests to check your judgment.

Step 3:Normalize the data

Normalization is a series of tests that eliminate redundancy in the data and make sure the data is associated with the correct entity or relationship. There are five tests. This section presents the first three of them. These three tests are the most important and so the most frequently used.

Why normalize?
The goals of normalization are to remove redundancy and to improve consistency. For example, if you store a customer's address in multiple locations, it is difficult to update all copies correctly when they move.

☞ For more information about the normalization tests, see a book on database design.

Normal forms

There are several tests for data normalization. When your data passes the first test, it is considered to be in first normal form. When it passes the second test, it is in second normal form, and when it passes the third test, it is in third normal form.

❖ To normalize data in a database

1. List the data.
   - Identify at least one key for each entity. Each entity must have an identifier.
   - Identify keys for relationships. The keys for a relationship are the keys from the two entities that it joins.
   - Check for calculated data in your supporting data list. Calculated data is not normally stored in a relational database.
2. Put data in first normal form.
   - If an attribute can have several different values for the same entry, remove these repeated values.
   - Create one or more entities or relationships with the data that you remove.
3. Put data in second normal form.
   - Identify entities and relationships with more than one key.
   - Remove data that depends on only one part of the key.
   - Create one or more entities and relationships with the data that you remove.
4. Put data in third normal form.
   - Remove data that depends on other data in the entity or relationship, not on the key.
   - Create one or more entities and relationships with the data that you remove.

Data and identifiers

Before you begin to normalize (test your design), simply list the data and identify a unique identifier each table. The identifier can be made up of one piece of data (attribute) or several (a compound identifier).

The identifier is the set of attributes that uniquely identifies each row in an entity. For example, the identifier for the Employee entity is the Employee ID attribute. The identifier for the Works In relationship consists of the Office Code and Employee ID attributes.

You can make an identifier for each relationship in your database by taking the identifiers from each of the entities that it connects. In the following table, the attributes identified with an asterisk are the identifiers for the entity or relationship.

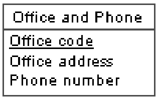
Entity or *Relationship*	**Attributes**
Office	*Office code Office address Phone number
Works in	*Office code *Employee ID
Department	*Department ID Department name
Heads	*Department ID *Employee ID
Member of	*Department ID *Employee ID
Skill	*Skill ID Skill name Skill description
Expert in	*Skill ID *Employee ID Skill level Date acquired
Employee	*Employee ID last name first name Social security number Address phone number date of birth

Putting data in first normal form

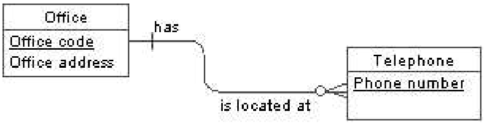
- To test for first normal form, look for attributes that can have repeating values.
- Remove attributes when multiple values can apply to a single item. Move

these repeating attributes to a new entity.

In the entity below, Phone number can repeat—an office can have more than one telephone number.



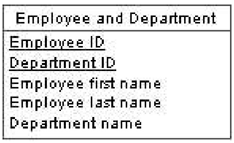
Remove the repeating attribute and make a new entity called Telephone. Set up a relationship between Office and Telephone.



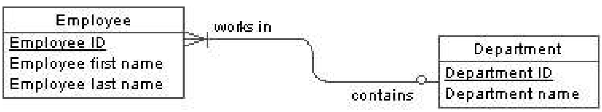
Putting data in second normal form

- Remove data that does not depend on the whole key.
- Look only at entities and relationships whose identifier is composed of more than one attribute. To test for second normal form, remove any data that does not depend on the whole identifier. Each attribute should depend on all of the attributes that comprise the identifier.

In this example, the identifier of the Employee and Department entity is composed of two attributes. Some of the data does not depend on both identifier attributes; for example, the department name depends on only one of those attributes, Department ID, and Employee first name depends only on Employee ID.



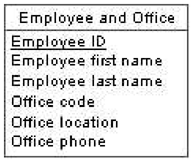
Move the identifier Department ID, which the other employee data does not depend on, to a entity of its own called Department. Also move any attributes that depend on it. Create a relationship between Employee and Department.



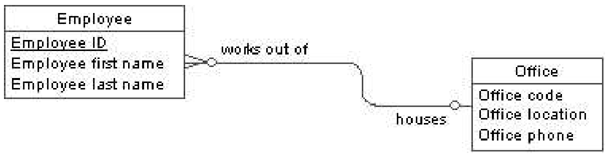
Putting data in third normal form

- Remove data that doesn't depend directly on the key.
- To test for third normal form, remove any attributes that depend on other attributes, rather than directly on the identifier.

In this example, the Employee and Office entity contains some attributes that depend on its identifier, Employee ID. However, attributes such as Office location and Office phone depend on another attribute, Office code. They do not depend directly on the identifier, Employee ID.



Remove Office code and those attributes that depend on it. Make another entity called Office. Then, create a relationship that connects Employee with Office.



Step 4:Resolve the relationships

When you finish the normalization process, your design is almost complete. All you need to do is to generate the **physical data model** that corresponds to your conceptual data model. This process is also known as resolving the relationships, because a large portion of the task involves converting the relationships in the conceptual model into the corresponding tables and foreign-key relationships.

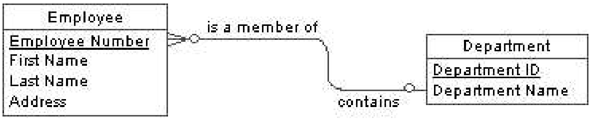
Whereas the conceptual model is largely independent of implementation details, the physical data model is tightly bound to the table structure and options available in a particular database application. In this case, that application is Adaptive Server Anywhere.

Resolving relationships that do not carry data

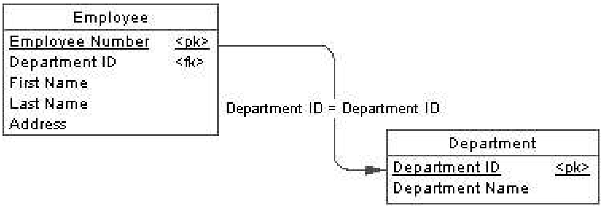
In order to implement relationships that do not carry data, you define foreign keys. A **foreign key** is a column or set of columns that contains primary key values from another table. The foreign key allows you to access data from more than one table at one time.

A database design tool such as the DataArchitect component of Sybase PowerDesigner can generate the physical data model for you. However, if you're doing it yourself there are some basic rules that help you decide where to put the keys.

- **One to many** An one-to-many relationship always becomes an entity and a foreign key relationship.

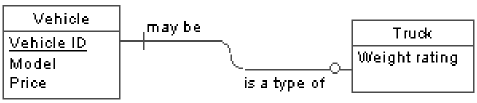


Notice that entities become tables. Identifiers in entities become (at least part of) the primary key in a table. Attributes become columns. In a one-to-many relationship, the identifier in the *one* entity will appear as a new foreign key column in the *many* table.

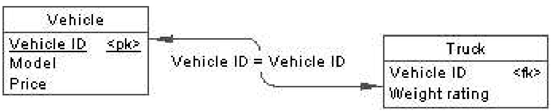


In this example, the Employee *entity* becomes an Employee *table* . Similarly, the Department entity becomes a Department table. A foreign key called Department ID appears in the Employee table.

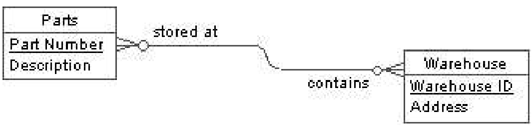
- **One to one** In a one-to-one relationship, the foreign key can go into either table. If the relationship is mandatory on one side, but optional on the other, it should go on the optional side. In this example, put the foreign key (Vehicle ID) in the Truck table because a vehicle does not have to be a truck.



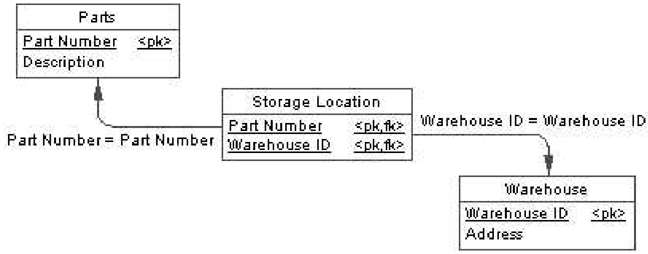
The above entity-relationship model thus resolves the database base structure, below.



- **Many to many** In a many-to-many relationship, a new table is created with two foreign keys. This arrangement is necessary to make the database efficient.

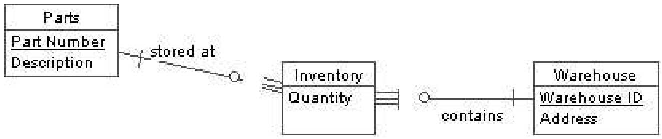


The new Storage Location table relates the Parts and Warehouse tables.



Resolving relationships that carry data

Some of your relationships may carry data. This situation often occurs in many-to-many relationships.



If this is the case, each entity resolves to a table. Each role becomes a foreign key that points to another table.

The Inventory entity borrows its identifiers from the Parts and Warehouse tables, because it depends on both of them. Once resolved, these borrowed identifiers form the primary key of the Inventory table.

Tip
A conceptual data model simplifies the design process because it hides a lot of details. For example, a many-to-many relationship always generates an extra table and two foreign key references. In a conceptual data model, you can usually denote all of this structure with a single connection.

Step 5:Verify the design

Before you implement your design, you need to make sure that it supports your needs. Examine the activities you identified at the start of the design process and make sure you can access all of the data that the activities require.

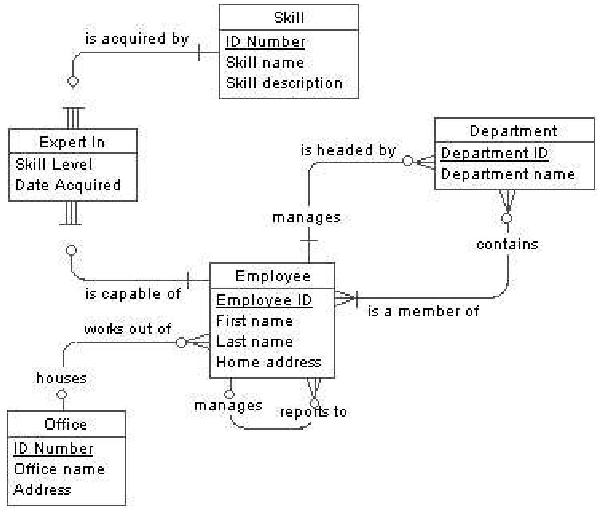
- Can you find a path to get the information you need?

- Does the design meet your needs?
- Is all of the required data available?

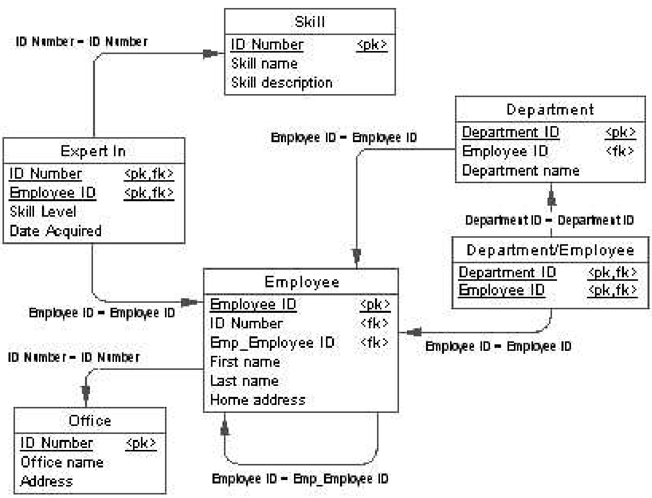
If you can answer yes to all the questions above, you are ready to implement your design.

Final design

Applying steps 1 through 3 to the database for the little company produces the following entity-relationship diagram. This database is now in third normal form.



The corresponding physical data model appears below.



Designing the database table properties

The database design specifies which tables you have and what columns each table contains. This section describes how to specify each column's properties.

For each column, you must decide the column name, the data type and size, whether or not NULL values are allowed, and whether you want the database to restrict the values allowed in the column.

Choosing column names

A column name can be any set of letters, numbers or symbols. However, you must enclose a column name in double quotes if it contains characters other than letters, numbers, or underscores, if it does not begin with a letter, or if it is the same as a keyword.

Choosing data types for columns

Available data types in Adaptive Server Anywhere include the following:

- Integer data types
- Decimal data types
- Floating-point data types
- Character data types
- Binary data types
- Date/time data types
- Domains (user-defined data types)
- Java class data types

☞ For more information about data types, see "SQL Data Types" [*ASA SQL Reference*, page 51].

The long binary data type can be used to store information such as images (for instance, stored as bitmaps) or word-processing documents in a database. These types of information are commonly called binary large objects, or BLOBS.

☞ For more information about each data type, see "SQL Data Types" [*ASA SQL Reference*, page 51].

NULL and NOT NULL

If the column value is mandatory for a record, you define the column as being NOT NULL. Otherwise, the column is allowed to contain the NULL value, which represents no value. The default in SQL is to allow NULL values, but you should explicitly declare columns NOT NULL unless there is a good reason to allow NULL values.

☞ For more information about the NULL value, see “NULL value” [*ASA SQL Reference,* page 48]. For information on its use in comparisons, see “Search conditions” [*ASA SQL Reference,* page 22].

Choosing constraints

Although the data type of a column restricts the values that are allowed in that column (for example, only numbers or only dates), you may want to further restrict the allowed values.

You can restrict the values of any column by specifying a CHECK constraint. You can use any valid condition that could appear in a WHERE clause to restrict the allowed values. Most CHECK constraints use either the BETWEEN or IN condition.

☞ For more information about valid conditions, see “Search conditions” [*ASA SQL Reference,* page 22]. For more information about assigning constraints to tables and columns, see “Ensuring Data Integrity” on page 75.

Example

The sample database has a table called Department, which has columns named dept_id, dept_name, and dept_head_id. Its definition is as follows:

Column	Data Type	Size	Null/Not Null	Constraint
dept_id	integer	—	not null	None
dept_name	char	40	not null	None
dept_head_id	integer	—	null	None

If you specify NOT NULL, a column value must be supplied for every row in the table.

CHAPTER 2

Working with Database Objects

About this chapter

This chapter describes the mechanics of creating, altering, and deleting database objects such as tables, views, and indexes.

Contents

Topic:	page
Introduction	26
Working with databases	27
Working with tables	37
Working with views	50
Working with indexes	58
Working with temporary tables	72
Copying database objects in Sybase Central	73

Introduction

With the Adaptive Server Anywhere tools, you can create a database file to hold your data. Once this file is created, you can begin managing the database. For example, you can add database objects, such as tables or users, and you can set overall database properties.

This chapter describes how to create a database and the objects within it. It includes procedures for Sybase Central, Interactive SQL, and command-line utilities. If you want more conceptual information before you begin, see the following chapters:

- "Designing Your Database" on page 3
- "Ensuring Data Integrity" on page 75
- "About Sybase Central" [*Introducing SQL Anywhere Studio,* page 48]
- "Using Interactive SQL" [*ASA Getting Started*, page 67]

The SQL statements for carrying out the tasks in this chapter are called the **data definition language** (DDL). The definitions of the database objects form the database schema: you can think of the schema as an empty database.

Procedures and triggers are also database objects, but they are discussed in "Using Procedures, Triggers, and Batches" on page 609.

Chapter contents

This chapter contains the following material:

- An introduction to working with database objects (this section)
- A description of how to create and work with the database itself
- A description of how to create and alter tables, views, and indexes

Working with databases

This section describes how to create and work with a database. As you read this section, keep in mind the following simple concepts:

- ♦ The databases that you can create (called relational databases) are a collection of tables, related by primary and foreign keys. These tables hold the information in a database, and the tables and keys together define the structure of the database. A database may be stored in one or more database files, on one or more devices.
- ♦ A database file also contains the system tables, which hold the schema definition as you build your database.

Creating a database

Adaptive Server Anywhere provides a number of ways to create a database: in Sybase Central, in Interactive SQL, and at the command line. Creating a database is also called initializing it. Once the database is created, you can connect to it and build the tables and other objects that you need in the database.

Transaction log

When you create a database, you must decide where to place the transaction log. This log stores all changes made to a database, in the order in which they are made. In the event of a media failure on a database file, the transaction log is essential for database recovery. It also makes your work more efficient. By default, it is placed in the same directory as the database file, but this is not recommended for production use.

☞ For more information on placing the transaction log, see “Configuring your database for data protection” [*ASA Database Administration Guide,* page 355].

Database file compatibility

An Adaptive Server Anywhere database is an operating system file. It can be copied to other locations just as any other file is copied.

Database files are compatible among all operating systems, except where file system file size limitations or Adaptive Server Anywhere support for large files apply. A database created from any operating system can be used from another operating system by copying the database file(s). Similarly, a database created with a personal server can be used with a network server. Adaptive Server Anywhere servers can manage databases created with earlier versions of the software, but old servers cannot manage newer databases.

☞ For more information about limitations, see “Size and number limitations” [*ASA Database Administration Guide,* page 674].

Using other applications to create databases

Some application design systems, such as Sybase PowerBuilder, contain tools for creating database objects. These tools construct SQL statements that are submitted to the server, typically through its ODBC interface. If you are using one of these tools, you do not need to construct SQL statements to create tables, assign permissions, and so on.

This chapter describes the SQL statements for defining database objects. You can use these statements directly if you are building your database from an interactive SQL tool, such as Interactive SQL. Even if you are using an application design tool, you may want to use SQL statements to add features to the database if they are not supported by the design tool.

For more advanced use, database design tools such as Sybase PowerDesigner provide a more thorough and reliable approach to developing well-designed databases.

☞ For more information about database design, see "Designing Your Database" on page 3.

Creating databases (Sybase Central)

You can create a database in Sybase Central using the Create Database utility. After you have created a database, it appears under its server in the left pane of Sybase Central.

For more information, see "Creating databases (SQL)" on page 29, and "Creating databases (command line)" on page 29.

❖ To create a new database (Sybase Central)

1. Choose Tools ➤ Adaptive Server Anywhere 9 ➤ Create Database.
2. Follow the instructions in the wizard.

❖ To create a new database based on a current connection

1. Connect to a database.
2. In the left pane, select the Adaptive Server Anywhere 9 plug-in.
3. In the right pane, click the Utilities tab.
4. In the right pane, double-click Create Database.
5. Follow the instructions in the wizard.

Creating databases for Windows CE

You can create databases for Windows CE by copying an Adaptive Server Anywhere database file to the device.

Sybase Central has features to make database creation easy for Windows CE databases. If you have Windows CE services installed on your Windows or Windows NT desktop, you have the option to create a Windows CE database when you create a database from Sybase Central. Sybase Central enforces the requirements for Windows CE databases, and optionally copies the resulting database file to your Windows CE machine.

Creating databases (SQL)

In Interactive SQL, you can use the CREATE DATABASE statement to create databases. You need to connect to an existing database before you can use this statement.

❖ To create a new database (SQL)

1. Connect to an existing database.

2. Execute a CREATE DATABASE statement.

☞ For more information, see “CREATE DATABASE statement” [*ASA SQL Reference*, page 292].

Example

Create a database file in the *c:\temp* directory with the database name *temp.db*.

```
CREATE DATABASE 'c:\\temp\\temp.db'
```

The directory path is relative to the database server. You set the permissions required to execute this statement on the server command line, using the `-gu` command-line option. The default setting requires DBA authority.

The backslash is an escape character in SQL, and must be doubled. For more information, see “Strings” [*ASA SQL Reference*, page 8].

Creating databases (command line)

You can create a database from a command line with the *dbinit* utility. With this utility, you can include command-line parameters to specify different options for the database.

❖ To create a new database (command line)

1. Open a command prompt.

2. Run the *dbinit* utility. Include any necessary parameters.

   For example, to create a database called *company.db* with a 4 Kb page size, type:

```
dbinit -p 4096 company.db
```

☞ For more information, see “The Initialization utility” [*ASA Database Administration Guide*, page 485].

Erasing a database

Erasing a database deletes all tables and data from disk, including the transaction log that records alterations to the database. All database files are read-only to prevent accidental modification or deletion of the database files.

In Sybase Central, you can erase a database using the Erase Database utility. You need to connect to a database to access this utility, but the Erase Database wizard lets you specify any database for erasing. In order to erase a non-running database, the database server must be running.

In Interactive SQL, you can erase a database using the DROP DATABASE statement. Required permissions can be set using the database server `-gu` command-line option. The default setting is to require DBA authority.

You can also erase a database from a command line with the *dberase* utility. The database to be erased must not be running when this utility is used.

❖ To erase a database (Sybase Central)

1. In the left pane, select the Adaptive Server Anywhere 9 plug-in.
2. In the right pane, click the Utilities tab.
3. In the right pane, double-click Erase Database.
4. Follow the instructions in the wizard.

❖ To erase a database (SQL)

1. Execute a DROP DATABASE statement.

   For example,

   ```
   DROP DATABASE 'c:\temp\temp.db'
   ```

❖ To erase a database (command line)

1. From a command line, run the *dberase* utility.

   For example,

   ```
   dberase company.db
   ```

☞ For more information, see “DROP DATABASE statement” [*ASA SQL Reference,* page 410], and “The Erase utility” [*ASA Database Administration Guide,* page 478].

Disconnecting from a database

When you are finished working with a database, you can disconnect from it. Adaptive Server Anywhere also gives you the ability to disconnect other users from a given database; for more information about doing this in Sybase Central, see “Managing connected users” [*ASA Database Administration Guide,* page 405].

You can obtain a user’s *connection-id* using the **connection_property** function to request the connection number. The following statement returns the connection ID of the current connection:

```
SELECT connection_property( 'number' )
```

❖ To disconnect from a database (Sybase Central)

1. Select a database.

2. Choose Tools ➤ Disconnect.

❖ To disconnect from a database (SQL)

1. Execute a DISCONNECT statement.

Example 1

The following statement shows how to use DISCONNECT from Interactive SQL to disconnect all connections:

```
DISCONNECT ALL
```

Example 2

The following statement shows how to use DISCONNECT in Embedded SQL:

```
EXEC SQL DISCONNECT :conn_name
```

❖ To disconnect other users from a database (SQL)

1. Connect to an existing database with DBA authority.

2. Execute a DROP CONNECTION statement.

Example

The following statement drops the connection with ID number 4.

```
DROP CONNECTION 4
```

☞ For more information, see "DISCONNECT statement [ESQL] [Interactive SQL]" [*ASA SQL Reference*, page 407], and "DROP CONNECTION statement" [*ASA SQL Reference*, page 411].

Setting properties for database objects

Most database objects (including the database itself) have properties that you can either view or set. Some properties are non-configurable and reflect the settings chosen when you created the database or object. Other properties are configurable.

The best way to view and set properties is to use the property sheets in Sybase Central.

If you are not using Sybase Central, properties can be specified when you create the object with a CREATE statement. If the object already exists, you can modify options with a SET OPTION statement.

❖ To view and edit the properties of a database object (Sybase Central)

1. In the left pane of Sybase Central, open the folder in which the object resides.

2. Select the object. The object's properties appear in the right pane of Sybase Central.

3. In the right pane, click the appropriate tabs to edit the desired properties.

   You can also view and edit properties on the object's property sheet. To view the property sheet, right-click the object and choose Properties from the popup menu.

Setting database options

Database options are configurable settings that change the way the database behaves or performs. In Sybase Central, all of these options are grouped together in the Database Options dialog. In Interactive SQL, you can specify an option in a SET OPTION statement.

❖ To set options for a database (Sybase Central)

1. Open the desired server.
2. Right-click the desired database and choose Options from the popup menu.
3. Edit the desired values.

❖ To set the options for a database (SQL)

1. Specify the desired properties within a SET OPTION statement.

> **Tips**
> With the Database Options dialog, you can also set database options for specific users and groups (when you open this dialog for a user or group, it is called the User Options dialog or Group Options dialog respectively).
>
> When you set options for the database itself, you are actually setting options for the PUBLIC group in that database because all users and groups inherit option settings from PUBLIC.

Specifying a consolidated database

In Sybase Central, you can specify the consolidated database for SQL Remote replication. The consolidated database is the one that serves as the “master” database in the replication setup. The consolidated database contains all of the data to be replicated, while its remote databases may only contain their own subsets of the data. In case of conflict or discrepancy, the consolidated database is considered to have the primary copy of all data.

For more information, see “Consolidated and remote databases” [*Introducing SQL Anywhere Studio*, page 21].

❖ To set a consolidated database (Sybase Central)

1. Right-click the desired database and choose Properties from the popup menu.
2. Click the SQL Remote tab.
3. Select the This Remote Database Has a Corresponding Consolidated Database option.
4. Configure the desired settings.

Displaying system objects in a database

In a database, a table, view, stored procedures, or domain is a system object. System tables store information about the database itself, while system views, procedures, and domains largely support Sybase Transact-SQL compatibility.

In Interactive SQL, you cannot display a list of all system objects, but you can browse the contents of a system table; for more information, see "Displaying system tables" on page 48.

❖ To display system objects in a database (Sybase Central)

1. Open the desired server.

2. Right-click the desired connected database and choose Filter Objects by Owner.

3. Select **SYS** and **dbo**, and then click OK.

   The system tables, system views, system procedures, and system domains appear in their respective folders. For example, system tables appear alongside normal tables in the Tables folder.

☞ For more information, see "System Tables" [*ASA SQL Reference*, page 611].

Logging SQL statements as you work with a database

As you work with a database in Sybase Central, the application automatically generates SQL statements depending on your actions. You can keep track of these statements in a separate pane, called Design Details or save the information to a file. The Design Details pane has a tab for each database and database server. The tab for database servers contains the same information as the Server Messages window.

When you work with Interactive SQL, you can also log statements that you execute.

☞ For information about logging statements in Interactive SQL, see "Logging commands" [*ASA Getting Started*, page 86].

❖ To log SQL statements generated by Sybase Central

1. From the View menu, choose Design Details.

   The Design Details pane appears at the bottom of the Sybase Central window.

2. Right-click in the Design Details pane and choose Options from the popup menu.

   The Options dialog appears.

3. In the resulting dialog, specify the desired settings. If you wish to save the logging information to a file, click the Save button.

Starting a database without connecting

With both Sybase Central and Interactive SQL, you can start a database without connecting to it.

❖ To start a database on a server without connecting (Sybase Central)

1. Right-click the desired server and choose Start Database from the popup menu.

2. In the Start Database dialog, type the desired values.

   The database appears under the server as a disconnected database.

❖ To start a database on a server without connecting (SQL)

1. Start Interactive SQL.

2. Execute a START DATABASE statement.

Example

Start the database file *c:\asa9\sample_2.db* as sam2 on the server named sample.

```
START DATABASE 'c:\asa9\sample_2.db'
AS sam2
ON sample
```

☞ For more information, see "START DATABASE statement" [*ASA SQL Reference*, page 566].

Installing the jConnect metadata support to an existing database

If a database was created without the jConnect metadata support, you can use Sybase Central to install it at a later date.

❖ To add jConnect metadata support to an existing database (Sybase Central)

1. Connect to the database you want to upgrade.
2. In the left pane, select the Adaptive Server Anywhere 9 plug-in.
3. In the right pane, click the Utilities tab.
4. In the right pane, double-click Upgrade Database.
5. Click Next on the introductory page of the wizard.
6. Select the database you want to upgrade from the list. Click Next.
7. You can choose to create a backup of the database if you wish. Click Next.
8. Select the Install jConnect Meta-Information Support option.
9. Follow the remaining instructions in the wizard.

Working with tables

When the database is first created, the only tables in the database are the system tables. System tables hold the database schema.

This section describes how to create, alter, and delete tables. You can execute the examples in Interactive SQL, but the SQL statements are independent of the administration tool you use. When you execute queries in Interactive SQL, you can edit the values in the result set.

☞ For more information, see “Editing table values in Interactive SQL” [*ASA Getting Started,* page 76].

To make it easier for you to re-create the database schema when necessary, create command files to define the tables in your database. The command files should contain the CREATE TABLE and ALTER TABLE statements.

☞ For more information about groups, tables, and connecting as another user, see “Referring to tables owned by groups” [*ASA Database Administration Guide,* page 410] and “Database object names and prefixes” [*ASA Database Administration Guide,* page 413].

Creating tables

When a database is first created, the only tables in the database are the system tables, which hold the database schema. You can then create new tables to hold your actual data, either with SQL statements in Interactive SQL or with Sybase Central.

There are two types of tables that you can create:

- **Base table** A table that holds persistent data. The table and its data continue to exist until you explicitly delete the data or drop the table. It is called a base table to distinguish it from temporary tables and from views.
- **Temporary table** Data in a temporary table is held for a single connection only. Global temporary table definitions (but not data) are kept in the database until dropped. Local temporary table definitions and data exist for the duration of a single connection only.

  ☞ For more information about temporary tables, see “Working with temporary tables” on page 72.

Tables consist of rows and columns. Each column carries a particular kind of information, such as a phone number or a name, while each row specifies a particular entry.

❖ To create a table (Sybase Central)

1. Connect to the database.
2. Open the Tables folder.
3. From the File menu, choose New ➤ Table.

   The Table Creation wizard appears.
4. In the Table Creation wizard:
   - ♦ Type a name for the new table.
   - ♦ Select an owner for the table.
   - ♦ Create a primary key for the table.
   - ♦ Configure the other desired options.
5. Click Finish.
6. On the Columns tab in the right pane, you can add columns to the table.
7. Choose File ➤ Save when finished.

❖ To create a table (SQL)

1. Connect to the database with DBA authority.
2. Execute a CREATE TABLE statement.

Example

The following statement creates a new table to describe qualifications of employees within a company. The table has columns to hold an identifying number, a name, and a type (technical or administrative) for each skill.

```
CREATE TABLE skill (
   skill_id INTEGER NOT NULL,
   skill_name CHAR( 20 ) NOT NULL,
   skill_type CHAR( 20 ) NOT NULL
)
```

☞ For more information, see “CREATE TABLE statement” [*ASA SQL Reference*, page 361].

Altering tables

This section describes how to change the structure or column definitions of a table. For example, you can add columns, change various column attributes, or delete columns entirely.

In Sybase Central, you can perform these tasks on the SQL tab in the right pane of Sybase Central. In Interactive SQL, you can perform these tasks with the ALTER TABLE statement.

If you are working with Sybase Central, you can also manage columns (add or remove them from the primary key, change their properties, or delete them) by working with menu commands when you have a column selected in the Columns folder.

☞ For information on altering database object properties, see "Setting properties for database objects" on page 32.

☞ For information on granting and revoking table permissions, see "Granting permissions on tables" [*ASA Database Administration Guide*, page 396] and "Revoking user permissions" [*ASA Database Administration Guide*, page 402].

Altering tables (Sybase Central)

You can alter tables in Sybase Central on the Columns tab in the right pane. For example, you can add or delete columns, change column definitions, or change table or column properties.

❖ To alter an existing table (Sybase Central)

1. Connect to the database.
2. Open the Tables folder.
3. In the left pane, select the table you want to alter.
4. Click the Columns tab in the right right pane and make the necessary changes.

> **Tips**
> You can add columns by selecting a table's Columns tab and choosing File ➤ Add Column.
>
> You can delete columns by selecting the column on the Columns tab and choosing File ➤ Remove Column.
>
> You can copy a column to a table by selecting the column on the Columns tab in the right pane and then clicking the Copy button. Select the desired table, click the Columns tab in the right pane, and then click the Paste button.

☞ For more information, see "ALTER TABLE statement" [*ASA SQL Reference*, page 250].

Altering tables (SQL)

You can alter tables in Interactive SQL using the ALTER TABLE statement.

❖ To alter an existing table (SQL)

1. Connect to the database with DBA authority.

2. Execute an ALTER TABLE statement.

Examples

The following command adds a column to the skill table to allow space for an optional description of the skill:

```
ALTER TABLE skill
ADD skill_description CHAR( 254 )
```

This statement adds a column called skill_description that holds up to a few sentences describing the skill.

You can also modify column attributes with the ALTER TABLE statement. The following statement shortens the skill_description column of the sample database from a maximum of 254 characters to a maximum of 80:

```
ALTER TABLE skill
MODIFY skill_description CHAR( 80 )
```

Any current entries that are longer than 80 characters are trimmed to conform to the 80-character limit, and a warning appears.

The following statement changes the name of the skill_type column to classification:

```
ALTER TABLE skill
RENAME skill_type TO classification
```

The following statement deletes the classification column.

```
ALTER TABLE skill
DROP classification
```

The following statement changes the name of the entire table:

```
ALTER TABLE skill
RENAME qualification
```

These examples show how to change the structure of the database. The ALTER TABLE statement can change just about anything pertaining to a table—you can use it to add or delete foreign keys, change columns from one type to another, and so on. In all these cases, once you make the change, stored procedures, views and any other item referring to this table will no longer work.

☞ For more information, see “ALTER TABLE statement” [*ASA SQL Reference*, page 250], and “Ensuring Data Integrity” on page 75.

Deleting tables

This section describes how to delete tables from a database. You can use either Sybase Central or Interactive SQL to perform this task. In Interactive SQL deleting a table is also called dropping it.

You cannot delete a table that is being used as an article in a SQL Remote publication. If you try to do this in Sybase Central, an error appears.

❖ To delete a table (Sybase Central)

1. Connect to the database.

2. Open the Tables folder for that database.

3. Right-click the table and choose Delete from the popup menu.

❖ To delete a table (SQL)

1. Connect to the database with DBA authority.

2. Execute a DROP TABLE statement.

Example

The following DROP TABLE command deletes all the records in the skill table and then removes the definition of the skill table from the database

```
DROP TABLE skill
```

Like the CREATE statement, the DROP statement automatically executes a COMMIT statement before and after dropping the table. This makes permanent all changes to the database since the last COMMIT or ROLLBACK. The drop statement also drops all indexes on the table.

☞ For more information, see "DROP statement" [*ASA SQL Reference,* page 408].

Browsing the information in tables

You can use Sybase Central or Interactive SQL to browse the data held within the tables of a database.

If you are working in Sybase Central, view the data in a table by clicking the Data tab in the right pane.

If you are working in Interactive SQL, execute the following statement:

```
SELECT * FROM table-name
```

You can edit the data in the table from the Interactive SQL Results tab or from Sybase Central.

Managing primary keys

The **primary key** is a unique identifier that is comprised of a column or combination of columns with values that do not change over the life of the data in the row. Because uniqueness is essential to good database design, it is best to specify a primary key when you define the table.

This section describes how to create and edit primary keys in your database. You can use either Sybase Central or Interactive SQL to perform these tasks.

> **Column order in multi-column primary keys**
> Primary key column order is determined by the order of the columns during table creation. It is not based on the order of the columns as specified in the primary key declaration.

Managing primary keys (Sybase Central)

In Sybase Central, the primary key of a table appears in several places:

- On the Columns tab of the table's property sheet.
- On the Columns tab in the right pane when a table is selected in the left pane.

The lists in both the table property sheet and on the Columns tab display the primary key columns (along with the non-key columns) in the order that they were created in the database. This may differ from the actual ordering of columns in the primary key.

❖ To create and edit the primary key (Sybase Central)

1. Open the Tables folder.
2. In the left pane, select the desired table.
3. In the right pane, click the Columns tab.
4. Change the primary as desired.

   To make a column a primary key column, place a checkmark in the checkbox beside the column name. Clear the checkbox to remote the column from the primary key.

Managing primary keys (SQL)

You can create and modify the primary key in Interactive SQL using the CREATE TABLE and ALTER TABLE statements. These statements let you set many table attributes, including column constraints and checks.

Columns in the primary key cannot contain NULL values. You must specify NOT NULL on the column in the primary key.

❖ To modify the primary key of an existing table (SQL)

1. Connect to the database with DBA authority.

2. Execute a ALTER TABLE statement.

Example 1

The following statement creates the same skill table as before, except that it adds a primary key:

```
CREATE TABLE skill (
  skill_id INTEGER NOT NULL,
  skill_name CHAR( 20 ) NOT NULL,
  skill_type CHAR( 20 ) NOT NULL,
  primary key( skill_id )
)
```

The primary key values must be unique for each row in the table which, in this case, means that you cannot have more than one row with a given skill_id. Each row in a table is uniquely identified by its primary key.

Example 2

The following statement adds the columns skill_id and skill_type to the primary key for the skill table:

```
ALTER TABLE skill (
  ADD PRIMARY KEY ( "skill_id", "skill_type" )
)
```

If a PRIMARY KEY clause is specified in an ALTER TABLE statement, the table must not already have a primary key that was created by the CREATE TABLE statement or another ALTER TABLE statement.

Example 3

The following statement removes all columns from the primary key for the skill table. Before you delete a primary key, make sure you are aware of the consequences in your database.

```
ALTER TABLE skill
  DELETE PRIMARY KEY
```

☞ For more information, see “ALTER TABLE statement” [*ASA SQL Reference*, page 250], and “Managing primary keys (Sybase Central)” on page 42.

Managing foreign keys

This section describes how to create and edit foreign keys in your database. You can use either Sybase Central or Interactive SQL to perform these tasks.

Foreign keys are used to relate values in a child table (or foreign table) to those in a parent table (or primary table). A table may have multiple foreign keys that refer to multiple parent tables linking various types of information.

Managing foreign keys (Sybase Central)

In Sybase Central, the foreign key of a table appears on the Foreign Keys tab (located on the right pane when a table is selected).

You cannot create a foreign key in a table if the table contains values for the foreign columns that can't be matched to values in the primary table's primary key.

After you have created a foreign key, you can keep track of it on each table's Referencing Tables tab in the right pane; this folder displays any foreign tables that reference the currently selected table.

❖ To create a new foreign key in a given table (Sybase Central)

1. Select the table for which you wish to create a foreign key.
2. Click the Foreign Keys tab in the right pane.
3. From the File menu, choose New > Foreign Key.

   The Foreign Key Creation wizard appears.
4. Follow the instructions in the wizard.

❖ To delete a foreign key (Sybase Central)

1. Select the table for which you wish to delete a foreign key.
2. Click the Foreign Keys tab in the right pane.
3. Right-click the foreign key you want to delete and choose Delete from the popup menu.

❖ To display which tables have foreign keys that reference a given table (Sybase Central)

1. In the left pane, select the desired table.

2. In the right pane, click the Referencing Tables tab.

> **Tips**
> When you create a foreign key using the wizard, you can set properties for the foreign key. To view properties after the foreign key is created, right-click the foreign key on the Foreign Keys tab and choose Properties from the popup menu.
>
> You can view the properties of a referencing table by right-clicking the table on the Referencing Tables tab and choosing Properties from the popup menu.

Managing foreign keys (SQL)

You can create and modify the foreign key in Interactive SQL using the CREATE TABLE and ALTER TABLE statements. These statements let you set many table attributes, including column constraints and checks.

A table can only have one primary key defined, but it may have as many foreign keys as necessary.

❖ To modify the foreign key of an existing table (SQL)

1. Connect to the database with DBA authority.

2. Execute a ALTER TABLE statement.

Example 1

You can create a table named emp_skill, which holds a description of each employee's skill level for each skill in which they are qualified, as follows:

```
CREATE TABLE emp_skill(
   emp_id INTEGER NOT NULL,
   skill_id INTEGER NOT NULL,
   "skill level" INTEGER NOT NULL,
   PRIMARY KEY( emp_id, skill_id ),
   FOREIGN KEY REFERENCES employee,
   FOREIGN KEY REFERENCES skill
)
```

The emp_skill table definition has a primary key that consists of two columns: the emp_id column and the skill_id column. An employee may have more than one skill, and so appear in several rows, and several employees may possess a given skill, so that the skill_id may appear several times. However, there may be no more than one entry for a given employee and skill combination.

The emp_skill table also has two foreign keys. The foreign key entries indicate that the emp_id column must contain a valid employee number from the employee table, and that the skill_id must contain a valid entry from the skill table.

Example 2

You can add a foreign key called foreignkey to the existing table skill and reference this foreign key to the primary key in the table contact, as follows:

```
ALTER TABLE skill
ADD FOREIGN KEY "foreignkey" ("skill_id")
REFERENCES "DBA"."contact" ("id")
```

This example creates a relationship between the skill_id column of the table skill (the foreign table) and the id column of the table contact (the primary table). The "DBA" signifies the owner of the table contact.

Example 3

You can specify properties for the foreign key as you create it. For example, the following statement creates the same foreign key as in Example 2, but it defines the foreign key as NOT NULL along with restrictions for when you update or delete.

```
ALTER TABLE skill
ADD NOT NULL FOREIGN KEY "foreignkey" ("skill_id")
REFERENCES "DBA"."contact" ("id")
ON UPDATE RESTRICT
ON DELETE RESTRICT
```

In Sybase Central, you can also specify properties in the Foreign Key Creation wizard or on the foreign key's property sheet.

☞ For more information, see "ALTER TABLE statement" [*ASA SQL Reference*, page 250], and "Managing foreign keys (Sybase Central)" on page 44.

Working with computed columns

A computed column is a column whose values are obtained from other columns. You cannot INSERT or UPDATE values in computed columns. However, any update that attempts to modify the computed column fires any triggers associated with the column.

Computed columns are declared in the CREATE TABLE or ALTER TABLE statement. Computed columns are created automatically when you create an index on a function.

Creating tables with computed columns

The following CREATE TABLE statement is used to create the product table in the Java sample tables:

```
CREATE TABLE product
(
  id    INTEGER NOT NULL,
  JProd asademo.Product NOT NULL,
  name CHAR(15) COMPUTE ( JProd>>name ),
  PRIMARY KEY ("id")
)
```

Adding computed columns to tables

The following statement adds a computed column named inventory_value to the product table:

```
ALTER TABLE product
ADD inventory_value INTEGER
  COMPUTE ( JProd.quantity * JProd.unit_price )
```

Modifying computed column expressions

You can change the expression used in a computed column with the ALTER TABLE statement. The following statement changes the expression that a computed column is based on.

```
ALTER TABLE table_name
ALTER column-name SET COMPUTE ( expression )
```

The column is recalculated when this statement is executed. If the new expression is invalid, the ALTER TABLE statement fails.

The following statement stops a column from being a computed column.

```
ALTER TABLE table_name
ALTER column-name DROP COMPUTE
```

Existing values in the column are not changed when this statement is executed, but they are no longer updated automatically.

Inserting and updating computed columns

Computed columns restrict the allowed INSERT and UPDATE statements.

- **No direct inserts or updates** You cannot insert a value directly into a computed column. If the column called Computed is a computed column, the following statement fails with a `Duplicate Insert Column` error:

  ```
  -- Incorrect statement
  INSERT INTO T1 (id, computed)
  VALUES( 3006, 'bad insert statement' )
  ```

  Similarly, you cannot use UPDATE statements to directly change the value of a computed column.

- **Listing column names** You must always explicitly specify column names in INSERT statements on tables with computed columns.

- **Triggers** If you define triggers on a computed column, any INSERT or UPDATE statement that affects the column fires the triggers.

When computed columns are recalculated

Computed columns are recalculated under the following circumstances:

- Any column is deleted, added, or renamed.
- The table is renamed.
- Any column's data type or COMPUTE clause is modified.
- A row is inserted.
- A row is updated.

Computed columns are *not* recalculated when queried. If you use a time-dependent expression, or one that depends on the state of the database in some other way, then the computed column may not give a proper result.

Copying tables or columns within/between databases

With Sybase Central, you can copy existing tables or columns and insert them into another location in the same database or into a completely different database.

☞ If you are not using Sybase Central, see one of the following locations:

- To insert SELECT statement results into a given location, see "SELECT statement" [*ASA SQL Reference*, page 541].
- To insert a row or selection of rows from elsewhere in the database into a table, see "INSERT statement" [*ASA SQL Reference*, page 476].

Displaying system tables

In a database, a table, view, stored procedure, or domain is a system object. **System tables** store the database's schema, or information about the database itself. System views, procedures, and domains largely support Sybase Transact-SQL compatibility.

All the information about tables in a database appears in the system tables. The information is distributed among several tables.

☞ For more information, see "System Tables" [*ASA SQL Reference*, page 611].

❖ To display system tables (Sybase Central)

1. Right-click the desired connected database and choose Filter Objects by Owner from the popup menu.

2. Select the checkbox beside SYS and click OK.

   The system tables, system views, system procedures, and system domains appear in their respective folders. For example, system tables appear alongside normal tables in the Tables folder.

❖ To browse system tables (SQL)

1. Connect to a database.

2. Execute a SELECT statement, specifying the system table you want to browse. The system tables are owned by the SYS user ID.

Example

Display the contents of the table sys.systable on the Results tab in the Results pane.

```
SELECT *
FROM SYS.SYSTABLE
```

Working with views

Views are computed tables. You can use views to show database users exactly the information you want to present, in a format you can control.

Similarities between views and base tables

Views are similar to the permanent tables of the database (a permanent table is also called a base table) in many ways:

- ♦ You can assign access permissions to views just as to base tables.
- ♦ You can perform SELECT queries on views.
- ♦ You can perform UPDATE, INSERT, and DELETE operations on some views.
- ♦ You can create views based on other views.

Differences between views and permanent tables

There are some differences between views and permanent tables:

- ♦ You cannot create indexes on views.
- ♦ You cannot perform UPDATE, INSERT, and DELETE operations on all views.
- ♦ You cannot assign integrity constraints and keys to views.
- ♦ Views refer to the information in base tables, but do not hold copies of that information. Views are recomputed each time you invoke them.

Benefits of tailoring access

Views let you tailor access to data in the database. Tailoring access serves several purposes:

- ♦ **Improved security** By allowing access to only the information that is relevant.
- ♦ **Improved usability** By presenting users and application developers with data in a more easily understood form than in the base tables.
- ♦ **Improved consistency** By centralizing in the database the definition of common queries.

Creating views

When you browse data, a SELECT statement operates on one or more tables and produces a result set that is also a table. Just like a base table, a result set from a SELECT query has columns and rows. A view gives a name to a particular query, and holds the definition in the database system tables.

Suppose you frequently need to list the number of employees in each department. You can get this list with the following statement:

```
SELECT dept_ID, count(*)
FROM employee
GROUP BY dept_ID
```

You can create a view containing the results of this statement using either Sybase Central or Interactive SQL.

❖ To create a new view (Sybase Central)

1. Connect to a database.
2. Open the Views folder for that database.
3. From the File menu, choose New ➤ View.

   The View Creation wizard appears.
4. Follow the instructions in the wizard. When the wizard exits, you can edit the code on the SQL tab in the right pane.
5. Complete the code by entering the table and the columns you want to use. For the example above, type **employee** and **dept_ID**.
6. From the File menu, choose Save View.

   New views appear in the Views folder.

❖ To create a new view (SQL)

1. Connect to a database.
2. Execute a CREATE VIEW statement.

Example

Create a view called DepartmentSize that contains the results of the SELECT statement given at the beginning of this section:

```
CREATE VIEW DepartmentSize AS
SELECT dept_ID, count(*)
FROM employee
GROUP BY dept_ID
```

Since the information in a view is not stored separately in the database, referring to the view executes the associated SELECT statement to retrieve the appropriate data.

On one hand, this is good because it means that if someone modifies the employee table, the information in the DepartmentSize view is automatically brought up to date. On the other hand, complicated SELECT statements may increase the amount of time SQL requires to find the correct information every time you use the view.

☞ For more information, see "CREATE VIEW statement" [*ASA SQL Reference*, page 382].

Using views

Restrictions on SELECT statements

There are some restrictions on the SELECT statements you can use as views. In particular, you cannot use an ORDER BY clause in the SELECT query. A characteristic of relational tables is that there is no significance to the ordering of the rows or columns, and using an ORDER BY clause would impose an order on the rows of the view. You can use the GROUP BY clause, subqueries, and joins in view definitions.

To develop a view, tune the SELECT query by itself until it provides exactly the results you need in the format you want. Once you have the SELECT query just right, you can add a phrase in front of the query to create the view. For example,

```
CREATE VIEW viewname AS
```

Updating views

UPDATE, INSERT, and DELETE statements are allowed on some views, but not on others, depending on its associated SELECT statement.

You cannot update views containing aggregate functions, such as COUNT(*). Nor can you update views containing a GROUP BY clause in the SELECT statement, or views containing a UNION operation. In all these cases, there is no way to translate the UPDATE into an action on the underlying tables.

Copying views

In Sybase Central, you can copy views between databases. To do so, select the view in the right pane of Sybase Central and drag it to the Views folder of another connected database. A new view is then created, and the original view's code is copied to it.

Note that only the view code is copied to the new view. The other view properties, such as permissions, are not copied.

Using the WITH CHECK OPTION clause

Even when INSERT and UPDATE statements are allowed against a view, it is possible that the inserted or updated rows in the underlying tables may not meet the requirements for the view itself. For example, the view has no new rows even though the INSERT or UPDATE modified the underlying tables.

Examples using the WITH CHECK OPTION clause

The following example illustrates the usefulness of the WITH CHECK OPTION clause. This optional clause is the final clause in the CREATE VIEW statement.

❖ To create a view displaying the employees in the sales department (SQL)

1. Type the following statements:

```
CREATE VIEW sales_employee
AS SELECT emp_id,
      emp_fname,
      emp_lname,
      dept_id
FROM employee
WHERE dept_id = 200
```

   The contents of this view are as follows:

```
SELECT *
FROM sales_employee
```

   They appear in Interactive SQL as follows:

emp_id	emp_fname	emp_lname	dept_id
129	Philip	Chin	200
195	Marc	Dill	200
299	Rollin	Overbey	200
467	James	Klobucher	200
...	...	...	...

2. **Transfer Philip Chin to the marketing department** This view update causes the entry to vanish from the view, as it no longer meets the view selection criterion.

```
UPDATE sales_employee
SET dept_id = 400
WHERE emp_id = 129
```

3. **List all employees in the sales department** Inspect the view.

```
SELECT *
FROM sales_employee
```

Emp_id	Emp_fname	Emp_lname	Dept_id
129	Philip	Chin	200
195	Marc	Dill	200
299	Rollin	Overbey	200
467	James	Klobucher	200
...	...	...	...

4. **List all employees in the sales department** Inspect the view.

```
SELECT *
FROM sales_employee
```

Emp_id	emp_fname	emp_lname	dept_id
195	Marc	Dill	200
299	Rollin	Overbey	200
467	James	Klobucher	200
641	Thomas	Powell	200
...	...	...	...

When you create a view using the WITH CHECK OPTION, any UPDATE or INSERT statement on the view is checked to ensure that the new row matches the view condition. If it does not, the operation causes an error and is rejected.

The following modified sales_employee view rejects the update statement, generating the following error message:

```
Invalid value for column 'dept_id' in table 'employee'
```

- **Create a view displaying the employees in the sales department (second attempt)** Use WITH CHECK OPTION this time.

```
CREATE VIEW sales_employee
AS SELECT emp_id, emp_fname, emp_lname, dept_id
    FROM employee
    WHERE dept_id = 200
WITH CHECK OPTION
```

The check option is inherited

If a view (say V2) is defined on the sales_employee view, any updates or inserts on V2 that cause the WITH CHECK OPTION criterion on sales_employee to fail are rejected, even if V2 is defined without a check option.

Modifying views

You can modify a view using both Sybase Central and Interactive SQL. When doing so, you cannot rename an existing view directly. Instead, you must create a new view with the new name, copy the previous code to it, and then delete the old view.

In Sybase Central, you can edit the code of views, procedures, and functions on the object's SQL tab in the right pane. You edit a view in a separate window by right-clicking the view and choosing Edit In New Window from the popup menu. In Interactive SQL, you can use the ALTER VIEW statement to modify a view. The ALTER VIEW statement replaces a view definition with a new definition, but it maintains the permissions on the view.

☞ For more information on altering database object properties, see "Setting properties for database objects" on page 32.

☞ For more information on setting permissions, see "Granting permissions on tables" [*ASA Database Administration Guide*, page 396] and "Granting permissions on views" [*ASA Database Administration Guide*, page 398]. For information about revoking permissions, see "Revoking user permissions" [*ASA Database Administration Guide*, page 402].

❖ To edit a view definition (Sybase Central)

1. Open the Views folder.

2. Select the desired view.

3. In the right pane, click the SQL tab and edit the view's code.

> **Tip**
> If you wish to edit multiple views, you may wish to open separate windows for each view rather than editing each view on the SQL tab in the right pane. You can open a separate window by right-clicking a view and choosing Edit In New Window from the popup menu.

❖ To edit a view definition (SQL)

1. Connect to a database with DBA authority or as the owner of the view.

2. Execute an ALTER VIEW statement.

Example

Rename the column names of the DepartmentSize view (described in the "Creating views" on page 50 section) so that they have more informative names.

```
ALTER VIEW DepartmentSize
  (Dept_ID, NumEmployees)
AS
  SELECT dept_ID, count(*)
  FROM Employee
  GROUP BY dept_ID
```

☞ For more information, see "ALTER VIEW statement" [*ASA SQL Reference*, page 259].

Deleting views

You can delete a view in both Sybase Central and Interactive SQL.

❖ To delete a view (Sybase Central)

1. Open the Views folder.

2. Right-click the desired view and choose Delete from the popup menu.

❖ To delete a view (SQL)

1. Connect to a database with DBA authority or as the owner of the view.

2. Execute a DROP VIEW statement.

Examples

Remove a view called DepartmentSize.

```
DROP VIEW DepartmentSize
```

☞ For more information, see “DROP statement” [*ASA SQL Reference,* page 408].

Browsing the information in views

To browse the data held within the views, you can use the Interactive SQL utility. This utility lets you execute queries to identity the data you want to view. For more information about using these queries, see “Queries: Selecting Data from a Table” on page 207.

If you are working in Sybase Central, you can right-click a view on which you have permission and choose View Data in Interactive SQL from the popup menu. This command opens Interactive SQL with the view contents displayed on the Results tab in the Results pane. To browse the view, Interactive SQL executes a `select * from owner.view` statement.

Views in the system tables

All the information about views in a database is held in the system table SYS.SYSTABLE. The information is presented in a more readable format in the system view SYS.SYSVIEWS. For more information about these, see “SYSTABLE system table” [*ASA SQL Reference,* page 678], and “SYSVIEWS system view” [*ASA SQL Reference,* page 700].

You can use Interactive SQL to browse the information in these tables. Type the following statement in the SQL Statements pane to see all the columns in the SYS.SYSVIEWS view:

```
SELECT *
FROM SYS.SYSVIEWS
```

To extract a text file containing the definition of a specific view, use a statement such as the following:

```
SELECT viewtext FROM SYS.SYSVIEWS
   WHERE viewname = 'DepartmentSize';
OUTPUT TO viewtext.sql
FORMAT ASCII
```

Working with indexes

Performance is an important consideration when designing and creating your database. Indexes can dramatically improve the performance of statements that search for a specific row or a specific subset of the rows. On the other hand, indexes take up additional disk space and may slow inserts, updates, and deletes.

Choosing a set of indexes

Choosing an appropriate set of indexes for a database is an important part of optimizing performance. Identifying an appropriate set can also be a demanding problem. The performance benefits from some indexes may be significant, but there are also costs associated with indexes, in both storage space and in overhead when modifying data.

The Index Consultant is a tool to assist you in proper selection of indexes. It analyzes either a single query or a set of operations, and recommends which indexes to add to your database. It also notifies you of indexes that are unused.

☞ For more information about the Index Consultant, see "Starting the Index Consultant" on page 65.

When to use indexes

An index provides an ordering on the rows in a column or columns of a table. An index is like a telephone book that initially sorts people by surname, and then sorts identical surnames by first names. This ordering speeds up searches for phone numbers for a particular surname, but it does not provide help in finding the phone number at a particular address. In the same way, a database index is useful only for searches on a specific column or columns.

Indexes get more useful as the size of the table increases. The average time to find a phone number at a given address increases with the size of the phone book, while it does not take much longer to find the phone number of, say, K. Kaminski, in a large phone book than in a small phone book.

The database server query optimizer automatically uses an index when a suitable index exists and when using one will improve performance.

Use indexes for frequently-searched columns

Indexes require extra space and may slightly reduce the performance of statements that modify the data in the table, such as INSERT, UPDATE, and DELETE statements. However, they can improve search performance dramatically and are highly recommended whenever you search data frequently.

☞ For more information about performance, see "Using indexes" on page 163.

Adaptive Server Anywhere automatically indexes primary key and foreign key columns. Thus, manually creating an index on a key column is not necessary and generally not recommended. If a column is only part of a key, an index may help.

Adaptive Server Anywhere automatically uses indexes to improve the performance of any database statement whenever it can. There is no need to explicitly refer to indexes once they are created. Also, the index is updated automatically when rows are deleted, updated or inserted.

☞ For information on altering database object properties, see "Setting properties for database objects" on page 32.

Using clustered indexes

Although standard indexes can dramatically improve the performance of statements that search for a specific row or a specific subset of the rows, two rows appearing sequentially in the index do not necessarily appear on the same page in the database.

However, you can further improve the performance of indexes by creating clustered indexes. Clustered indexes in Adaptive Server Anywhere store the table rows in approximately the same order as they appear in the corresponding index.

Using the clustered index feature increases the chance that the two rows will appear on the same page in the database. This can lead to performance benefits by further reducing the number of times each page needs to be read into memory.

For example, in a case where you select two rows that appear sequentially in a clustered index, it is possible that you are retrieving two rows that appear sequentially on the same page, thus reducing the number of pages to read into memory by half.

The clustering of indexes in Adaptive Server Anywhere is approximate. While the server attempts to preserve the key order, total clustering is not guaranteed. As well, the clustering degrades over time, as more and more rows are inserted into your database.

You can implement one clustered index per table, using the following statements:

- The CREATE TABLE statement
- The ALTER TABLE statement
- The CREATE INDEX statement
- The DECLARE LOCAL TEMPORARY TABLE statement

Several statements work in conjunction with each other to allow you to maintain and restore the clustering effect:

- The UNLOAD TABLE statement allows you to unload a table in the order of the index key.
- The LOAD TABLE statement inserts rows into the table in the order of the index key.
- The INSERT statement attempts to put new rows on the same table page as the one containing adjacent rows as per the primary key order.
- The REORGANIZE table statement can restore the clustering by rearranging the rows according to the clustering index. On tables where clustering is not specified, tables are ordered using the primary key.

The Optimizer assumes that the table rows are stored in key order and costs index scans accordingly.

Creating indexes

Indexes are created on one or more columns of a specified table. You can create indexes on base tables or temporary tables, but you cannot create an index on a view. To create an individual index, you can use either Sybase Central or Interactive SQL. You can use the Index Consultant to guide you in a proper selection of indexes for your database.

❖ To create a new index for a given table (Sybase Central)

1. Open the Indexes folder.
2. From the File menu, choose New ➤ Index.

   The Index Creation wizard appears.
3. Name the index and select the table from the list. Click Next.
4. Follow the instructions in the wizard.

   New indexes appear in the Indexes folder.

❖ To create a new index for a given table (SQL)

1. Connect to a database with DBA authority or as the owner of the table on which the index is created.

2. Execute a CREATE INDEX statement.

☞ In addition to creating indexes on one or more columns in a table, you can create indexes on a built-in function using a computed column. For more information, see “CREATE INDEX statement” [*ASA SQL Reference*, page 319].

Example

To speed up a search on employee surnames in the sample database, you could create an index called EmpNames with the following statement:

```
CREATE INDEX EmpNames
ON employee (emp_lname, emp_fname)
```

☞ For more information, see “CREATE INDEX statement” [*ASA SQL Reference*, page 319], and “Monitoring and Improving Performance” on page 153.

Validating indexes

You can validate an index to ensure that every row referenced in the index actually exists in the table. For foreign key indexes, a validation check also ensures that the corresponding row exists in the primary table, and that their hash values match. This check complements the validity checking carried out by the VALIDATE TABLE statement.

❖ To validate an index (Sybase Central)

1. Connect to a database with DBA authority or as the owner of the table on which the index is created.

2. In the left pane, open the Indexes folder.

3. Right-click the desired index and choose Validate from the popup menu.

❖ To validate an index (SQL)

1. Connect to a database with DBA authority or as the owner of the table on which the index is created.

2. Execute a VALIDATE INDEX statement.

❖ To validate an index (command line)

1. Open a command prompt.
2. Run the *dbvalid* utility.

Examples

Validate an index called EmployeeIndex. If you supply a table name instead of an index name, the primary key index is validated.

```
VALIDATE INDEX EmployeeIndex
```

Validate an index called EmployeeIndex. The **-i** switch specifies that each object name given is an index.

```
dbvalid -i EmployeeIndex
```

☞ For more information, see "VALIDATE INDEX statement" [*ASA SQL Reference,* page 602], and "The Validation utility" [*ASA Database Administration Guide,* page 547].

Dropping indexes

If an index is no longer required, you can remove it from the database in Sybase Central or in Interactive SQL.

❖ To drop an index (Sybase Central)

1. Connect to a database with DBA authority or as the owner of the table on which the index is created.
2. In the left pane, open the Indexes folder.
3. Right-click the desired index and choose Delete from the popup menu.

❖ To drop an index (SQL)

1. Connect to a database with DBA authority or as the owner of the table associated with the index.
2. Execute a DROP INDEX statement.

Example

The following statement removes the index from the database:

```
DROP INDEX EmpNames
```

☞ For more information, see "DROP statement" [*ASA SQL Reference,* page 408].

Index Consultant overview

The selection of a proper set of indexes can make a big difference to the performance of your database. To help you in the task of selecting such a set of indexes, Adaptive Server Anywhere includes an Index Consultant. The Index Consultant guides you through the process of selecting indexes for a single query or for a set of database requests (called a **workload**). It creates many different sets of virtual indexes. For each set, the Index Consultant optimizes queries and other requests as if those virtual indexes were present. The Index Consultant then gathers the results of these explorations into a set of recommendations.

There are several stages in the Index Consultant's work. Understanding these stages helps you make the most of the tool.

1. Starting the Index Consultant.

   You can run the Index Consultant from either Interactive SQL or from Sybase Central. Access the Index Consultant from Interactive SQL to analyze indexes for a single query, and from Sybase Central to analyze indexes for a workload.

   ☞ For information on how to start the Index Consultant, see "Starting the Index Consultant" on page 65.

2. Capturing a workload.

   A workload is a set of queries or other data manipulation statements over which the Index Consultant tries to optimize performance. Depending on your goals, you may wish to make your workload a representative set of operations, or you may wish to identify a set of key bottleneck operations. The Index Consultant can capture one or more workloads, and can store them for later analysis.

   For more information, see "Understanding workloads" on page 66.

3. Analyzing the workload.

   The Index Consultant analyzes a workload or single query by generating candidate indexes and exploring their effect on performance. To explore the effect of different candidate indexes, the Index Consultant repeatedly re-optimizes the queries in the workload under different sets of indexes. It does not execute the queries.

   The Index Consultant can also store the results of multiple analyses on any workload, using different settings.

   When analyzing a workload, the Index Consultant presents you with a set of options:

- **Recommend clustered indexes** If this option is selected, the Index Consultant analyzes the effect of clustered indexes as well as unclustered indexes.

  Properly selected clustered indexes can provide significant performance improvements over unclustered indexes for some workloads, but you must reorganize the table (using the REORGANIZE TABLE statement) for them to be effective. In addition, the analysis takes longer if the effects of clustered indexes are considered.

  ☞ For more information about clustered indexes, see "Using clustered indexes" on page 59.

- **Keep existing secondary indexes** The Index Consultant can carry out its analysis by either maintaining the existing set of secondary indexes in the database, or by ignoring the existing secondary indexes. A secondary index is an index that is not a unique constraint or a primary or foreign key. Indexes that are present to enforce referential integrity constraints are always considered when selecting access plans.

The analysis includes the following steps:

- **Generate candidate indexes** For each workload, the Index Consultant generates a set of candidate indexes. Creating a real index on a large table can be a time consuming operation, so the Index Consultant creates its candidates as virtual indexes. A virtual index cannot be used to actually execute queries, but the query optimizer can use virtual indexes to estimate the cost of execution plans as if such an index were available. Virtual indexes allow the Index Consultant to carry out "what-if" analysis without the expense of creating and managing real indexes. Virtual indexes have a limit of four columns.

- **Testing the benefits and costs of candidate indexes** The Index Consultant asks the Adaptive Server Anywhere query optimizer to estimate the cost of executing the queries in the workload, with and without different combinations of candidate indexes.

- **Generating recommendations** The Index Consultant assembles the results of the query costs and sorts the indexes by the total benefit they provide. It provides a SQL script, which you can run to carry out the recommendations or which you can save for your own review and analysis.

☞ For more information, see "Understanding the analysis" on page 67.

4. Implementing the recommendations.

   The Index Consultant provides a SQL script that you can run to implement its recommendations. Before doing so, you may wish to assess the recommendations in the light of your own knowledge of your database.

> **Using the Index Consultant with Interactive SQL**
> The Index Consultant can only analyze one statement at at time from ISQL.

☞ For more information, see “Assessing the recommendations” on page 69, and “Implementing the recommendations” on page 70.

Starting the Index Consultant

The Index Consultant guides you in the proper selection of indexes. You can use the Index Consultant in the following ways:

- **Interactive SQL** You can use the Index Consultant from Interactive SQL to analyze the benefits of indexes for an individual query.
- **Sybase Central** You can use the Index Consultant from Sybase Central to analyze the benefits of indexes for a workload, or set of database requests.

❖ To start the Index Consultant (Sybase Central)

1. In the left pane of Sybase Central, right-click the Indexes folder.
2. From the popup menu, choose Index Consultant.

❖ To start the Index Consultant (Interactive SQL)

1. Enter a query that you wish to analyze into the SQL Statements pane of Interactive SQL.
2. Choose Tools ➤ Index Consultant.

Stopping the Index Consultant

The Index Consultant does have an impact on database performance while it is capturing a workload for analysis. For this reason, the database server window displays an informational message while the Index Consultant is capturing a workload.

Usually, the Index Consultant is stopped from the Sybase Central user interface. There may be occasions when it is necessary to stop the Index Consultant from another machine: for example, if the Index Consultant is inadvertantly left running.

To pause or stop the capturing of a workload, call the sa_pause_workload_capture procedure or the sa_stop_workload_capture, respectively:

```
call sa_pause_workload_capture;
call sa_stop_workload_capture;
```

To stop the Index Consultant, call the sa_stop_index_consultant system stored procedure:

```
call sa_stop_index_consultant
```

Understanding the Index Consultant

Selecting the best set of indexes for a database is not a problem that has a single well-defined answer. The recommendations of the Index Consultant are based on an extensive search of the outcomes of alternative indexing schemes, and careful analysis of the costs and benefits associated with indexes. Nevertheless, the nature of the problem is such that the Index Consultant recommendations cannot be guaranteed to always lead to an optimal set of indexes.

This section describes some aspects of how the Index Consultant works. The goal of the section is to provide information that enables you to better judge the recommendations it provides.

Understanding workloads

The first step of Index Consultant operation is to capture a workload of data manipulation and query operations. It does this by capturing information as an application or set of applications carries out operations on the database.

The workload consists of all SELECT, INSERT, UPDATE, and DELETE statements executed during the capture step. The context of these operations is not captured as part of the workload. For example, although queries executed as part of a stored procedure, trigger, or event handler are captured as part of a workload, the surrounding code is not captured. This leads to the following consequences:

♦ Parameters are not captured.

  Parameterized SQL statements are stored by substituting an appropriate literal value with the statement definition. For example, if a query with a parameter in the WHERE clause is executed 15 times with different values for the parameter, the Index Consultant captures 15 distinct queries, each with a separate constant instead of the parameter.

♦ Queries against temporary tables cannot be analyzed.

Although queries against temporary tables are collected as part of the workload, the data present in the temporary table is not captured. Consequently, the query cannot be analyzed during the analysis step. The Index Consultant cannot provide recommendations for suitable indexes on temporary tables.

- Connection state is not entirely captured.

  The connection state includes the set of database options in effect when a query is executed. The OPTIMIZATION_GOAL option often has a major effect on the execution plan chosen by the optimizer, and is stored along with the query. Other options are not stored, however.

- Server state is not captured.

  The server state includes whether data is available in cache or whether it must be fetched from disk. It also includes the effect of concurrent operations.

> **Caution**
> *Do not change the database schema during the workload capture step. Do not change the database schema between the capture step and the analysis step. Such changes invalidate the Index Consultant recommendations.*

Understanding the analysis

The analysis step is carried out by repeatedly carrying out the following set of operations:

1. Create a candidate set of virtual indexes.

   A virtual index contains no actual data and cannot be used for actual query execution. It can be used by the optimizer when selecting an appropriate execution plan for a query. The Index Consultant generates many alternative sets of virtual indexes.

2. Optimize the workload operations for this candidate set of virtual indexes.

   The Index Consultant retrieves the plan for each statement in the workload, as chosen by the Adaptive Server Anywhere query optimizer. The optimizer considers applicable virtual indexes from the candidate set for each statement. However, the statements are not executed. The Index Consultant does not modify user data.

   For each query, the query optimizer compares the execution cost of many alternative execution plans. It estimates the execution cost based on an internal cost model. One important choice that influences the cost of each execution plan is which tables to access using an index, and which to access without using an index. Each set of virtual indexes opens up new execution plan alternatives and closes others.

The cost model depends on the state of the database server. Specifically, although the Index Consultant itself does not read data from disk or execute operations against the database, the cost model depends on which data is in cache and which must be accessed from disk. Therefore, running the Index Consultant may not generate the same recommendations each time you run an analysis on a particular workload. For example, running the Index Consultant on a database server that has just started up (and so has no data in cache) may provide different recommendations to running it on a database server that has been in operation for some time.

☞ For more information about the cost model, see "Optimizer estimates" on page 369.

Understanding the recommendations

The Index Consultant provides a set of tabs with the results of a given analysis. The results of an analysis can be saved for later review.

Summary tab

The Summary tab provides an overview of the workload and the analysis, including such information as the number of queries in the workload, the number of recommended indexes, the number of pages required for the recommended indexes, and the benefit that the recommended indexes are expected to yield. The benefit number is measured in internal units of cost.

Recommended Indexes tab

The Recommended Indexes tab contains data about each of the recommended indexes. Among the information provided is the following:

- **Clustered** Each table can have at most one clustered index. In some cases, a clustered index can provide significantly more benefit than an unclustered index.

  For more information about clustered indexes, see "Using clustered indexes" on page 59.

- **Pages** The estimated number of database pages required to hold the index if you choose to create it.

  For more information about database page sizes, see "The Initialization utility" [*ASA Database Administration Guide*, page 485].

- **Relative Benefit** A number from one to ten, indicating the estimated overall benefit of creating the specified index. A higher number indicates a greater estimated benefit.

  The relative benefit is computed using an internal algorithm, separately from the Total Cost Benefit column. There are several factors included in estimating the relative benefit that do not appear in the total cost benefit. For example, it can happen that the presence of one index dramatically affects the benefits associated with a second index. In this case, the relative benefit attempts to estimate the separate impact of each index.

☞ For more information, see "Assessing the recommendations" on page 69.

- **Total Benefit** The cost decrease associated with the index, summed over all operations in the workload, measured in internal units of cost.

  For more information on the cost model, see "Optimizer estimates" on page 369.

- **Update Cost** Adding an index introduces cost, both in additional storage space and in extra work required when data is modified. The Update Cost column is an estimate of the additional maintenance cost associated with an index. It is measured in internal units of cost.

- **Total Cost Benefit** The total benefit minus the update cost associated with the index.

Requests tab The Requests tab provides a breakdown of the impact of the recommendations for individual requests within the workload. The information includes the estimated cost before and after applying the recommended indexes, as well as the virtual indexes used by the query. A button enables you to view the best execution plan found for the request.

Updates tab The Updates tab provides a breakdown of the impact of the recommendations.

Unused Indexes tab The Unused Indexes tab lists indexes that already exist in the database that were not used in the execution of any requests in the workload. Only secondary indexes are listed: that is, neither indexes on primary keys and foreign keys nor unique constraints are listed.

Log tab The Log tab lists activities that have been completed for this analysis.

Assessing the recommendations

Although the Index Consultant recommendations are based on an extensive search of available options, it is good practice to evaluate the recommendations before implementing them in a production database. For example, you may wish to carry out checks such as the following:

- **Do the proposed indexes match your own expectations?** If you know the data in your database well, and you know the queries being run against the database, you may wish to check the usefulness of the proposed indexes against your own knowledge. Perhaps a proposed index only affects a single query that is run rarely, or perhaps it is on a small table and makes relatively little overall impact. Perhaps an index that the Index Consultant suggests should be dropped is used for some other task that was not included in your workload.

- **Are there strong correlations between the effects of proposed indexes?** The index recommendations attempt to evaluate the relative benefit of each index separately. It may be the case, however, that two indexes are of use only if both exist (a query may use both if they exist, and none if either is missing). You may want to study the Requests tab and inspect the query plans to see how the proposed indexes are being used.

- **Are you able to re-organize a table when creating a clustered index?** To take full advantage of a clustered index, you should reorganize the table on which it is created using the REORGANIZE TABLE statement. If the Index Consultant recommends many clustered indexes, you may have to unload and reload your database to get the full benefit. Unloading and reloading tables can be a time-consuming operation and can require large disk space resources. You may want to confirm that you have the time and resources you need to implement the recommendations.

- **Do the server and connection state during the analysis reflect a realistic state during product operation?** The results of the analysis depend on the state of the server, including which data is in the cache. They also depend on the state of the connection, including some database option settings. As the analysis creates only virtual indexes, and does not execute requests, the state of the server is essentially static during the analysis (except for changes introduced by other connections). If the state does not represent the typical operation of your database, you may wish to rerun the analysis under different conditions.

Implementing the recommendations

The Index Consultant provides its recommendations as a SQL script. You can implement the recommendations from the Index Consultant, or you can save the script for later use.

The names of the proposed indexes are generated from the name of the analysis. You may wish to rename them before creating the indexes in the database.

☞ For information on running command files from Interactive SQL, see "Running SQL command files" on page 553.

Indexes in the system tables

All the information about indexes in a database is held in the system tables SYS.SYSINDEX and SYS.SYSIXCOL. The information is presented in a more readable format in the system view SYS.SYSINDEXES. You can use Sybase Central or Interactive SQL to browse the information in these tables.

Working with temporary tables

Temporary tables, whether local or global, serve the same purpose: temporary storage of data. The difference between the two, and the advantages of each, however, lies in the duration each table exists.

A **local temporary** table exists only for the duration of a connection or, if defined inside a compound statement, for the duration of the compound statement.

☞ For more information, see “DECLARE LOCAL TEMPORARY TABLE statement” [*ASA SQL Reference*, page 397].

The definition of the **global temporary** table remains in the database permanently, but the rows exist only within a given connection. When you close the database connection, the data in the global temporary table disappears. However, the table definition remains with the database for you to access when you open your database next time.

Temporary tables are stored in the temporary file. Like any other dbspace, pages from the temporary file can be cached. Operations on temporary tables are never written to the transaction log.

☞ For more information, see “CREATE TABLE statement” [*ASA SQL Reference*, page 361].

Copying database objects in Sybase Central

In Sybase Central, you can copy existing database objects and insert them into another location in the same database or in a completely different database.

To copy an object, select the object in the left pane of Sybase Central and drag it to the appropriate folder or container, or copy the object and then paste it in the appropriate folder or container. A new object is created, and the original object's code is copied to the new object. When copying objects within the same database, you must rename the new object.

You can also paste objects onto other objects in the database. For example, if you paste a table onto a user, this gives the user permissions on the table.

Copying a database object's code for use in other applications

In Sybase Central, when you copy any of the objects from the following list, the SQL for the object is copied to the clipboard so it can be pasted into other applications, such as Interactive SQL or a text editor. For example, if you copy an index in Sybase Central and paste it into a text editor, the CREATE INDEX statement for that index appears.

- Articles
- Check constraints
- Columns (Copy button only)
- Domains
- Events
- External logins
- Foreign keys
- Indexes
- Message types
- Procedures and functions
- Publications
- Remote servers
- System triggers
- Tables
- Triggers

- UltraLite projects
- UltraLite statements
- Unique constraints
- Users
- Views
- Web services

CHAPTER 3

Ensuring Data Integrity

About this chapter

Building integrity constraints right into the database is the surest way to make sure your data stays in good shape. This chapter describes the facilities in Adaptive Server Anywhere for ensuring that the data in your database is valid and reliable.

You can enforce several types of integrity constraints. For example, you can ensure individual entries are correct by imposing constraints and CHECK constraints on tables and columns. Setting column properties by choosing an appropriate data type or setting special default values assists this task.

The SQL statements in this chapter use the CREATE TABLE and ALTER TABLE statements, basic forms of which were introduced in "Working with Database Objects" on page 25.

Contents

Topic:	page
Data integrity overview	76
Using column defaults	79
Using table and column constraints	85
Using domains	89
Enforcing entity and referential integrity	92
Integrity rules in the system tables	97

Data integrity overview

If data has integrity, the data is valid—correct and accurate—and the relational structure of the database is intact. Referential integrity constraints enforce the relational structure of the database. These rules maintain the consistency of data between tables.

Adaptive Server Anywhere supports stored procedures, which give you detailed control over how data enters the database. You can also create triggers, or customized stored procedures invoked automatically when a certain action, such as an update of a particular column, occurs.

☞ For more information on procedures and triggers see "Using Procedures, Triggers, and Batches" on page 609.

How data can become invalid

Here are a few examples of how the data in a database may become invalid if proper checks are not made. You can prevent each of these examples from occurring using facilities described in this chapter.

Incorrect information

- An operator types the date of a sales transaction incorrectly.
- An employee's salary becomes ten times too small because the operator missed a digit.

Duplicated data

- Two different people add the same new department (with **dept_id** 200) to the department table of the organization's database.

Foreign key relations invalidated

- The department identified by **dept_id** 300 closes down and one employee record inadvertently remains unassigned to a new department.

Integrity constraints belong in the database

To ensure the validity of data in a database, you need to formulate checks to define valid and invalid data, and design rules to which data must adhere (also known as business rules). Together, checks and rules become **constraints**.

Build integrity constraints into database

Constraints that are built into the database itself are more reliable than constraints that are built into client applications or that are spelled out as instructions to database users. Constraints built into the database become part of the definition of the database itself, and the database enforces them consistently across all applications. Setting a constraint once in the database imposes it for all subsequent interactions with the database.

In contrast, constraints built into client applications are vulnerable every time the software changes, and may need to be imposed in several applications, or in several places in a single client application.

How database contents change

Changes occur to information in database tables when you submit SQL statements from client applications. Only a few SQL statements actually modify the information in a database. You can:

- ♦ Update information in a row of a table using the UPDATE statement.
- ♦ Delete an existing row of a table using the DELETE statement.
- ♦ Insert a new row into a table using the INSERT statement.

Data integrity tools

To maintain data integrity, you can use defaults, data constraints, and constraints that maintain the referential structure of the database.

Defaults

You can assign default values to columns to make certain kinds of data entry more reliable. For example:

- ♦ A column can have a current date default value for recording the date of transactions with any user or client application action.
- ♦ Other types of default values allow column values to increment automatically without any specific user action other than entering a new row. With this feature, you can guarantee that items (such as purchase orders for example) are unique, sequential numbers.

☞ For more information on these and other column defaults, see "Using column defaults" on page 79.

Constraints

You can apply several types of constraints to the data in individual columns or tables. For example:

- ♦ A NOT NULL constraint prevents a column from containing a null entry.
- ♦ A CHECK constraint assigned to a column can ensure that every item in the column meets a particular condition. For example, you can ensure that salary column entries fit within a specified range and thus protect against user error when typing in new values.
- ♦ CHECK constraints can be made on the relative values in different columns. For example, you can ensure that a date_returned entry is later than a date_borrowed entry in a library database.
- ♦ Triggers can enforce more sophisticated CHECK conditions. For more information on triggers, see "Using Procedures, Triggers, and Batches" on page 609.

As well, column constraints can be inherited from domains. For more information on these and other table and column constraints, see "Using table and column constraints" on page 85.

Entity and referential integrity

Relationships, defined by the primary keys and foreign keys, tie together the information in relational database tables. You must build these relations directly into the database design. The following integrity rules maintain the structure of the database:

- **Entity integrity** Keeps track of the primary keys. It guarantees that every row of a given table can be uniquely identified by a primary key that guarantees IS NOT NULL.
- **Referential integrity** Keeps track of the foreign keys that define the relationships between tables. It guarantees that all foreign key values either match a value in the corresponding primary key or contain the NULL value if they are defined to allow NULL.

☞ For more information about enforcing referential integrity, see "Enforcing entity and referential integrity" on page 92. For more information about designing appropriate primary and foreign key relations, see "Designing Your Database" on page 3.

Triggers for advanced integrity rules

You can also use triggers to maintain data integrity. A **trigger** is a procedure stored in the database and executed automatically whenever the information in a specified table changes. Triggers are a powerful mechanism for database administrators and developers to ensure that data remains reliable.

☞ For more information about triggers, see "Using Procedures, Triggers, and Batches" on page 609.

SQL statements for implementing integrity constraints

The following SQL statements implement integrity constraints:

- **CREATE TABLE statement** This statement implements integrity constraints during creation of the database.
- **ALTER TABLE statement** This statement adds integrity constraints to an existing database, or modifies constraints for an existing database.
- **CREATE TRIGGER statement** This statement creates triggers that enforce more complex business rules.
- **CREATE DOMAIN statement** This statement creates a user-defined data type. The definition of the data type can include constraints.

☞ For more information about the syntax of these statements, see "SQL Statements" [*ASA SQL Reference*, page 213].

Using column defaults

Column defaults automatically assign a specified value to particular columns whenever someone enters a new row into a database table. The default value assigned requires no any action on the part of the client application, however if the client application does specify a value for the column, the new value overrides the column default value.

Column defaults can quickly and automatically fill columns with information, such as the date or time a row is inserted, or the user ID of the person typing the information. Using column defaults encourages data integrity, but does not enforce it. Client applications can always override defaults.

Supported default values

SQL supports the following default values:

- A string specified in the CREATE TABLE statement or ALTER TABLE statement
- A number specified in the CREATE TABLE statement or ALTER TABLE statement
- An automatically incremented number: one more than the previous highest value in the column
- Universally Unique Identifiers (UUIDs) and Globally Unique Identifiers (GUIDs) generated using the NEWID function.
- The current date, time, or timestamp
- The current user ID of the database user
- A NULL value
- A constant expression, as long as it does not reference database objects

Creating column defaults

You can use the CREATE TABLE statement to create column defaults at the time a table is created, or the ALTER TABLE statement to add column defaults at a later time.

Example

The following statement adds a condition to an existing column named **id** in the **sales_order** table, so that it automatically increments (unless a client application specifies a value):

```
ALTER TABLE sales_order
MODIFY id DEFAULT AUTOINCREMENT
```

☞ Each of the other default values is specified in a similar manner. For more information, see "ALTER TABLE statement" [*ASA SQL Reference*, page 250] and "CREATE TABLE statement" [*ASA SQL Reference*, page 361].

Modifying and deleting column defaults

You can change or remove column defaults using the same form of the ALTER TABLE statement you used to create defaults. The following statement changes the default value of a column named **order_date** from its current setting to CURRENT DATE:

```
ALTER TABLE sales_order
MODIFY order_date DEFAULT CURRENT DATE
```

You can remove column defaults by modifying them to be NULL. The following statement removes the default from the **order_date** column:

```
ALTER TABLE sales_order
MODIFY order_date DEFAULT NULL
```

Working with column defaults in Sybase Central

You can add, alter, and delete column defaults in Sybase Central using the Value tab of the column properties sheet.

❖ To display the property sheet for a column

1. Connect to the database.
2. Open the Tables folder for that database.
3. Double-click the table holding the column you want to change.
4. In the right pane, click the Columns tab.
5. Select the desired column.
6. Choose File ➤ Properties.

   The column's property sheet appears.

Current date and time defaults

For columns with the DATE, TIME, or TIMESTAMP data type, you can use the current date, current time, or current timestamp as a default. The default you choose must be compatible with the column's data type.

Useful examples of current date default

A current date default might be useful to record:

- dates of phone calls in a contact database

- dates of orders in a sales entry database
- the date a patron borrows a book in a library database

Current timestamp

The current timestamp is similar to the current date default, but offers greater accuracy. For example, a user of a contact management application may have several contacts with a single customer in one day: the current timestamp default would be useful to distinguish these contacts.

Since it records a date and the time down to a precision of millionths of a second, you may also find the current timestamp useful when the sequence of events is important in a database.

For more information about timestamps, times, and dates, see “SQL Data Types” [*ASA SQL Reference*, page 51].

The user ID default

Assigning a DEFAULT USER to a column is an easy and reliable way of identifying the person making an entry in a database. This information may be required; for example, when salespeople are working on commission.

Building a user ID default into the primary key of a table is a useful technique for occasionally connected users, and helps to prevent conflicts during information updates. These users can make a copy of tables relevant to their work on a portable computer, make changes while not connected to a multi-user database, and then apply the transaction log to the server when they return.

The AUTOINCREMENT default

The AUTOINCREMENT default is useful for numeric data fields where the value of the number itself may have no meaning. The feature assigns each new row a value of one greater than the previous highest value in the column. You can use AUTOINCREMENT columns to record purchase order numbers, to identify customer service calls or other entries where an identifying number is required.

Autoincrement columns are typically primary key columns or columns constrained to hold unique values (see “Enforcing entity integrity” on page 92). For example, autoincrement default is effective when the column is the first column of an index, because the server uses an index or key definition to find the highest value.

While using the autoincrement default in other cases is possible, doing so can adversely affect database performance. For example, in cases where the next value for each column is stored as an integer (4 bytes), using values greater than $2^{31} - 1$ or large double or numeric values may cause wraparound to negative values.

☞ You can retrieve the most recent value inserted into an autoincrement column using the @@identity global variable. For more information, see "@@identity global variable" [*ASA SQL Reference*, page 45].

Autoincrement and negative numbers

Autoincrement is intended to work with positive integers.

The initial autoincrement value is set to 0 when the table is created. This value remains as the highest value assigned when inserts are done that explicitly insert negative values into the column. An insert where no value is supplied causes the AUTOINCREMENT to generate a value of 1, forcing any other generated values to be positive.

In UltraLite applications, the autoincrement value is not set to 0 when the table is created, and AUTOINCREMENT generates negative numbers when a signed data type is used for the column.

You should define AUTOINCREMENT columns as unsigned to prevent negative values from being used.

Autoincrement and the IDENTITY column

☞ A column with the AUTOINCREMENT default is referred to in Transact-SQL applications as an IDENTITY column. For information on IDENTITY columns, see "The special IDENTITY column" on page 456.

The NEWID default

UUIDs (Universally Unique IDentifiers), also known as GUIDs (Globally Unique IDentifiers), can be used to uniquely identify rows in a table. The values are generated such that a value produced on one computer will not match that produced on another. They can therefore be used as keys in replication and synchronization environments.

Using UUID values as primary keys has some tradeoffs when you compare them with using GLOBAL AUTOINCREMENT values. For example,

- UUIDs can be easier to set up than GLOBAL AUTOINCREMENT, since there is no need to assign each remote database a unique database id. There is also no need to consider the number of databases in the system or the number of rows in individual tables. The Extraction utility [dbxtract] can be used to deal with the assignment of database ids. This isn't usually a concern for GLOBAL AUTOINCREMENT if the BIGINT datatype is used, but it needs to be considered for smaller datatypes.

- UUID values are considerably larger than those required for GLOBAL AUTOINCREMENT, and will require more table space in both primary and foreign tables. Indexes on these columns will also be less efficient when UUIDs are used. In short, GLOBAL AUTOINCREMENT is likely to perform better.

- UUIDs have no implicit ordering. For example, if A and B are UUID values, A > B does not imply that A was generated after B, even when A and B were generated on the same computer. If you require this behavior, an additional column and index may be necessary.
- If UUID values are generated by an application (as opposed to the server), the values must be inserted as UUID strings and converted using strtouuid(). Attempting to insert binary values directly may result in values colliding with those generated by the server or another system.

☞ For more information, see the “NEWID function [Miscellaneous]” [*ASA SQL Reference*, page 159] , the “STRTOUUID function [STRING]” [*ASA SQL Reference*, page 192] , the “UUIDTOSTR function [STRING]” [*ASA SQL Reference*, page 200] , or the “UNIQUEIDENTIFIER data type [Binary]” [*ASA SQL Reference*, page 73].

The NULL default

For columns that allow NULL values, specifying a NULL default is exactly the same as not specifying a default at all. If the client inserting the row does not explicitly assign a value, the row automatically receives A NULL value.

You can use NULL defaults when information for some columns is optional or not always available, and when it is not required for the data in the database be correct.

☞ For more information about the NULL value, see “NULL value” [*ASA SQL Reference*, page 48].

String and number defaults

You can specify a specific string or number as a default value, as long as the column holds a string or number data type. You must ensure that the default specified can be converted to the column’s data type.

Default strings and numbers are useful when there is a typical entry for a given column. For example, if an organization has two offices, the headquarters in **city_1** and a small office in **city_2**, you may want to set a default entry for a location column to **city_1**, to make data entry easier.

Constant expression defaults

You can use a constant expression as a default value, as long as it does not reference database objects. Constant expressions allow column defaults to contain entries such as *the date fifteen days from today* , which would be entered as

```
... DEFAULT ( dateadd( day, 15, getdate() ) )
```

Using table and column constraints

Along with the basic table structure (number, name and data type of columns, name and location of the table), the CREATE TABLE statement and ALTER TABLE statement can specify many different table attributes that allow control over data integrity. Constraints allow you to place restrictions on the values that can appear in a column, or on the relationship between values in different columns. Constraints can be either table-wide constraints, or can apply to individual columns.

> ***Caution***
> *Altering tables can interfere with other users of the database. Although you can execute the ALTER TABLE statement while other connections are active, you cannot execute the ALTER TABLE statement if any other connection is using the table you want to alter. For large tables, ALTER TABLE is a time-consuming operation, and all other requests referencing the table being altered are prohibited while the statement is processing.*

This section describes how to use constraints to help ensure the accuracy of data in the table.

Using CHECK constraints on columns

You use a CHECK condition to ensure that the values in a column satisfy some definite criterion or rule. For example, these rules or criteria may simply be required for data to be reasonable, or they may be more rigid rules that reflect organization policies and procedures.

CHECK conditions on individual column values are useful when only a restricted range of values are valid for that column.

Example 1

- You can enforce a particular formatting requirement. For example, if a table has a column for phone numbers you may wish to ensure that users type them all in the same manner. For North American phone numbers, you could use a constraint such as:

```
ALTER TABLE customer
MODIFY phone
CHECK ( phone LIKE '(___) ___-____' )
```

Example 2

- You can ensure that the entry matches one of a limited number of values. For example, to ensure that a **city** column only contains one of a certain number of allowed cities (say, those cities where the organization has offices), you could use a constraint such as:

```
ALTER TABLE office
MODIFY city
CHECK ( city IN ( 'city_1', 'city_2', 'city_3' ) )
```

- By default, string comparisons are case insensitive unless the database is explicitly created as a case-sensitive database.

Example 3

- You can ensure that a date or number falls in a particular range. For example, you may require that the **start_date** column of an employee table must be between the date the organization was formed and the current date using the following constraint:

  ```
  ALTER TABLE employee
  MODIFY start_date
  CHECK ( start_date BETWEEN '1983/06/27'
                     AND CURRENT DATE )
  ```

- You can use several date formats. The YYYY/MM/DD format in this example has the virtue of always being recognized regardless of the current option settings.

Column CHECK tests only fail if the condition returns a value of FALSE. If the condition returns a value of UNKNOWN, the change is allowed.

Using CHECK constraints on tables

A CHECK condition applied as a constraint on the table typically ensures that two values in a row being added or modified have a proper relation to each other.

When you give a name to the constraint, the constraint is held individually in the system tables, and you can replace or delete them individually. Since this is more flexible behavior, it is recommended that you either name a CHECK constraint or use an individual column constraint wherever possible.

For example, in a library database, the **date_borrowed** must come before the **date_returned**.

```
ALTER TABLE loan
ADD CONSTRAINT valid_date CHECK(date_returned >= date_borrowed)
```

☞ For more information, see "ALTER TABLE statement" [*ASA SQL Reference*, page 250].

Inheriting column CHECK constraints from domains

You can attach CHECK constraints to domains. Columns defined on those data types inherit the CHECK constraints. A CHECK constraint explicitly specified for the column overrides that from the domain.

Any column defined using the **posint** data type accepts only positive integers unless the column itself has a CHECK constraint explicitly specified. In the following example, the domain accepts only positive integers. Since any variable prefixed with the @ sign is replaced by the name of the column when the CHECK constraint is evaluated, any variable name prefixed with @ could be used instead of **@col**.

```
CREATE DATATYPE posint INT
CHECK ( @col > 0 )
```

An ALTER TABLE statement with the DELETE CHECK clause deletes all CHECK constraints from the table definition, including those inherited from domains.

Any changes made to constraint in a domain definition after a column is defined on that domain are *not* applied to the column. The column gets the constraints from the domain when it is created, but there is no further between the two.

☞ For more information about domains, see “Domains” [*ASA SQL Reference,* page 74].

Working with table and column constraints in Sybase Central

In Sybase Central, you add, alter, and delete column constraints on the Constraints tab of the table or column property sheet.

❖ To manage constraints

1. Open the Tables folder.

2. In the right pane, double-click the table you want to alter.

3. The right pane has separate tabs for unique constraints and check constraints.

4. Make the appropriate changes to the constraint you wish to modify. For example, to add a table or column constraint, click the Check Constraints tab and choose File ➤ New ➤ Table Check Constraint or File ➤ New ➤ Column Check Constraint.

Modifying and deleting CHECK constraints

There are several ways to alter the existing set of CHECK constraints on a table.

- You can add a new CHECK constraint to the table or to an individual column.

- You can delete a CHECK constraint on a column by setting it to NULL. For example, the following statement removes the CHECK constraint on the **phone** column in the **customer** table:

```
ALTER TABLE customer
MODIFY phone CHECK NULL
```

- ♦ You can replace a CHECK constraint on a column in the same way as you would add a CHECK constraint. For example, the following statement adds or replaces a CHECK constraint on the **phone** column of the **customer** table:

```
ALTER TABLE customer
MODIFY phone
CHECK ( phone LIKE '___-___-____' )
```

- ♦ You can modify a CHECK constraint defined on the table:
  - You can add a new CHECK constraint using ALTER TABLE with an ADD *table-constraint* clause.
  - If you have defined constraint names, you can modify individual constraints.
  - If you have not defined constraint names, you can delete all existing CHECK constraints (including column CHECK constraints and CHECK constraints inherited from domains) using ALTER TABLE DELETE CHECK, and then add in new CHECK constraints.

    To use the ALTER TABLE statement with the DELETE CHECK clause:

    ```
    ALTER TABLE table_name
    DELETE CHECK
    ```

Sybase Central lets you add, modify and delete both table and column CHECK constraints. For more information, see "Working with table and column constraints in Sybase Central" on page 87.

Deleting a column from a table does not delete CHECK constraints associated with the column held in the table constraint. Not removing the constraints produces a `column not found` error message upon any attempt to insert, or even just query, data in the table.

Table CHECK constraints fail only if a value of FALSE is returned. A value of UNKNOWN allows the change.

Using domains

A **domain** is a user-defined data type that, together with other attributes, can restrict the range of acceptable values or provide defaults. A domain extends one of the built-in data types. The range of permissible values is usually restricted by a check constraint. In addition, a domain can specify a default value and may or may not allow nulls.

You can define your own domains for a number of reasons.

♦ A number of common errors can be prevented if inappropriate values cannot be entered. A constraint placed on a domain ensures that all columns and variables intended to hold values in a desired range or format can hold only the intended values. For example, a data type can ensure that all credit card numbers typed into the database contain the correct number of digits.

♦ Domains can make it much easier to understand applications and the structure of a database.

♦ Domains can prove convenient. For example, you may intend that all table identifiers are positive integers that, by default, auto-increment. You could enforce this restriction by entering the appropriate constraints and defaults each time you define a new table, but it is less work to define a new domain, then simply state that the identifier can take only values from the specified domain.

☞ For more information about domains, see "SQL Data Types" [*ASA SQL Reference*, page 51].

Creating domains (Sybase Central)

You can use Sybase Central to create a domain or assign it to a column.

❖ To create a new domain (Sybase Central)

1. In the left pane, select the Domains folder.
2. Choose File ➤ New ➤ Domain.

   The Domain Creation wizard appears.
3. Follow the instructions in the wizard.

All domains appear in the Domains folder in Sybase Central.

❖ To assign domains to columns (Sybase Central)

1. For the desired table, click the Columns tab in the right pane.
2. In the data type column for the desired column, either:
   - Select the domain from the dropdown list, or
   - Click the button next to the dropdown list and choose the domain on the property sheet.

Creating domains (SQL)

You can use the CREATE DOMAIN statement to create and define domains.

❖ To create a new domain (SQL)

1. Connect to a database.
2. Execute a CREATE DOMAIN statement.

Example 1: Simple domains

Some columns in the database are to be used for people's names and others are to store addresses. You might then define type following domains.

```
CREATE DOMAIN persons_name CHAR(30)
CREATE DOMAIN street_address CHAR(35)
```

Having defined these domains, you can use them much as you would the built-in data types. For example, you can use these definitions to define a tables as follows.

```
CREATE TABLE customer (
   id INT  DEFAULT AUTOINCREMENT  PRIMARY KEY
   name persons_name
   address street_address
)
```

Example 2: Default values, check constraints, and identifiers

In the above example, the table's primary key is specified to be of type integer. Indeed, many of your tables may require similar identifiers. Instead of specifying that these are integers, it is much more convenient to create an identifier domain for use in these applications.

When you create a domain, you can specify a default value and provide check constraint to ensure that no inappropriate values are typed into any column of this type.

Integer values are commonly used as table identifiers. A good choice for unique identifiers is to use positive integers. Since such identifiers are likely to be used in many tables, you could define the following domain.

```
CREATE DOMAIN identifier INT
DEFAULT AUTOINCREMENT
CHECK ( @col > 0 )
```

This check constraint uses the variable @col. Using this definition, you can rewrite the definition of the customer table, shown above.

```
CREATE TABLE customer (
   id identifier PRIMARY KEY
   name persons_name
   address street_address
)
```

Example 3: Built-in domains

Adaptive Server Anywhere comes with some domains pre-defined. You can use these pre-defined domains as you would a domain that you created yourself. For example, the following monetary domain has already been created for you.

```
CREATE DOMAIN MONEY NUMERIC(19,4)
NULL
```

☞ For more information, see “CREATE DOMAIN statement” [*ASA SQL Reference*, page 300].

Deleting domains

You can use either Sybase Central or a DROP DOMAIN statement to delete a domain.

Only the user DBA or the user who created a domain can drop it. In addition, since a domain cannot be dropped if any variable or column in the database is an instance of the domain, you need to first drop any columns or variables of that type before you can drop the domain.

❖ To delete a domain (Sybase Central)

1. Open the Domains folder.

2. Right-click the desired domain and choose Delete from the popup menu.

❖ To delete a domain (SQL)

1. Connect to a database.

2. Execute a DROP DOMAIN statement.

Example

The following statement drops the customer_name domain.

```
DROP DOMAIN customer_name
```

☞ For more information, see “DROP statement” [*ASA SQL Reference*, page 408].

Enforcing entity and referential integrity

The relational structure of the database enables the personal server to identify information within the database, and ensures that all the rows in each table uphold the relationships between tables (described in the database structure).

Enforcing entity integrity

When a user inserts or updates a row, the database server ensures that the primary key for the table is still valid: that each row in the table is uniquely identified by the primary key.

Example 1

The **employee** table in the sample database uses an employee ID as the primary key. When you add a new employee to the table, the database server checks that the new employee ID value is unique and is not NULL.

Example 2

The **sales_order_items** table in the sample database uses two columns to define a primary key.

This table holds information about items ordered. One column contains an **id** specifying an order, but there may be several items on each order, so this column by itself cannot be a primary key. An additional **line_id** column identifies which line corresponds to the item. The columns **id** and **line_id**, taken together, specify an item uniquely, and form the primary key.

If a client application breaches entity integrity

Entity integrity requires that each value of a primary key be unique within the table, and that no NULL values exist. If a client application attempts to insert or update a primary key value, providing values that are not unique would breach entity integrity. A breach in entity integrity prevents the new information from being added to the database, and instead sends the client application an error.

The application programmer should decide how to present this information to the user and enable the user to take appropriate action. The appropriate action is usually as simple as asking the user to provide a different, unique value for the primary key.

Primary keys enforce entity integrity

Once you specify the primary key for each table, maintaining entity integrity requires no further action by either client application developers or by the database administrator.

The table owner defines the primary key for a table when they create it. If they modify the structure of a table at a later date, they can also redefine the primary key.

Some application development systems and database design tools allow you to create and alter database tables. If you are using such a system, you may not have to enter the CREATE TABLE or ALTER TABLE statement explicitly: the application may generate the statement itself from the information you provide.

☞ For more information about creating primary keys, see “Managing primary keys” on page 42. For the detailed syntax of the CREATE TABLE statement, see “CREATE TABLE statement” [*ASA SQL Reference*, page 361]. For information about changing table structure, see the “ALTER TABLE statement” [*ASA SQL Reference*, page 250].

Enforcing referential integrity

A foreign key (made up of a particular column or combination of columns) relates the information in one table (the **foreign** table) to information in another (**referenced** or **primary**) table. For the foreign key relationship to be valid, the entries in the foreign key must correspond to the primary key values of a row in the referenced table. Occasionally, some other unique column combination may be referenced instead of a primary key.

Example 1

The sample database contains an employee table and a department table. The primary key for the employee table is the employee ID, and the primary key for the department table is the department ID. In the employee table, the department ID is called a **foreign key** for the department table because each department ID in the employee table corresponds exactly to a department ID in the department table.

The foreign key relationship is a many-to-one relationship. Several entries in the employee table have the same department ID entry, but the department ID is the primary key for the department table, and so is unique. If a foreign key could reference a column in the department table containing duplicate entries, or entries with a NULL value, there would be no way of knowing which row in the department table is the appropriate reference. This is a mandatory foreign key.

Example 2

Suppose the database also contained an office table listing office locations. The employee table might have a foreign key for the office table that indicates which city the employee’s office is in. The database designer can choose to leave an office location unassigned at the time the employee is hired, for example, either because they haven’t been assigned to an office yet, or because they don’t work out of an office. In this case, the foreign key can allow NULL values, and is optional.

Foreign keys enforce referential integrity

Like primary keys, you use the CREATE TABLE or ALTER TABLE statements to create foreign keys. Once you create a foreign key, the column or columns in the key can contain only values that are present as primary key values in the table associated with the foreign key.

☞ For more information about creating foreign keys, see "Managing primary keys" on page 42.

Losing referential integrity

Your database can lose referential integrity if someone:

- updates or deletes a primary key value. All the foreign keys referencing that primary key would become invalid.
- adds a new row to the foreign table, and enters a value for the foreign key that has no corresponding primary key value. The database would become invalid.

Adaptive Server Anywhere provides protection against both types of integrity loss.

If a client application breaches referential integrity

If a client application updates or deletes a primary key value in a table, and if a foreign key references that primary key value elsewhere in the database, there is a danger of a breach of referential integrity.

Example

If the server allowed the primary key to be updated or deleted, and made no alteration to the foreign keys that referenced it, the foreign key reference would be invalid. Any attempt to use the foreign key reference, for example in a SELECT statement using a KEY JOIN clause, would fail, as no corresponding value in the referenced table exists.

While Adaptive Server Anywhere handles breaches of entity integrity in a generally straightforward fashion by simply refusing to enter the data and returning an error message, potential breaches of referential integrity become more complicated. You have several options (known as referential integrity actions) available to help you maintain referential integrity.

Referential integrity actions

Maintaining referential integrity when updating or deleting a referenced primary key can be as simple as disallowing the update or delete. Often, however, it is also possible to take a specific action on each foreign key to maintain referential integrity. The CREATE TABLE and ALTER TABLE statements allow database administrators and table owners to specify what action to take on foreign keys that reference a modified primary key when a breach occurs.

You can specify each of the available referential integrity actions separately for updates and deletes of the primary key:

- **RESTRICT** Generates an error and prevents the modification if an attempt to modify a referenced primary key value occurs. This is the default referential integrity action.

- **SET NULL** Sets all foreign keys that reference the modified primary key to NULL.

- **SET DEFAULT** Sets all foreign keys that reference the modified primary key to the default value for that column (as specified in the table definition).

- **CASCADE** When used with ON UPDATE, this action updates all foreign keys that reference the updated primary key to the new value. When used with ON DELETE, this action deletes all rows containing foreign keys that reference the deleted primary key.

System triggers implement referential integrity actions. The trigger, defined on the primary table, is executed using the permissions of the owner of the *secondary* table. This behavior means that cascaded operations can take place between tables with different owners, without additional permissions having to be granted.

Referential integrity checking

For foreign keys defined to RESTRICT operations that would violate referential integrity, default checks occur at the time a statement executes. If you specify a CHECK ON COMMIT clause, then the checks occur only when the transaction is committed.

Using a database option to control check time

Setting the WAIT_FOR_COMMIT database option controls the behavior when a foreign key is defined to restrict operations that would violate referential integrity. The CHECK ON COMMIT clause can override this option.

With the default WAIT_FOR_COMMIT set to OFF, operations that would leave the database inconsistent cannot execute. For example, an attempt to DELETE a department that still has employees in it is not allowed. The following statement gives the error `primary key for row in table 'department' is referenced in another table`:

```
DELETE FROM department
WHERE dept_id = 200
```

Setting WAIT_FOR_COMMIT to ON causes referential integrity to remain unchecked until a commit executes. If the database is in an inconsistent state, the database disallows the commit and reports an error. In this mode, a database user could delete a department with employees in it, however, the user cannot commit the change to the database until they:

- Delete or reassign the employees belonging to that department.
- Redo the search condition on a SELECT statement to select the rows that violate referential integrity.
- Insert the **dept_id** row back into the **department** table.
- Roll back the transaction to undo the DELETE operation.

Integrity rules in the system tables

All the information about database integrity checks and rules is held in the following system tables:

System table	Description
SYS.SYSTABLE	The **view_def** column of SYS.SYSTABLE holds CHECK constraints. For views, the **view_def** holds the CREATE VIEW command that created the view. You can check whether a particular table is a base table or a view by looking at the **table_type** column, which is BASE or VIEW.
SYS.SYSTRIGGER	SYS.SYSTRIGGER holds referential integrity actions. The **referential_action** column holds a single character indicating whether the action is cascade (C), delete (D), set null (N), or restrict (R). The **event** column holds a single character specifying the event that causes the action to occur: insert, delete (A), insert, update (B), update (C), a delete (D), delete, update (E),insert (I), update (U), insert, delete, update (M). The **trigger_time** column shows whether the action occurs after (A) or before (B) the triggering event.
SYS.SYSFOREIGNKEYS	This view presents the foreign key information from the two tables SYS.SYSFOREIGNKEY and SYS.SYSFKCOL in a more readable format.
SYS.SYSCOLUMNS	This view presents the information from the SYS.SYSCOLUMN table in a more readable format. It includes default settings and primary key information for columns.

☞ For more information about the contents of each system table, see "System Tables" [*ASA SQL Reference*, page 611]. You can use Sybase Central or Interactive SQL to browse these tables and views.

CHAPTER 4

Using Transactions and Isolation Levels

About this chapter

You can group SQL statements into transactions, which have the property that either all statements are executed or none is executed. You should design each transaction to perform a task that changes your database from one consistent state to another.

This chapter describes transactions and how to use them in applications. It also describes how Adaptive Server Anywhere you can set isolation levels to limit the interference among concurrent transaction.

Contents

Topic:	page
Introduction to transactions	100
Isolation levels and consistency	104
Transaction blocking and deadlock	110
Choosing isolation levels	112
Isolation level tutorials	116
How locking works	131
Particular concurrency issues	145
Replication and concurrency	148
Summary	151

Introduction to transactions

To ensure data integrity, it is essential that you can identify states in which the information in your database is **consistent**. The concept of consistency is best illustrated through an example:

Consistency example

Suppose you use your database to handle financial accounts, and you wish to transfer money from one client's account to another. The database is in a consistent state both before and after the money is transferred; but it is not in a consistent state after you have debited money from one account and before you have credited it to the second. During a transferal of money, the database is in a consistent state when the total amount of money in the clients' accounts is as it was before any money was transferred. When the money has been half transferred, the database is in an inconsistent state. Either both or neither of the debit and the credit must be processed.

Transactions are logical units of work

A **transaction** is a logical unit of work. Each transaction is a sequence of logically related commands that accomplish one task and transform the database from one consistent state into another. The nature of a consistent state depends on your database.

The statements within a transaction are treated as an indivisible unit: either all are executed or none is executed. At the end of each transaction, you **commit** your changes to make them permanent. If for any reason some of the commands in the transaction do not process properly, then any intermediate changes are undone, or **rolled back**. Another way of saying this is that transactions are **atomic**.

Grouping statements into transactions is key both to protecting the consistency of your data (even in the event of media or system failure), and to managing concurrent database operations. Transactions may be safely interleaved and the completion of each transaction marks a point at which the information in the database is consistent.

In the event of a system failure or database crash during normal operation, Adaptive Server Anywhere performs automatic recovery of your data when the database is next started. The automatic recovery process recovers all completed transactions, and rolls back any transactions that were uncommitted when the failure occurred. The atomic character of transactions ensures that databases are recovered to a consistent state.

☞ For more information about database backups and data recovery, see "Backup and Data Recovery" [*ASA Database Administration Guide*, page 337].

For more information about concurrent database usage, see "Introduction to concurrency" on page 102.

Using transactions

Adaptive Server Anywhere expects you to group your commands into transactions. Knowing which commands or actions signify the start or end of a transaction lets you take full advantage of this feature.

Starting transactions

Transactions start with one of the following events:

- The first statement following a connection to a database
- The first statement following the end of a transaction

Completing transactions

Transactions complete with one of the following events:

- A COMMIT statement makes the changes to the database permanent.
- A ROLLBACK statement undoes all the changes made by the transaction.
- A statement with a side effect of an automatic commit is executed: data definition commands, such as ALTER, CREATE, COMMENT, and DROP all have the side effect of an automatic commit.
- A disconnection from a database performs an implicit rollback.
- ODBC and JDBC have an autocommit setting that enforces a COMMIT after each statement. By default, ODBC and JDBC require autocommit to be on, and each statement is a single transaction. If you want to take advantage of transaction design possibilities, then you should turn autocommit off.

  ☞ For more information on autocommit, see "Setting autocommit or manual commit mode" [*ASA Programming Guide,* page 47].

- Setting the database option CHAINED to OFF is similar to enforcing an autocommit after each statement. By default, connections that use jConnect or Open Client applications have CHAINED set to OFF.

  ☞ For more information, see "Setting autocommit or manual commit mode" [*ASA Programming Guide,* page 47], and "CHAINED option [compatibility]" [*ASA Database Administration Guide,* page 581].

Options in Interactive SQL

Interactive SQL lets you control when and how transactions from your application terminate:

- If you set the option AUTO_COMMIT to ON, Interactive SQL automatically commits your results following every successful statement and automatically perform a ROLLBACK after each failed statement.

- The setting of the option COMMIT_ON_EXIT controls what happens to uncommitted changes when you exit Interactive SQL. If this option is set to ON (the default), Interactive SQL does a COMMIT; otherwise it undoes your uncommitted changes with a ROLLBACK statement.

☞ Adaptive Server Anywhere also supports Transact-SQL commands such as BEGIN TRANSACTION, for compatibility with Sybase Adaptive Server Enterprise. For further information, see "Transact-SQL Compatibility" on page 439.

Introduction to concurrency

Concurrency is the ability of the database server to process multiple transactions at the same time. Were it not for special mechanisms within the database server, concurrent transactions could interfere with each other to produce inconsistent and incorrect information.

Example

A database system in a department store must allow many clerks to update customer accounts concurrently. Each clerk must be able to update the status of the accounts as they assist each customer: they cannot afford to wait until no one else is using the database.

Who needs to know about concurrency

Concurrency is a concern to all database administrators and developers. Even if you are working with a single-user database, you must be concerned with concurrency if you wish to process instructions from multiple applications or even from multiple connections from a single application. These applications and connections can interfere with each other in exactly the same way as multiple users in a network setting.

Transaction size affects concurrency

The way you group SQL statements into transactions can have significant effects on data integrity and on system performance. If you make a transaction too short and it does not contain an entire logical unit of work, then inconsistencies can be introduced into the database. If you write a transaction that is too long and contains several unrelated actions, then there is greater chance that a ROLLBACK will unnecessarily undo work that could have been committed quite safely into the database.

If your transactions are long, they can lower concurrency by preventing other transactions from being processed concurrently.

There are many factors that determine the appropriate length of a transaction, depending on the type of application and the environment.

Savepoints within transactions

You may identify important states within a transaction and return to them selectively using **savepoints** to separate groups of related statements.

A SAVEPOINT statement defines an intermediate point during a transaction. You can undo all changes after that point using a ROLLBACK TO SAVEPOINT statement. Once a RELEASE SAVEPOINT statement has been executed or the transaction has ended, you can no longer use the savepoint.

No locks are released by the RELEASE SAVEPOINT or ROLLBACK TO SAVEPOINT commands: locks are released only at the end of a transaction.

Naming and nesting savepoints

Using named, nested savepoints, you can have many active savepoints within a transaction. Changes between a SAVEPOINT and a RELEASE SAVEPOINT can be canceled by rolling back to a previous savepoint or rolling back the transaction itself. Changes within a transaction are not a permanent part of the database until the transaction is committed. All savepoints are released when a transaction ends.

Savepoints cannot be used in bulk operations mode. There is very little additional overhead in using savepoints.

Isolation levels and consistency

There are four isolation levels

Adaptive Server Anywhere allows you to control the degree to which the operations in one transaction are visible to the operations in other concurrent transactions. You do so by setting a database option called the **isolation level**. Adaptive Server Anywhere has four different isolation levels (numbered 0 through 3) that prevent some or all inconsistent behavior. Level 3 provides the highest level of isolation. Lower levels allow more inconsistencies, but typically have better performance. Level 0 is the default setting.

All isolation levels guarantee that each transaction will execute completely or not at all, and that no updates will be lost.

Typical types of inconsistency

There are three typical types of inconsistency that can occur during the execution of concurrent transactions. This list is not exhaustive as other types of inconsistencies can also occur. These three types are mentioned in the ISO SQL/92 standard and are important because behavior at lower isolation levels is defined in terms of them.

- **Dirty read** Transaction A modifies a row, but does not commit or roll back the change. Transaction B reads the modified row. Transaction A then either further changes the row before performing a COMMIT, or rolls back its modification. In either case, transaction B has seen the row in a state which was never committed.
  - For more information about how isolation levels create dirty reads, see "Dirty read tutorial" on page 116.

- **Non-repeatable read** Transaction A reads a row. Transaction B then modifies or deletes the row and performs a COMMIT. If transaction A then attempts to read the same row again, the row will have been changed or deleted.
  - For more information about non-repeatable reads, see "Non-repeatable read tutorial" on page 119.

- **Phantom row** Transaction A reads a set of rows that satisfy some condition. Transaction B then executes an INSERT, or an UPDATE on a row which did not previously meet A's condition. Transaction B commits these changes. These newly committed rows now satisfy the condition. Transaction A then repeats the initial read and obtains a different set of rows.
  - For more information about phantom rows, see "Phantom row tutorial" on page 123.

Other types of inconsistencies can also exist. These three were chosen for the ISO SQL/92 standard because they are typical problems and because it was convenient to describe amounts of locking between transactions in terms of them.

Isolation levels and dirty reads, non-repeatable reads, and phantom rows

The isolation levels are different with respect to the type of inconsistent behavior that Adaptive Server Anywhere allows. An x means that the behavior is prevented, and a ✔ means that the behavior may occur.

Isolation level	Dirty reads	Non-repeatable reads	Phantom rows
0	✔	✔	✔
1	x	✔	✔
2	x	x	✔
3	x	x	x

This table demonstrates two points:

- Each isolation level eliminates one of the three typical types of inconsistencies.
- Each level eliminates the types of inconsistencies eliminated at all lower levels.

The four isolation levels have different names under ODBC. These names are based on the names of the inconsistencies that they prevent, and are described in "The ValuePtr parameter" on page 107.

Cursor instability

Another significant inconsistency is **cursor instability**. When this inconsistency is present, a transaction can modify a row that is being referenced by another transaction's cursor. Cursor stability ensures that applications using cursors do not introduce inconsistencies into the data in the database.

Example

Transaction A reads a row using a cursor. Transaction B modifies that row. Not realizing that the row has been modified, Transaction A modifies it, rendering the affected row's data incorrect.

Eliminating cursor instability

Adaptive Server Anywhere achieves **cursor stability** at isolation levels 1, 2, and 3. Cursor stability ensures that no other transactions can modify information that is contained in the present row of your cursor. The information in a row of a cursor may be the copy of information contained in a particular table or may be a combination of data from different rows of multiple tables. More than one table will likely be involved whenever you use a join or sub-selection within a SELECT statement.

☞ For information on programming SQL procedures and cursors, see "Using Procedures, Triggers, and Batches" on page 609.

☞ Cursors are used only when you are using Adaptive Server Anywhere through another application. For more information, see "Using SQL in Applications" [*ASA Programming Guide,* page 11].

A related but distinct concern for applications using cursors is whether changes to underlying data are visible to the application. You can control the changes that are visible to applications by specifying the sensitivity of the cursor.

☞ For more information about cursor sensitivity, see "Adaptive Server Anywhere cursors" [*ASA Programming Guide,* page 30].

Setting the isolation level

Each connection to the database has its own isolation level. In addition, the database can store a default isolation level for each user or group. The PUBLIC setting enables you to set a single default isolation level for the entire database's group.

The isolation level is a database option. You change database options using the SET OPTION statement. For example, the following command sets the isolation level for the current user to 3, the highest level.

```
SET OPTION ISOLATION_LEVEL = 3
```

You can change the isolation of your connection and the default level associated with your user ID using the SET OPTION command. If you have permission, you can also change the isolation level for other users or groups.

❖ To set the isolation level for the current user ID

1. Execute the SET OPTION statement. For example, the following statement sets the isolation level to 3 for the current user:

   ```
   SET OPTION ISOLATION_LEVEL = 3
   ```

❖ To set the isolation level for a user or group

1. Connect to the database as a user with DBA authority.
2. Execute the SET OPTION statement, adding the name of the group and a period before ISOLATION_LEVEL. For example, the following command sets the default isolation for the special group PUBLIC to 3.

```
SET OPTION PUBLIC.ISOLATION_LEVEL = 3
```

❖ To set the isolation level just for your present session

1. Execute the SET OPTION statement using the TEMPORARY keyword. For example, the following statement sets the isolation level to 3 for the duration of your connection:

```
SET TEMPORARY OPTION ISOLATION_LEVEL = 3
```

Once you disconnect, your isolation level reverts to its previous value.

Default isolation level

When you connect to a database, the database server determines your initial isolation level as follows:

1. A default isolation level may be set for each user and group. If a level is stored in the database for your user ID, then the database server uses it.
2. If not, the database server checks the groups to which you belong until it finds a level. All users are members of the special group PUBLIC. If it finds no other setting first, then Adaptive Server Anywhere will use the level assigned to that group.

☞ For more information about users and groups, see “Managing User IDs and Permissions” [*ASA Database Administration Guide*, page 389].

☞ For more information about the SET OPTION statement syntax, see “SET OPTION statement” [*ASA SQL Reference*, page 556].

☞ You may wish to change the isolation level in mid-transaction if, for example, just one table or group of tables requires serialized access. For information about changing the isolation level within a transaction, see “Changing isolation levels within a transaction” on page 109.

Setting the isolation level from an ODBC-enabled application

ODBC applications call **SQLSetConnectAttr** with **Attribute** set to SQL_ATTR_TXN_ISOLATION and **ValuePtr** set according to the corresponding isolation level:

The ValuePtr parameter

ValuePtr	Isolation Level
SQL_TXN_READ_-UNCOMMITTED	0
SQL_TXN_READ_COMMITTED	1
SQL_TXN_REPEATABLE_READ	2
SQL_TXT_SERIALIZABLE	3

Changing an isolation level via ODBC

You can change the isolation level of your connection via ODBC using the function **SQLSetConnectOption** in the library *ODBC32.dll*.

The **SQLSetConnectOption** function reads three parameters: the value of the ODBC connection handle, the fact that you wish to set the isolation level, and the value corresponding to the isolation level. These values appear in the table below.

String	Value
SQL_TXN_ISOLATION	108
SQL_TXN_READ_-UNCOMMITTED	1
SQL_TXN_READ_COMMITTED	2
SQL_TXN_REPEATABLE_READ	4
SQL_TXT_SERIALIZABLE	8

Do not use the SET OPTION statement to change an isolation level from within an ODBC application. Since the ODBC driver does not parse the statements, execution of any statement in ODBC will not be recognized by the ODBC driver.

Example

The following function call sets the isolation level of the connection MyConnection to isolation level 2:

```
SQLSetConnectOption( MyConnection.hDbc,
                     SQL_TXN_ISOLATION,
                     SQL_TXN_REPEATABLE_READ )
```

ODBC uses the isolation feature to support assorted database lock options. For example, in PowerBuilder you can use the Lock attribute of the transaction object to set the isolation level when you connect to the database. The Lock attribute is a string, and is set as follows:

```
SQLCA.lock = "RU"
```

The Lock option is honored only at the moment the CONNECT occurs.

Changes to the Lock attribute after the CONNECT have no effect on the connection.

Changing isolation levels within a transaction

Sometimes you will find that different isolation levels are suitable for different parts of a single transaction. Adaptive Server Anywhere allows you to change the isolation level of your database in the middle of a transaction.

When you change the ISOLATION_LEVEL option in the middle of a transaction, the new setting affects only the following:

- Any cursors opened after the change
- Any statements executed after the change

You may wish to change the isolation level during a transaction, as doing so affords you control over the number of locks your transaction places. You may find a transaction needs to read a large table, but perform detailed work with only a few of the rows. If an inconsistency would not seriously affect your transaction, set the isolation to a low level while you scan the large table to avoid delaying the work of others.

You may also wish to change the isolation level in mid transaction if, for example, just one table or group of tables requires serialized access.

For an example in which the isolation level is changed in the middle of a transaction, see "Phantom row tutorial" on page 123.

Viewing the isolation level

You can inspect the isolation level of the current connection using the CONNECTION_PROPERTY function.

❖ To view the isolation level for the current connection

1. Execute the following statement:

```
SELECT CONNECTION_PROPERTY('ISOLATION_LEVEL')
```

Transaction blocking and deadlock

When a transaction is being executed, the database server places locks on rows to prevent other transactions from interfering with the affected rows. **Locks** control the amount and types of interference permitted.

Adaptive Server Anywhere uses **transaction blocking** to allow transactions to execute concurrently without interference, or with limited interference. Any transaction can acquire a lock to prevent other concurrent transactions from modifying or even accessing a particular row. This transaction blocking scheme always stops some types of interference. For example, a transaction that is updating a particular row of a table always acquires a lock on that row to ensure that no other transaction can update or delete the same row at the same time.

Transaction blocking

When a transaction attempts to carry out an operation, but is forbidden by a lock held by another transaction, a conflict arises and the progress of the transaction attempting to carry out the operation is impeded or blocked.

"Two-phase locking" on page 140 describes deadlock, which occurs when two or more transactions are blocked by each other in such a way that none can proceed.

Sometimes a set of transactions arrive at a state where none of them can proceed. For more information, see "Deadlock" on page 111.

The BLOCKING option

If two transactions have each acquired a read lock on a single row, the behavior when one of them attempts to modify that row depends on the database setting BLOCKING. To modify the row, that transaction must block the other, yet it cannot do so while the other transaction has it blocked.

- If BLOCKING is ON (the default), then the transaction that attempts to write waits until the other transaction releases its read lock. At that time, the write goes through.
- If BLOCKING has been set to OFF, then the transaction that attempts to write receives an error.

When BLOCKING is OFF, the transaction terminates instead of waiting and any changes it has made are rolled back. In this event, try executing the transaction again, later.

Blocking is more likely to occur at higher isolation levels because more locking and more checking is done. Higher isolation levels usually provide less concurrency. How much less depends on the individual natures of the concurrent transactions.

For more information about the BLOCKING option, see "BLOCKING option [database]" [*ASA Database Administration Guide,* page 581].

Deadlock

Transaction blocking can lead to **deadlock**, a situation in which a set of transactions arrive at a state where none of them can proceed.

Reasons for deadlocks

A deadlock can arise for two reasons:

- **A cyclical blocking conflict** Transaction A is blocked on transaction B, and transaction B is blocked on transaction A. Clearly, more time will not solve the problem, and one of the transactions must be canceled, allowing the other to proceed. The same situation can arise with more than two transactions blocked in a cycle.
- **All active database threads are blocked** When a transaction becomes blocked, its database thread is not relinquished. If the database is configured with three threads and transactions A, B, and C are blocked on transaction D which is not currently executing a request, then a deadlock situation has arisen since there are no available threads.

Adaptive Server Anywhere automatically rolls back the last transaction that became blocked (eliminating the deadlock situation), and returns an error to that transaction indicating which form of deadlock occurred.

The number of database threads that the server uses depends on the individual database's setting. For information about setting the number of database threads, see "Controlling threading behavior" [*ASA Database Administration Guide,* page 15].

Determining who is blocked

You can use the sa_conn_info system procedure to determine which connections are blocked on which other connections. This procedure returns a result set consisting of a row for each connection. One column of the result set lists whether the connection is blocked, and if so which other connection it is blocked on.

☞ For more information, see "sa_conn_info system procedure" [*ASA SQL Reference,* page 710].

Choosing isolation levels

The choice of isolation level depends on the kind of task an application is carrying out. This section gives some guidelines for choosing isolation levels.

When you choose an appropriate isolation level you must balance the need for consistency and accuracy with the need for concurrent transactions to proceed unimpeded. If a transaction involves only one or two specific values in one table, it is unlikely to interfere as much with other processes as one which searches many large tables and may need to lock many rows or entire tables and may take a very long time to complete.

For example, if your transactions involve transferring money between bank accounts or even checking account balances, you will likely want to do your utmost to ensure that the information you return is correct. On the other hand, if you just want a rough estimate of the proportion of inactive accounts, then you may not care whether your transaction waits for others or not and indeed may be willing to sacrifice some accuracy to avoid interfering with other users of the database.

Furthermore, a transfer may affect only the two rows which contain the two account balances, whereas all the accounts must be read in order to calculate the estimate. For this reason, the transfer is less likely to delay other transactions.

Adaptive Server Anywhere provides four levels of isolation: levels 0, 1, 2, and 3. Level 3 provides complete isolation and ensures that transactions are interleaved in such a manner that the schedule is serializable.

Serializable schedules

To process transactions concurrently, the database server must execute some component statements of one transaction, then some from other transactions, before continuing to process further operations from the first. The order in which the component operations of the various transactions are interleaved is called the **schedule**.

Applying transactions concurrently in this manner can result in many possible outcomes, including the three particular inconsistencies described in the previous section. Sometimes, the final state of the database also could have been achieved had the transactions been executed sequentially, meaning that one transaction was always completed in its entirety before the next was started. A schedule is called **serializable** whenever executing the transactions sequentially, in some order, could have left the database in the same state as the actual schedule.

For more information about how Adaptive Server Anywhere handles serialization, see "Two-phase locking" on page 140.

Serializability is the commonly accepted criterion for correctness. A serializable schedule is accepted as correct because the database is not influenced by the concurrent execution of the transactions.

The isolation level affects a transaction's serializability. At isolation level 3, all schedules are serializable. The default setting is 0.

Serializable means that concurrency has added no effect

Even when transactions are executed sequentially, the final state of the database can depend upon the order in which these transactions are executed. For example, if one transaction sets a particular cell to the value 5 and another sets it to the number 6, then the final value of the cell is determined by which transaction executes last.

Knowing a schedule is serializable does not settle which order transactions would best be executed, but rather states that concurrency has added no effect. Outcomes which may be achieved by executing the set of transactions sequentially in some order are all assumed correct.

Unserializable schedules introduce inconsistencies

The inconsistencies introduced in "Typical types of inconsistency" on page 104 are typical of the types of problems that appear when the schedule is not serializable. In each case, the inconsistency appeared because the statements were interleaved in such a way as to produce a result that would not be possible if all transactions were executed sequentially. For example, a dirty read can only occur if one transaction can select rows while another transaction is in the middle of inserting or updating data in the same row.

Typical transactions at various isolation levels

Various isolation levels lend themselves to particular types of tasks. Use the information below to help you decide which level is best suited to each particular operation.

Typical level 0 transactions

Transactions that involve browsing or performing data entry may last several minutes, and read a large number of rows. If isolation level 2 or 3 is used, concurrency can suffer. Isolation level of 0 or 1 is typically used for this kind of transaction.

For example, a decision support application that reads large amounts of information from the database to produce statistical summaries may not be significantly affected if it reads a few rows that are later modified. If high isolation is required for such an application, it may acquire read locks on large amounts of data, not allowing other applications write access to it.

Typical level 1 transactions

Isolation level 1 is particularly useful in conjunction with cursors, because this combination ensures cursor stability without greatly increasing locking requirements. Adaptive Server Anywhere achieves this benefit through the early release of read locks acquired for the present row of a cursor. These locks must persist until the end of the transaction at either levels two or three in order to guarantee repeatable reads.

For example, a transaction that updates inventory levels through a cursor is particularly suited to this level, because each of the adjustments to inventory levels as items are received and sold would not be lost, yet these frequent adjustments would have minimal impact on other transactions.

Typical level 2 transactions

At isolation level 2, rows that match your criterion cannot be changed by other transactions. You can thus employ this level when you must read rows more than once and rely that rows contained in your first result set won't change.

Because of the relatively large number of read locks required, you should use this isolation level with care. As with level 3 transactions, careful design of your database and indexes reduce the number of locks acquired and hence can improve the performance of your database significantly.

Typical level 3 transactions

Isolation level 3 is appropriate for transactions that demand the most in security. The elimination of phantom rows lets you perform multi-step operations on a set of rows without fear that new rows will appear partway through your operations and corrupt the result.

However much integrity it provides, isolation level 3 should be used sparingly on large systems that are required to support a large number of concurrent transactions. Adaptive Server Anywhere places more locks at this level than at any other, raising the likelihood that one transaction will impede the process of many others.

Improving concurrency at isolation levels 2 and 3

Isolation levels 2 and 3 use a lot of locks and so good design is of particular importance for databases that make regular use of these isolation levels. When you must make use of serializable transactions, it is important that you design your database, in particular the indices, with the business rules of your project in mind. You may also improve performance by breaking large transactions into several smaller ones, thus shortening the length of time that rows are locked.

Although serializable transactions have the most potential to block other transactions, they are not necessarily less efficient. When processing these transactions, Adaptive Server Anywhere can perform certain optimizations that may improve performance, in spite of the increased number of locks.

For example, since all rows read must be locked whether or not they match the a search criteria, the database server is free to combine the operation of reading rows and placing locks.

Reducing the impact of locking

You should avoid running transactions at isolation level 3 whenever practical. They tend to place large number of locks and hence impact the efficient execution of other concurrent transactions.

When the nature of an operation demands that it run at isolation level 3, you can lower its impact on concurrency by designing the query to read as few rows and index entries as possible. These steps will help the level 3 transaction run more quickly and, of possibly greater importance, will reduce the number of locks it places.

In particular, you may find that adding an index may greatly help speed up transactions, particularly when at least one of them must execute at isolation level 3. An index can have two benefits:

- An index enables rows to be located in an efficient manner
- Searches that make use of the index may need fewer locks.

☞ For more information about the details of the locking methods employed by Adaptive Server Anywhere is located in "How locking works" on page 131.

☞ For more information on performance and how Adaptive Server Anywhere plans its access of information to execute your commands, see "Monitoring and Improving Performance" on page 153.

Isolation level tutorials

The different isolation levels behave in very different ways, and which one you will want to use depends on your database and on the operations you are carrying out. The following set of tutorials will help you determine which isolation levels are suitable for different tasks.

Dirty read tutorial

The following tutorial demonstrates one type of inconsistency that can occur when multiple transactions are executed concurrently. Two employees at a small merchandising company access the corporate database at the same time. The first person is the company's Sales Manager. The second is the Accountant.

The Sales Manager wants to increase the price of tee shirts sold by their firm by $0.95, but is having a little trouble with the syntax of the SQL language. At the same time, unknown to the Sales Manager, the Accountant is trying to calculate the retail value of the current inventory to include in a report he volunteered to bring to the next management meeting.

> **Tip:**
> Before altering your database in the following way, it is prudent to test the change by using SELECT in place of UPDATE.

In this example, you will play the role of two people, both using the demonstration database concurrently.

1. Start Interactive SQL.
2. Connect to the sample database as the Sales Manager:
   - In the Connect dialog, choose the ODBC data source ASA 9.0 Sample.
   - On the Advanced tab, type the following string to make the window easier to identify:

     ```
     ConnectionName=Sales Manager
     ```

   Click OK to connect.
3. Start a second instance of Interactive SQL.
4. Connect to the sample database as the Accountant:
   - In the Connect dialog, choose the ODBC data source ASA 9.0 Sample.
   - On the Advanced tab, type the following string to make the window easier to identify:

     ```
     ConnectionName=Accountant
     ```

- Click OK to connect.

5. As the Sales Manager, raise the price of all the tee shirts by $0.95:
   - In the window labeled Sales Manager, execute the following commands:

```
SELECT id, name, unit_price
FROM product;
UPDATE PRODUCT
SET unit_price = unit_price + 95
WHERE NAME = 'Tee Shirt'
```

   The result is:

id	name	unit_price
300	Tee Shirt	104.00
301	Tee Shirt	109.00
302	Tee Shirt	109.00
400	Baseball Cap	9.00
...	...	...

   You observe immediately that you should have entered 0.95 instead of 95, but before you can fix your error, the Accountant accesses the database from another office.

6. The company's Accountant is worried that too much money is tied up in inventory. As the Accountant, execute the following commands to calculate the total retail value of all the merchandise in stock:

```
SELECT SUM( quantity * unit_price )
  AS inventory
FROM product
```

   The result is:

inventory
21453.00

   Unfortunately, this calculation is not accurate. The Sales Manager accidentally raised the price of the visor $95, and the result reflects this erroneous price. This mistake demonstrates one typical type of inconsistency known as a **dirty read**. You, as the Accountant, accessed data which the Sales Manager has entered, but has not yet committed.

☞ You can eliminate dirty reads and other inconsistencies explained in "Isolation levels and consistency" on page 104.

7. As the Sales Manager, fix the error by rolling back your first changes and entering the correct UPDATE command. Check that your new values are correct.

```
ROLLBACK;
UPDATE product
SET unit_price = unit_price + 0.95
WHERE NAME = 'Tee Shirt';
```

id	name	unit_price
300	Tee Shirt	9.95
301	Tee Shirt	14.95
302	Tee Shirt	14.95
400	Baseball Cap	9.00
...	...	...

8. The Accountant does not know that the amount he calculated was in error. You can see the correct value by executing his SELECT statement again in his window.

```
SELECT SUM( quantity * unit_price )
  AS inventory
FROM product;
```

inventory
6687.15

9. Finish the transaction in the Sales Manager's window. She would enter a COMMIT statement to make his changes permanent, but you may wish to enter a ROLLBACK, instead, to avoid changing the copy of the demonstration database on your machine.

```
ROLLBACK;
```

The Accountant unknowingly receives erroneous information from the database because the database server is processing the work of both the Sales Manager and the Accountant concurrently.

Non-repeatable read tutorial

The example in “Dirty read tutorial” on page 116 demonstrated the first type of inconsistency, namely the dirty read. In that example, an Accountant made a calculation while the Sales Manager was in the process of updating a price. The Accountant’s calculation used erroneous information which the Sales Manager had entered and was in the process of fixing.

The following example demonstrates another type of inconsistency: non-repeatable reads. In this example, you will play the role of the same two people, both using the demonstration database concurrently. The Sales Manager wishes to offer a new sales price on plastic visors. The Accountant wishes to verify the prices of some items that appear on a recent order.

This example begins with both connections at isolation level 1, rather than at isolation level 0, which is the default for the demonstration database supplied with Adaptive Server Anywhere. By setting the isolation level to 1, you eliminate the type of inconsistency which the previous tutorial demonstrated, namely the dirty read.

1. Start Interactive SQL.

2. Connect to the sample database as the Sales Manager:

   - In the Connect dialog, choose the ODBC data source ASA 9.0 Sample.
   - On the Advanced tab, enter the following string to make the window easier to identify:

     ```
     ConnectionName=Sales Manager
     ```

   - Click OK to connect.

3. Start a second instance of Interactive SQL.

4. Connect to the sample database as the Accountant:

   - In the Connect dialog, choose the ODBC data source ASA 9.0 Sample.
   - On the Advanced tab, enter the following string to make the window easier to identify:

     ```
     ConnectionName=Accountant
     ```

   - Click OK to connect.

5. Set the isolation level to 1 for the Accountant’s connection by executing the following command.

   ```
   SET TEMPORARY OPTION ISOLATION_LEVEL = 1
   ```

6. Set the isolation level to 1 in the Sales Manager's window by executing the following command:

```
SET TEMPORARY OPTION ISOLATION_LEVEL = 1
```

7. The Accountant decides to list the prices of the visors. As the Accountant, execute the following command:

```
SELECT id, name, unit_price FROM product
```

id	name	unit_price
300	Tee Shirt	9.00
301	Tee Shirt	14.00
302	Tee Shirt	14.00
400	Baseball Cap	9.00
...	...	...

8. The Sales Manager decides to introduce a new sale price for the plastic visor. As the Sales Manager, execute the following command:

```
SELECT id, name, unit_price FROM product
WHERE name = 'Visor';
UPDATE product
SET unit_price = 5.95 WHERE id = 501;
COMMIT;
```

id	name	unit_price
500	Visor	7.00
501	Visor	5.95

9. Compare the price of the visor in the Sales Manager window with the price for the same visor in the Accountant window. The Accountant window still displays the old price, even though the Sales Manager has entered the new price and committed the change.

   This inconsistency is called a **non-repeatable read**, because if the Accountant did the same SELECT a second time in the *same transaction* , he wouldn't get the same results. Try it for yourself. As the Accountant, execute the select command again. Observe that the Sales Manager's sale price now displays.

```
SELECT id, name, price
FROM product
```

id	name	unit_price
300	Tee Shirt	9.00
301	Tee Shirt	14.00
302	Tee Shirt	14.00
400	Baseball Cap	9.00
...	...	...

Of course if the Accountant had finished his transaction, for example by issuing a COMMIT or ROLLBACK command before using SELECT again, it would be a different matter. The database is available for simultaneous use by multiple users and it is completely permissible for someone to change values either before or after the Accountant's transaction. The change in results is only inconsistent because it happens in the middle of his transaction. Such an event makes the schedule unserializable.

10. The Accountant notices this behavior and decides that from now on he doesn't want the prices changing while he looks at them. Repeatable reads are eliminated at isolation level 2. Play the role of the Accountant:

    ```
    SET TEMPORARY OPTION ISOLATION_LEVEL = 2;
    SELECT id, name, unit_price
    FROM product
    ```

11. The Sales Manager decides that it would be better to delay the sale on the plastic visor until next week so that she won't have to give the lower price on a big order that she's expecting will arrive tomorrow. In her window, try to execute the following statements. The command will start to execute, and then his window will appear to freeze.

    ```
    UPDATE product
    SET unit_price = 7.00
    WHERE id = 501
    ```

    The database server must guarantee repeatable reads at isolation level 2. To do so, it places a read lock on each row of the product table that the Accountant reads. When the Sales Manager tries to change the price back, her transaction must acquire a write lock on the plastic visor row of the product table. Since write locks are exclusive, her transaction must wait until the Accountant's transaction releases its read lock.

12. The Accountant is finished looking at the prices. He doesn't want to risk accidentally changing the database, so he completes his transaction with a ROLLBACK statement.

    ```
    ROLLBACK
    ```

Observe that as soon as the database server executes this statement, the Sales Manager's transaction completes.

id	name	unit_price
500	Visor	7.00
501	Visor	7.00

13. The Sales Manager can finish now. She wishes to commit her change to restore the original price.

```
COMMIT
```

Types of Locks and different isolation levels

When you upgraded the Accountant's isolation from level 1 to level 2, the database server used read locks where none had previously been acquired. In general, each isolation level is characterized by the types of locks needed and by how locks held by other transactions are treated.

At isolation level 0, the database server needs only write locks. It makes use of these locks to ensure that no two transactions make modifications that conflict. For example, a level 0 transaction acquires a write lock on a row before it updates or deletes it, and inserts any new rows with a write lock already in place.

Level 0 transactions perform no checks on the rows they are reading. For example, when a level 0 transaction reads a row, it doesn't bother to check what locks may or may not have been acquired on that row by other transactions. Since no checks are needed, level 0 transactions are particularly fast. This speed comes at the expense of consistency. Whenever they read a row which is write locked by another transaction, they risk returning dirty data.

At level 1, transactions check for write locks before they read a row. Although one more operation is required, these transactions are assured that all the data they read is committed. Try repeating the first tutorial with the isolation level set to 1 instead of 0. You will find that the Accountant's computation cannot proceed while the Sales Manager's transaction, which updates the price of the tee shirts, remains incomplete.

When the Accountant raised his isolation to level 2, the database server began using read locks. From then on, it acquired a read lock for his transaction on each row that matched his selection.

Transaction blocking

In the above tutorial, the Sales Manager window froze during the execution of her UPDATE command. The database server began to execute her command, then found that the Accountant's transaction had acquired a read lock on the row that the Sales Manager needed to change. At this point, the database server simply paused the execution of the UPDATE. Once the

Accountant finished his transaction with the ROLLBACK, the database server automatically released his locks. Finding no further obstructions, it then proceeded to complete execution of the Sales Manager's UPDATE.

In general, a locking conflict occurs when one transaction attempts to acquire an exclusive lock on a row on which another transaction holds a lock, or attempts to acquire a shared lock on a row on which another transaction holds an exclusive lock. One transaction must wait for another transaction to complete. The transaction that must wait is said to be **blocked** by another transaction.

When the database server identifies a locking conflict which prohibits a transaction from proceeding immediately, it can either pause execution of the transaction, or it can terminate the transaction, roll back any changes, and return an error. You control the route by setting the BLOCKING option. When BLOCKING is ON the second transaction waits, as in the above tutorial.

☞ For more information about the blocking option, see "The BLOCKING option" on page 110.

Phantom row tutorial

The following tutorial continues the same scenario. In this case, the Accountant views the department table while the Sales Manager creates a new department. You will observe the appearance of a phantom row.

If you have not done so, do steps 1 through 4 of the previous tutorial, "Non-repeatable read tutorial" on page 119, so that you have two instances of Interactive SQL.

1. Set the isolation level to 2 in the Sales Manager window by executing the following command.

   ```
   SET TEMPORARY OPTION ISOLATION_LEVEL = 2;
   ```

2. Set the isolation level to 2 for the Accountant window by executing the following command.

   ```
   SET TEMPORARY OPTION ISOLATION_LEVEL = 2;
   ```

3. In the Accountant window, enter the following command to list all the departments.

   ```
   SELECT * FROM department
   ORDER BY dept_id;
   ```

dept_id	dept_name	dept_head_id
100	R & D	501
200	Sales	902
300	Finance	1293
400	Marketing	1576
...	...	...

4. The Sales Manager decides to set up a new department to focus on the foreign market. Philip Chin, who has emp_id 129, will head the new department.

   ```
   INSERT INTO department
      (dept_id, dept_name, dept_head_id)
      VALUES(600, 'Foreign Sales', 129);
   ```

   The final command creates the new entry for the new department. It appears as a new row at the bottom of the table in the Sales Manager's window.

5. The Accountant, however, is not aware of the new department. At isolation level 2, the database server places locks to ensure that no row changes, but places no locks that stop other transactions from inserting new rows.

   The Accountant will only discover the new row if he executes his SELECT command again. In the Accountant's window, execute the SELECT statement again. You will see the new row appended to the table.

   ```
   SELECT *
   FROM department
   ORDER BY dept_id;
   ```

dept_id	dept_name	dept_head_id
100	R & D	501
200	Sales	902
300	Finance	1293
500	Shipping	703
...	...	...

The new row that appears is called a **phantom row** because, from the Accountant's point of view, it appears like an apparition, seemingly from nowhere. The Accountant is connected at isolation level 2. At that level, the database server acquires locks only on the rows that he is using. Other rows are left untouched and hence there is nothing to prevent the Sales Manager from inserting a new row.

6. The Accountant would prefer to avoid such surprises in future, so he raises the isolation level of his current transaction to level 3. Enter the following commands for the Accountant.

```
SET TEMPORARY OPTION ISOLATION_LEVEL = 3
SELECT *
FROM department
ORDER BY dept_id
```

7. The Sales Manager would like to add a second department to handle sales initiative aimed at large corporate partners. Execute the following command in the Sales Manager's window.

```
INSERT INTO department
   (dept_id, dept_name, dept_head_id)
VALUES(700, 'Major Account Sales', 902)
```

   The Sales Manager's window will pause during execution because the Accountant's locks block the command. Click the Interrupt the SQL Statement button on the toolbar (or choose Stop from the SQL menu) to interrupt this entry.

8. To avoid changing the demonstration database that comes with Adaptive Server Anywhere, you should roll back the insertion of the new departments. Execute the following command in the Sales Manager's window:

```
ROLLBACK
```

When the Accountant raised his isolation to level 3 and again selected all rows in the department table, the database server placed anti-insert locks on each row in the table, and one extra phantom lock to avoid insertion at the end of the table. When the Sales Manager attempted to insert a new row at the end of the table, it was this final lock that blocked her command.

Notice that the Sales Manager's command was blocked even though the Sales Manager is still connected at isolation level 2. The database server places anti-insert locks, like read locks, as demanded by the isolation level and statements of each transactions. Once placed, these locks must be respected by all other concurrent transactions.

☞ For more information on locking, see "How locking works" on page 131.

Practical locking implications tutorial

The following continues the same scenario. In this tutorial, the Accountant and the Sales Manager both have tasks that involve the sales order and sales order items tables. The Accountant needs to verify the amounts of the commission checks paid to the sales employees for the sales they made during the month of April 2001. The Sales Manager notices that a few orders have not been added to the database and wants to add them.

Their work demonstrates phantom locking. A **phantom lock** is a shared lock placed on an indexed scan position to prevent phantom rows. When a transaction at isolation level 3 selects rows which match a given criterion, the database server places anti-insert locks to stop other transactions from inserting rows which would also match. The number of locks placed on your behalf depends both on the search criterion and on the design of your database.

If you have not done so, do steps 1 through 3 of the previous tutorial which describe how to start two instances of Interactive SQL.

1. Set the isolation level to 2 in both the Sales Manager window and the Accountant window by executing the following command.

   ```
   SET TEMPORARY OPTION ISOLATION_LEVEL = 2
   ```

2. Each month, the sales representatives are paid a commission, which is calculated as a percentage of their sales for that month. The Accountant is preparing the commission checks for the month of April 2001. His first task is to calculate the total sales of each representative during this month.

   Enter the following command in the Accountant's window. Prices, sales order information, and employee data are stored in separate tables. Join these tables using the foreign key relationships to combine the necessary pieces of information.

   ```
   SELECT emp_id, emp_fname, emp_lname,
      SUM(sales_order_items.quantity * unit_price)
         AS "April sales"
   FROM employee
      KEY JOIN sales_order
      KEY JOIN sales_order_items
      KEY JOIN product
   WHERE '2001-04-01' <= order_date
      AND order_date < '2001-05-01'
   GROUP BY  emp_id, emp_fname, emp_lname
   ```

emp_id	emp_fname	emp_lname	April sales
129	Philip	Chin	2160.00
195	Marc	Dill	2568.00
299	Rollin	Overbey	5760.00
467	James	Klobucher	3228.00
…	…	…	…

3. The Sales Manager notices that a big order sold by Philip Chin was not entered into the database. Philip likes to be paid his commission promptly, so the Sales manager enters the missing order, which was placed on April 25.

   In the Sales Manager's window, enter the following commands. The Sales order and the items are entered in separate tables because one order can contain many items. You should create the entry for the sales order before you add items to it. To maintain referential integrity, the database server allows a transaction to add items to an order only if that order already exists.

```
INSERT into sales_order
VALUES ( 2653, 174, '2001-04-22', 'r1',
      'Central', 129);
INSERT into sales_order_items
VALUES ( 2653, 1, 601, 100, '2001-04-25' );
COMMIT;
```

4. The Accountant has no way of knowing that the Sales Manager has just added a new order. Had the new order been entered earlier, it would have been included in the calculation of Philip Chin's April sales.

   In the Accountant's window, calculate the April sales totals again. Use the same command, and observe that Philip Chin's April sales changes to $4560.00.

emp_id	emp_fname	emp_lname	April sales
129	Philip	Chin	4560.00
195	Marc	Dill	2568.00
299	Rollin	Overbey	5760.00
467	James	Klobucher	3228.00
…	…	…	…

   Imagine that the Accountant now marks all orders placed in April to indicate that commission has been paid. The order that the Sales Manager just entered might be found in the second search and marked as paid, even though it was not included in Philip's total April sales!

5. At isolation level 3, the database server places anti-insert locks to ensure that no other transactions can add a row which matches the criterion of a search or select.

   First, roll back the insertion of Philip's missing order: Execute the following statement in the Sales Manager's window.

   ```
   ROLLBACK
   ```

6. In the Accountant's window, execute the following two statements.

   ```
   ROLLBACK;
   SET TEMPORARY OPTION ISOLATION_LEVEL = 3;
   ```

7. In the Sales Manager's window, execute the following statements to remove the new order.

   ```
   DELETE
   FROM sales_order_items
   WHERE id = 2653;
   DELETE
   FROM sales_order
   WHERE id = 2653;
   COMMIT;
   ```

8. In the Accountant's window, execute same query as before.

   ```
   SELECT emp_id, emp_fname, emp_lname,
      SUM(sales_order_items.quantity * unit_price)
         AS "April sales"
   FROM employee
      KEY JOIN sales_order
      KEY JOIN sales_order_items
      KEY JOIN product
   WHERE '2001-04-01' <= order_date
      AND order_date < '2001-05-01'
   GROUP BY  emp_id, emp_fname, emp_lname
   ```

   Because you set the isolation to level 3, the database server will automatically place anti-insert locks to ensure that the Sales Manager can't insert April order items until the Accountant finishes his transaction.

9. Return to the Sales Manager's window. Again attempt to enter Philip Chin's missing order.

   ```
   INSERT INTO sales_order
   VALUES ( 2653, 174, '2001-04-22',
            'r1','Central', 129)
   ```

The Sales Manager's window will hang; the operation will not complete. Click the Interrupt the SQL Statement button on the toolbar (or choose Stop from the SQL menu) to interrupt this entry.

10. The Sales Manager can't enter the order in April, but you might think that she could still enter it in May.

    Change the date of the command to May 05 and try again.

    ```
    INSERT INTO sales_order
    VALUES ( 2653, 174, '2001-05-05', 'r1',
          'Central', 129)
    ```

    The Sales Manager's window will hang again. Click the Interrupt the SQL Statement button on the toolbar (or choose Stop from the SQL menu) to interrupt this entry. Although the database server places no more locks than necessary to prevent insertions, these locks have the potential to interfere with a large number of other transactions.

    The database server places locks in table indices. For example, it places a phantom lock in an index so a new row cannot be inserted immediately before it. However, when no suitable index is present, it must lock every row in the table.

    In some situations, anti-insert locks may block some insertions into a table, yet allow others.

11. The Sales Manager wishes to add a second item to order 2651. Use the following command.

    ```
    INSERT INTO sales_order_items
    VALUES ( 2651, 2, 302, 4, '2001-05-22' )
    ```

    All goes well, so the Sales Manager decides to add the following item to order 2652 as well.

    ```
    INSERT INTO sales_order_items
    VALUES ( 2652, 2, 600, 12, '2001-05-25' )
    ```

    The Sales Manager's window will hang. Click the Interrupt the SQL Statement button on the toolbar (or choose Stop from the SQL menu) to interrupt this entry.

12. Conclude this tutorial by undoing any changes to avoid changing the demonstration database. Enter the following command in the Sales Manager's window.

    ```
    ROLLBACK
    ```

    Enter the same command in the Accountant's window.

    ```
    ROLLBACK
    ```

You may now close both windows.

How locking works

When the database server processes a transaction, it can lock one or more rows of a table. The locks maintain the reliability of information stored in the database by preventing concurrent access by other transactions. They also improve the accuracy of result queries by identifying information which is in the process of being updated.

The database server places these locks automatically and needs no explicit instruction. It holds all the locks acquired by a transaction until the transaction is completed, for example by either a COMMIT or ROLLBACK statement, with a single exception noted in "Early release of read locks" on page 142.

The transaction that has access to the row is said to hold the lock. Depending on the type of lock, other transactions may have limited access to the locked row, or none at all.

Obtaining information about locks on a table

You can use the sa_locks system procedure to list information about locks that are held in the database. For more information, see "sa_locks system procedure" [*ASA SQL Reference*, page 721].

You can also view locks in Sybase Central. Select the database in the left pane, and a tab called Table Locks appears in the right pane. For each lock, this tab shows you the connection ID, user ID, table name, lock type, and lock name.

Objects that can be locked

Adaptive Server Anywhere places locks on the following objects.

- **Rows in tables** A transaction can lock a particular row to prevent another transaction from changing it. A transaction must place a write lock on a row if it intends to modify the row.
- **Insertion points between rows** Transactions typically scan rows using the ordering imposed by an index, or scan rows sequentially. In either case, a lock can be placed on the scan position. For example, placing a lock in an index can prevent another transaction from inserting a row with a specific value or range of values.
- **Table schemas** A transaction can lock the schema of a table, preventing other transactions from modifying the table's structure.

Of these objects, rows are likely the most intuitive. It is understandable that a transaction reading, updating, deleting, or inserting a row should limit the simultaneous access to other transactions. Similarly, a transaction changing the structure of a table, perhaps inserting a new column, could greatly impact other transactions. In such a case, it is essential to limit the access of other transactions to prevent errors.

Row orderings

You can use an index to order rows based on a particular criterion established when the index was constructed.

When there is no index, Adaptive Server Anywhere orders rows by their physical placement on disk. In the case of a sequential scan, the specific ordering is defined by the internal workings of the database server. You should not rely on the order of rows in a sequential scan. From the point of view of scanning the rows, however, Adaptive Server Anywhere treats the request similarly to an indexed scan, albeit using an ordering of its own choosing. It can place locks on positions in the scan as it would were it using an index.

Through locking a scan position, a transaction prevents some actions by other transactions relating to a particular range of values in that ordering of the rows. Insert and anti-insert locks are always placed on scan positions.

For example, a transaction might delete a row, hence deleting a particular primary key value. Until this transaction either commits the change or rolls it back, it must protect its right to do either. In the case of a deleted row, it must ensure that no other transaction can insert a row using the same primary key value, hence making a rollback operation impossible. A lock on the scan position this row occupied reserves this right while having the least impact on other transactions.

Types of locks

Adaptive Server Anywhere uses four distinct types of locks to implement its locking scheme and ensure appropriate levels of isolation between transactions:

- **read lock** (shared)
- **phantom lock or anti-insert lock** (shared)
- **write lock** (exclusive)
- **anti-phantom lock or insert lock** (shared)

Remember that the database server places these locks automatically and needs no explicit instruction.

Each of these locks has a separate purpose, and they all work together. Each prevents a particular set of inconsistencies that could occur in their absence.

Depending on the isolation level you select, the database server will use some or all of them to maintain the degree of consistency you require.

The above types of locks have the following uses:

- A transaction acquires a **write lock** whenever it inserts, updates, or deletes a row. No other transaction can obtain either a read or a write lock on the same row when a write lock is set. A write lock is an exclusive lock.
- A transaction can acquire a **read lock** when it reads a row. Several transactions can acquire read locks on the same row (a read lock is a shared or nonexclusive lock). Once a row has been read locked, no other transaction can obtain a write lock on it. Thus, a transaction can ensure that no other transaction modifies or deletes a row by acquiring a read lock.
- An **anti-insert lock**, or **phantom lock**, is a shared lock placed on an indexed scan position to prevent phantom rows. It prevents other transactions from inserting a row into a table immediately before the row which is anti-insert locked. Anti-insert locks for lookups using indexes require a read lock on each row that is read, and one extra read lock to prevent insertions into the index at the end of the result set. Phantom rows for lookups that do not use indexes require a read lock on all rows in a table to prevent insertions from altering the result set, and so can have a bad effect on concurrency.
- An **insert lock**, or **anti-phantom lock**, is a shared lock placed on an indexed scan position to reserve the right to insert a row. Once one transaction acquires an insert lock on a row, no other transaction can acquire an anti-insert lock on the same row. A read lock on the corresponding row is always acquired at the same time as an insert lock to ensure that no other process can update or destroy the row, thereby bypassing the insert lock.

Adaptive Server Anywhere uses these four types of locks as necessary to ensure the level of consistency that you require. You do not need to explicitly request the use of a particular lock. Instead, you control the level of consistency, as is explained in the next section. Knowledge of the types of locks will guide you in choosing isolation levels and understanding the impact of each level on performance.

Exclusive versus shared locks

These four types of locks each fall into one of two categories:

- **Exclusive locks** Only one transaction can hold an exclusive lock on a row of a table at one time. No transaction can obtain an exclusive lock while any other transaction holds a lock of any type on the same row.

Once a transaction acquires an exclusive lock, requests to lock the row by other transactions will be denied.

Write locks are exclusive.

- **Shared locks** Any number of transactions may acquire shared locks on any one row at the same time. Shared locks are sometimes referred to as non-exclusive locks.

  Read locks, insert locks, and anti-insert locks are shared.

Only one transaction should change any one row at one time. Otherwise, two simultaneous transactions might try to change one value to two different new ones. Hence, it is important that a write lock be exclusive.

By contrast, no difficulty arises if more than one transaction wants to read a row. Since neither is changing it, there is no conflict of interest. Hence, read locks may be shared.

You may apply similar reasoning to anti-insert and insert locks. Many transactions can prevent the insertion of a row in a particular scan position by each acquiring an anti-insert lock. Similar logic applies for insert locks. When a particular transaction requires exclusive access, it can easily achieve exclusive access by obtaining both an anti-insert and an insert lock on the same row. These locks do not conflict when they are held by the same transaction.

Which specific locks conflict?

The following table identifies the combination of locks that conflict.

	read	**write**	**anti-insert**	**insert**
read		conflict		
write	conflict	conflict		
anti-insert				conflict
insert			conflict	

These conflicts arise only when the locks are held by different transactions. For example, one transaction can obtain both anti-insert and insert locks on a single scan position to obtain exclusive access to a location.

Locking during queries

The locks that Adaptive Server Anywhere uses when a user enters a SELECT statement depend on the transaction's isolation level.

SELECT statements at isolation level 0

No locking operations are required when executing a SELECT statement at isolation level 0. Each transaction is not protected from changes introduced by other transactions. It is the responsibility of the programmer or database user to interpret the result of these queries with this limitation in mind.

SELECT statements at isolation level 1

You may be surprised to learn that Adaptive Server Anywhere uses almost no more locks when running a transaction at isolation level 1 than it does at isolation level 0. Indeed, the database server modifies its operation in only two ways.

The first difference in operation has nothing to do with acquiring locks, but rather with respecting them. At isolation level 0, a transaction is free to read any row, whether or not another transaction has acquired a write lock on it. By contrast, before reading each row an isolation level 1 transaction must check whether a write lock is in place. It cannot read past any write-locked rows because doing so might entail reading dirty data.

The second difference in operation creates cursor stability. Cursor stability is achieved by acquiring a read lock on the current row of a cursor. This read lock is released when the cursor is moved. More than one row may be affected if the contents of the cursor is the result of a join. In this case, the database server acquires read locks on all rows which have contributed information to the cursor’s current row and removes all these locks as soon as another row of the cursor is selected as current. A read lock placed to ensure cursor stability is the only type of lock that does not persist until the end of a transaction.

SELECT statements at isolation level 2

At isolation level 2, Adaptive Server Anywhere modifies its procedures to ensure that your reads are repeatable. If your SELECT command returns values from every row in a table, then the database server acquires a read lock on each row of the table as it reads it. If, instead, your SELECT contains a WHERE clause, or another condition which restricts the rows to selected, then the database server instead reads each row, tests the values in the row against your criterion, and then acquires a read lock on the row if it meets your criterion.

As at all isolation levels, the locks acquired at level 2 include all those set at levels 1 and 0. Thus, cursor stability is again ensured and dirty reads are not permitted.

SELECT statements at isolation level 3

When operating at isolation level 3, Adaptive Server Anywhere is obligated to ensure that all schedules are serializable. In particular, in addition to the requirements imposed at each of the lower levels, it must eliminate phantom rows.

To accommodate this requirement, the database server uses read locks and anti-insert locks. When you make a selection, the database server acquires a read lock on each row that contributes information to your result set. Doing so ensures that no other transactions can modify that material before you have finished using it.

This requirement is similar to the procedures that the database server uses at isolation level 2, but differs in that a lock must be acquired for each row read, *whether or not it meets any attached criteria* . For example, if you select the names of all employees in the sales department, then the server must lock all the rows which contain information about a sales person, whether the transaction is executing at isolation level 2 or 3. At isolation level 3, however, it must also acquire read locks on each of the rows of employees which are *not* in the sales department. Otherwise, someone else accessing the database could potentially transfer another employee to the sales department while you were still using your results.

The fact that a read lock must be acquired on each row whether or not it meets your criteria has two important implications.

- ♦ The database server may need to place many more locks than would be necessary at isolation level 2.
- ♦ The database server can operate a little more efficiently: It can immediately acquire a read lock on each row at as it reads it, since the locks must be placed whether or not the information in the row is accepted.

The number of anti-insert locks the server places can very greatly and depends upon your criteria and on the indexes available in the table. Suppose you select information about the employee with Employee ID 123. If the employee ID is the primary key of the employee table, then the database server can economize its operations. It can use the index, which is automatically built for a primary key, to locate the row efficiently. In addition, there is no danger that another transaction could change another Employee's ID to 123 because primary key values must be unique. The server can guarantee that no second employee is assigned that ID number simply by acquiring a read lock on only the one row containing information about the employee with that number.

By contrast, the database server would acquire more locks were you instead to select all the employees in the sales department. Since any number of employees could be added to the department, the server will likely have to read every row in the employee table and test whether each person is in sales. If this is the case, both read and anti-insert locks must be acquired for each row.

Locking during inserts

INSERT operations create new rows. Adaptive Server Anywhere employs the following procedure to ensure data integrity.

For more information about how locks are used during inserts, see "Anti-insert locks" on page 139.

1. Make a location in memory to store the new row. The location is initially hidden from the rest of the database, so there is as yet no concern that another transaction could access it.
2. Fill the new row with any supplied values.
3. Write lock the new row.
4. Place an insert lock in the table to which the row is being added. Recall that insert locks are exclusive, so once the insert lock is acquired, no other transaction can block the insertion by acquiring an anti-insert lock.
5. Insert the row into the table. Other transactions can now, for the first time, see that the new row exists. They can't modify or delete it, though, because of the write lock acquired earlier.
6. Update all affected indexes and verify both referential integrity and uniqueness, where appropriate. Verifying referential integrity means ensuring that no foreign key points to a primary key that does not exist. Primary key values must be unique. Other columns may also be defined to contain only unique values, and if any such columns exist, uniqueness is verified.
7. The transaction can be committed provided referential integrity will not be violated by doing so: record the operation in the transaction log file and release all locks.
8. Insert other rows as required, if you have selected the cascade option, and fire triggers.

Uniqueness

You can ensure that all values in a particular column, or combination of columns, are unique. The database server always performs this task by building an index for the unique column, even if you do not explicitly create one.

In particular, all primary key values must be unique. The database server automatically builds an index for the primary key of every table. Thus, you should not ask the database server to create an index on a primary key, as that index would be a redundant index.

Orphans and referential integrity

A foreign key is a reference to a primary key, usually in another table. When that primary key doesn't exist, the offending foreign key is called an **orphan**. Adaptive Server Anywhere automatically ensures that your database contains no orphans. This process is referred to as **verifying referential integrity**. The database server verifies referential integrity by counting orphans.

WAIT FOR COMMIT

You can ask the database server to delay verifying referential integrity to the end of your transaction. In this mode, you can insert one row which contains a foreign key, then insert a second row which contains the missing primary key. You must perform both operations in the same transaction. Otherwise, the database server will not allow your operations.

To request that the database server delay referential integrity checks until commit time, set the value of the option WAIT_FOR_COMMIT to ON. By default, this option is OFF. To turn it on, issue the following command:

```
SET OPTION WAIT_FOR_COMMIT = ON;
```

Before committing a transaction, the database server verifies that referential integrity is maintained by checking the number of orphans your transaction has created. At the end of every transaction, that number must be zero.

Even if the necessary primary key exists at the time you insert the row, the database server must ensure that it still exists when you commit your results. It does so by placing a read lock on the target row. With the read lock in place, any other transaction is still free to read that row, but none can delete or alter it.

Locking during updates

The database server modifies the information contained in a particular record using the following procedure.

1. Write lock the affected row.
2. If any entries changed are included in an index, delete each index entry corresponding to the old values. Make a record of any orphans created by doing so.
3. Update each of the affected values.
4. If indexed values were changed, add new index entries. Verify uniqueness where appropriate and verify referential integrity if a primary or foreign key was changed.
5. The transaction can be committed provided referential integrity will not be violated by doing so: record the operation in the transaction log file, including the previous values of all entries in the row, and release all locks.

6. Cascade the insert or delete operations, if you have selected this option and primary or secondary keys are affected.

You may be surprised to see that the deceptively simple operation of changing a value in a table can necessitate a rather large number of operations. The amount of work that the database server needs to do is much less if the value you are changing is not part of a primary or foreign key. It is lower still if it is not contained in an index, either explicitly or implicitly because you have declared that attribute unique.

The operation of verifying referential integrity during an UPDATE operation is no less simple than when the verification is performed during an INSERT. In fact, when you change the value of a primary key, you may create orphans. When you insert the replacement value, the database server must check for orphans once more.

Locking during deletes

The DELETE operation follows almost the same steps as the INSERT operation, except in the opposite order.

1. Write lock the affected row.

2. Delete each index entry present for the any values in the row. Immediately prior to deleting each index entry, acquire one or more anti-insert locks as necessary to prevent another transaction inserting a similar entry before the delete is committed. In order to verify referential integrity, the database server also keeps track of any orphans created as a side effect of the deletion.

3. Remove the row from the table so that it is no longer visible to other transactions. The row cannot be destroyed until the transaction is committed because doing so would remove the option of rolling back the transaction.

4. The transaction can be committed provided referential integrity will not be violated by doing so: record the operation in the transaction log file including the values of all entries in the row, release all locks, and destroy the row.

5. Cascade the delete operation, if you have selected this option and have modified a primary or foreign key.

Anti-insert locks

The database server must ensure that the DELETE operation can be rolled back. It does so in part by acquiring anti-insert locks. These locks are not exclusive; however, they deny other transactions the right to insert rows that make it impossible to roll back the DELETE operation. For example, the row deleted may have contained a primary key value, or another unique value. Were another transaction allowed to insert a row with the same value, the DELETE could not be undone without violating the uniqueness property.

Adaptive Server Anywhere enforces uniqueness constraints through indexes. In the case of a simple table with only a one-attribute primary key, a single phantom lock may suffice. Other arrangements can quickly escalate the number of locks required. For example, the table may have no primary key or other index associated with any of the attributes. Since the rows in a table have no fundamental ordering, the only way of preventing inserts may be to anti-insert lock the entire table.

Deleting a row can mean acquiring a great many locks. You can minimize the effect on concurrency in your database in a number of ways. As described earlier, indexes and primary keys reduce the number of locks required because they impose an ordering on the rows in the table. The database server automatically takes advantage of these orderings. Instead of acquiring locks on every row in the table, it can simply lock the *next* row. Without the index, the rows have no order and thus the concept of a next row is meaningless.

The database server acquires anti-insert locks on the row following the row deleted. Should you delete the last row of a table, the database server simply places the anti-insert lock on an invisible end row. In fact, if the table contains no index, the number of anti-insert locks required is one more than the number of rows in the table.

Anti-insert locks and read locks

While one or more anti-insert locks exclude an insert lock and one or more read locks exclude a write lock, no interaction exists between anti-insert/insert locks and read/write locks. For example, although a write lock cannot be acquired on a row that contains a read lock, it can be acquired on a row that has only an anti-insert lock. More options are open to the database server because of this flexible arrangement, but it means that the server must generally take the extra precaution of acquiring a read lock when acquiring an anti-insert lock. Otherwise, another transaction could delete the row.

Two-phase locking

Often, the general information about locking provided in the earlier sections will suffice to meet your needs. There are times, however, when you may benefit from more knowledge of what goes on inside the database server when you perform basic types of operations. This knowledge will provide you with a better basis from which to understand and predict potential problems that users of your database may encounter.

Two-phase locking is important in the context of ensuring that schedules are serializable. The **two-phase locking protocol** specifies a procedure each transaction follows.

This protocol is important because, if observed by all transactions, it will guarantee a serializable, and thus correct, schedule. It may also help you understand why some methods of locking permit some types of inconsistencies.

The two-phase locking protocol

1. Before operating on any row, a transaction must acquire a lock on that row.

2. After releasing a lock, a transaction must never acquire any more locks.

In practice, a transaction normally holds locks until it terminates with either a COMMIT or ROLLBACK statement. Releasing locks before the end of the transaction disallows the operation of rolling back the changes whenever doing so would necessitate operating on rows to return them to an earlier state.

The two-phase locking protocol allows the statement of the following important theorem:

The two-phase locking theorem
If all transactions obey the two-phase locking protocol, then all possible interleaved schedules are serializable.

In other words, if all transactions follow the two-phase locking protocol, then none of the inconsistencies mentioned above are possible.

This protocol defines the operations necessary to ensure complete consistency of your data, but you may decide that some types of inconsistencies are permissible during some operations on your database. Eliminating all inconsistency often means reducing the efficiency of your database.

Write locks are placed on modified, inserted, and deleted rows regardless of isolation level. They are always held until commit and rollback.

Read locks at different isolation levels

Isolation level	Read locks
0	None
1	On rows that appear in the result set; they are held only when a cursor is positioned on a row.
2	On rows that appear in the result set; they are held until the user executes a COMMIT or a ROLL-BACK.
3	On all rows read and all insertion points crossed in the computation of a result set

☞ For more information, see "Serializable schedules" on page 112

The details of locking are best broken into two sections: what happens during an INSERT, UPDATE, DELETE or SELECT and how the various isolation levels affect the placement of read, anti-insert, and insert locks.

Although you can control the amount of locking that takes place within the database server by setting the isolation level, there is a good deal of locking that occurs at all levels, even at level 0. These locking operations are fundamental. For example, once one transaction updates a row, no other transaction can modify the same row before the first transaction completes. Without this precaution, you could not rollback the first transaction.

The locking operations that the database server performs at isolation level 0 are the best to learn first exactly because they represent the foundation. The other levels add locking features, but do not remove any present in the lower levels. Thus, moving to higher isolation level adds operations not present at lower levels.

Early release of read locks

At isolation level 3, a transaction acquires a read lock on every row it reads. Ordinarily, a transaction never releases a lock before the end of the transaction. Indeed, it is essential that a transaction does not release locks early if the schedule is to be serializable.

Adaptive Server Anywhere always retains write locks until a transaction completes. If it were to release a lock sooner, another transaction could modify that row making it impossible to roll back the first transaction.

Read locks are released only in one, special circumstance. Under isolation level 1, transactions acquire a read lock on a row only when it becomes the current row of a cursor. Under isolation level 1, however, when that row is no longer current, the lock is released. This behavior is acceptable because the database server does not need to guarantee repeatable reads at isolation level 1.

☞ For more information about isolation levels, see "Choosing isolation levels" on page 112.

Special optimizations

The previous sections describe the locks acquired when all transactions are operating at a given isolation level. For example, when all transactions are running at isolation level 2, locking is performed as described in the appropriate section, above.

In practice, your database is likely to need to process multiple transactions that are at different levels. A few transactions, such as the transfer of money between accounts, must be serializable and so run at isolation level 3. For other operations, such as updating an address or calculating average daily sales, a lower isolation level will often suffice.

While the database server is not processing any transactions at level 3, it optimizes some operations so as to improve performance. In particular, many extra anti-insert and insert locks are often necessary to support a level 3 transaction. Under some circumstances, the database server can avoid either placing or checking for some types of locks when no level 3 transactions are present.

For example, the database server uses anti-insert locks to guard against two distinct types of circumstances:

1. Ensure that deletes in tables with unique attributes can be rolled back.

2. Eliminate phantom rows in level 3 transactions.

If no level 3 transactions are using a particular table, then the database server need not place anti-insert locks in the index of a table that contains no unique attributes. If, however, even one level 3 transaction is present, all transactions, even those at level 0, must place anti-insert locks so that the level 3 transactions can identify their operations.

Naturally, the database server always attaches notes to a table when it attempts the types of optimizations described above. Should a level 3 transaction suddenly start, you can be confident that the necessary locks will be put in place for it.

You may have little control over the mix of isolation levels in use at one time as so much will depend on the particular operations that the various users of your database wish to perform. Where possible, however, you may wish to select the time that level 3 operations execute because they have the potential to cause significant slowing of database operations. The impact is magnified because the database server is forced to perform extra operations for lower-level operations.

Particular concurrency issues

This section discusses the following particular concurrency issues:

- "Primary key generation" on page 145
- "Data definition statements and concurrency" on page 146

Primary key generation

You will encounter situations where the database should automatically generate a unique number. For example, if you are building a table to store sales invoices you might prefer that the database assign unique invoice numbers automatically, rather than require sales staff to pick them.

There are many methods for generating such numbers.

Example

For example, invoice numbers could be obtained by adding 1 to the previous invoice number. This method will not work when there is more than one person adding invoices to the database. Two people may decide to use the same invoice number.

There is more than one solution to the problem:

- Assign a range of invoice numbers to each person who adds new invoices.

  You could implement this scheme by creating a table with the columns user name and invoice number. The table would have one row for each user that adds invoices. Each time a user adds an invoice, the number in the table would be incremented and used for the new invoice. In order to handle all tables in the database, the table should have three columns: table name, user name, and last key value. You should periodically check that each person still has a sufficient supply of numbers.

- Create a table with the columns: table name and last key value.

  One row in this table would contain the last invoice number used. Each time someone adds an invoice, establish a new connection, increment the number in the table, and commit the change immediately. The incremented number can be used for the new invoice. Other users will be able to grab invoice numbers because you updated the row with a separate transaction that only lasted an instant.

- Use a column with a default value of NEWID in conjunction with the UNIQUEIDENTIFIER binary data type to generate a universally unique identifier.

  UUID and GUID values can be used to uniquely identify rows in a table. The values are generated such that a value produced on one computer will not match that produced on another. They can therefore be used as keys in replication and synchronization environments.

For more information about generating unique identifiers, see "The NEWID default" on page 82.

- Use a column with a default value of AUTOINCREMENT.

  For example,

```
CREATE TABLE orders (
   order_id INTEGER NOT NULL DEFAULT AUTOINCREMENT,
   order_date DATE,
   primary key( order_id )
)
```

  On inserts into the table, if a value is not specified for the autoincrement column, a unique value is generated. If a value is specified, it will be used. If the value is larger than the current maximum value for the column, that value will be used as a starting point for subsequent inserts. The value of the most recently inserted row in an autoincrement column is available as the global variable **@@identity**.

Unique values in replicated databases
Different techniques are required if you replicate your database and more than one person can add entries which must later be merged. For more information, see "Replication and concurrency" on page 148.

Data definition statements and concurrency

Data definition statements that change an entire table, such as CREATE INDEX, ALTER TABLE, and TRUNCATE TABLE, are prevented whenever the statement table is currently being used by another connection. These data definition statements can be time consuming and the database server will not process requests referencing the same table while the command is being processed.

The CREATE TABLE statement does not cause any concurrency conflicts.

The GRANT statement, REVOKE statement, and SET OPTION statement also do not cause concurrency conflicts. These commands affect any new SQL statements sent to the database server, but do not affect existing outstanding statements.

GRANT and REVOKE for a user are not allowed if that user is connected to the database.

Data definition statements and replicated databases
Using data definition statements in replicated databases requires special care. For more information see the separate manual entitled *Data Replication with SQL Remote* .

Replication and concurrency

Some computers on your network might be portable computers that people take away from the office or which are occasionally connected to the network. There may be several database applications that they would like to use while not connected to the network.

Database replication is the ideal solution to this problem. Using SQL Remote or MobiLink synchronization, you can publish information in a consolidated, or master, database to any number of other computers. You can control precisely the information replicated on any particular computer. Any person can receive particular tables, or even portions of the rows or columns of a table. By customizing the information each receives, you can ensure that their copy of the database is no larger than necessary to contain the information they require.

☞ Extensive information on SQL Remote replication and MobiLink synchronization is provided in the separate manuals entitled *SQL Remote User's Guide* and *MobiLink Synchronization User's Guide*. The information in this section is, thus, not intended to be complete. Rather, it introduces concepts related directly to locking and concurrency considerations.

SQL Remote and MobiLink allow replicated databases to be updated from a central, consolidated database, as well as updating this same central data as the results of transactions processed on the remote machine. Since updates can occur in either direction, this ability is referred to as **bi-directional replication**.

Since the results of transactions can affect the consolidated database, whether they are processed on the central machine or on a remote one, the effect is that of allowing concurrent transactions.

Transactions may happen at the same time on different machines. They may even involve the same data. In this case, though, the machines may not be physically connected. No means may exist by which the remote machine can contact the consolidated database to set any form of lock or identify which rows have changed. Thus, locks can not prevent inconsistencies as they do when all transactions are processed by a single server.

An added complication is introduced by the fact that any given remote machine may not hold a full copy of the database. Consider a transaction executed directly on the main, consolidated database. It may affect rows in two or more tables. The same transaction might not execute on a remote database, as there is no guarantee that one or both of the affected tables is replicated on that machine. Even if the same tables exist, they may not contain exactly the same information, depending upon how recently the information in the two databases has been synchronized.

To accommodate the above constraints, replication is not based on transactions, but rather on operations. An **operation** is a change to one row in a table. This change could be the result of an UPDATE, INSERT, or DELETE statement. An operation resulting from an UPDATE or DELETE identifies the initial values of each column and a transaction resulting from an INSERT or UPDATE records the final values.

A transaction may result in none, one, or more than one operation. One operation will never result from two or more transactions. If two transactions modify a table, then two or more corresponding operations will result.

If an operation results from a transaction processed on a remote computer, then it must be passed to the consolidated database so that the information can be merged. If, on the other hand, an operation results from a transaction on the consolidated computer, then the operation may need to be sent to *some* remote sites, but not others. Since each remote site may contain a replica of a portion of the complete database, SQL Remote knows to pass the operation to a remote site only when it affects that portion of the database.

Transaction log based replication

SQL Remote uses a **transaction log based** replication mechanism. When you activate SQL Remote on a machine, it scans the transaction log to identify the operations it must transfer and prepares one or more messages.

SQL Remote can pass these messages between computers using a number of methods. It can create files containing the messages and store them in a designated directory. Alternatively, SQL Remote can pass messages using any of the most common messaging protocols. You likely can use your present e-mail system.

Conflicts may arise when merging operations from remote sites into the consolidated database. For example, two people, each at a different remote site, may have changed the same value in the same table. Whereas the locking facility built into Adaptive Server Anywhere can eliminate conflict between concurrent transactions handled by the same server, it is impossible to automatically eliminate all conflicts between two remote users who both have permission to change the same value.

As the database administrator, you can avoid this potential problem through suitable database design or by writing conflict resolution algorithms. For example, you can decide that only one person will be responsible for updating a particular range of values in a particular table. If such a restriction is impractical, then you can instead use the conflict resolution facilities of SQL Remote to implement triggers and procedures which resolve conflicts in a manner appropriate to the data involved.

☞ SQL Remote provides the tools and programming facilities you need to take full advantage of database replication. For further information, see the *SQL Remote User's Guide* and the *MobiLink Synchronization User's Guide*.

Summary

Transactions and locking are perhaps second only in importance to relations between tables. The integrity and performance of any database can benefit from the judicious use of locking and careful construction of transactions. Both are essential to creating databases that must execute a large number of commands concurrently.

Transactions group SQL statements into logical units of work. You may end each by either rolling back any changes you have made or by committing these changes and so making them permanent.

Transactions are essential to data recovery in the event of system failure. They also play a pivotal role in interweaving statements from concurrent transactions.

To improve performance, multiple transactions must be executed concurrently. Each transaction is composed of component SQL statements. When two or more transactions are to be executed concurrently, the database server must schedule the execution of the individual statements. Concurrent transactions have the potential to introduce new, inconsistent results that could not arise were these same transactions executed sequentially.

Many types of inconsistencies are possible, but four typical types are particularly important because they are mentioned in the ISO SQL/92 standard and the isolation levels are defined in terms of them.

- **Dirty read** One transaction reads data modified, but not yet committed, by another.
- **Non-repeatable read** A transaction reads the same row twice and gets different values.
- **Phantom row** A transaction selects rows, using a certain criterion, twice and finds new rows in the second result set.
- **Lost Update** One transaction's changes to a row are completely lost because another transaction is allowed to save an update based on earlier data.

A schedule is called serializable whenever the effect of executing the statements according to the schedule is the same as could be achieved by executing each of the transactions sequentially. Schedules are said to be **correct** if they are serializable. A serializable schedule will cause none of the above inconsistencies.

Locking controls the amount and types of interference permitted. Adaptive Server Anywhere provides you with four levels of locking: isolation levels 0, 1, 2, and 3. At the highest isolation, level 3, Adaptive Server Anywhere guarantees that the schedule is serializable, meaning that the effect of executing all the transactions is equivalent to running them sequentially.

Unfortunately, locks acquired by one transaction may impede the progress of other transactions. Because of this problem, lower isolation levels are desirable whenever the inconsistencies they may allow are tolerable. Increased isolation to improve data consistency frequently means lowering the concurrency, the efficiency of the database at processing concurrent transactions. You must frequently balance the requirements for consistency against the need for performance to determine the best isolation level for each operation.

Conflicting locking requirements between different transactions may lead to blocking or deadlock. Adaptive Server Anywhere contains mechanisms for dealing with both these situations, and provides you with options to control them.

Transactions at higher isolation levels do not, however, *always* impact concurrency. Other transactions will be impeded only if they require access to locked rows. You can improve concurrency through careful design of your database and transactions. For example, you can shorten the time that locks are held by dividing one transaction into two shorter ones, or you might find that adding an index allows your transaction to operate at higher isolation levels with fewer locks.

The increased popularity of portable computers will frequently mean that your database may need to be replicated. Replication is an extremely convenient feature of Adaptive Server Anywhere, but it introduces new considerations related to concurrency. These topics are covered in a separate manual.

CHAPTER 5

Monitoring and Improving Performance

About this chapter

This chapter describes how to monitor and improve the performance of your database.

Contents

Topic:	page
Performance analysis tools	154
Top performance tips	161
Using the cache to improve performance	176
Using indexes to improve performance	181
Using keys to improve query performance	182
Sorting query results	184
Use of work tables in query processing	185
Monitoring database performance	187
Fragmentation	193
Profiling database procedures	197

Performance analysis tools

While improving database performance doesn't have to be labour-intensive, it's always best to start with a plan. Evaluate the current performance of your database, and consider all your options before changing anything. By re-evaluating your database schema using Adaptive Server Anywhere's performance features and performance analysis tools, you can diagnose and correct performance problems and keep your database performing at its optimum.

Ultimately, how well your database performs depends heavily on the design of its bones. And so, one of the most basic of ways of improving performance is with good schema design. The database schema is the skeleton of your database, and includes definitions of such things as tables, views, triggers, and the relationships between them. Re-evaluate your database schema and make note of the following areas where small changes can offer impressive gains.

A variety of tools are available to help you analyze and monitor the current performance of your Adaptive Server Anywhere database. Tools include request-level logging, procedure profiling, graphical plans, the Performance Monitor and timing utilities.

Request-level logging

Request-level logging is a good starting point for performance analysis of a specific application when it is not obvious whether the server or the client is at fault. It is also useful in determining the specific request to the server that might be responsible for problems.

Request level logging logs individual requests received from and responses sent to an application. It's most useful for determining what the server is being asked to do by the application.

Logged information includes timestamps, connection ids, and request type, for example. You can use the -zr database server option to specify what type of information is logged. You can redirect the output to a file for further analysis using the -zo option.

The **sa_get_request_times ([request_log_filename [, connection_id]])** stored procedure reads a request-level log and populates a global temporary table **satmp_request_time** with statements from the log and their execution times. The time recorded is straightforward for INSERT/UPDATE/DELETE statements. For queries, the time recorded is the total elapsed time from PREPARE to DROP (describe/open/fetch/close). That means you need to be aware of any open cursors.

Analyze **satmp_request_time** for candidates. Statements that are cheap but frequently executed may represent performance problems

You can use sa_get_request_profile([request_log_filename [, connection_id]]) to call **sa_get_request_times()** and summarize the resulting **satmp_request_time** into another global temporary table **satmp_request_profile**. This procedure also groups statements together and provides the number of calls, execution times, and so on.

Filtering request-level logs

Output to the request-level log can be filtered to include only requests from a specific connection or from a specific database. This can help reduce the size of the log when monitoring a server with many active connections or multiple databases.

❖ To filter according to a connection

1. Use the following syntax:

```
call sa_server_option('requests_for_connection',connection-
        id)
```

   where *connection-id* can be obtained from **sa_conn_info()**.

❖ To filter according to a database

1. Use the following syntax:

```
call sa_server_option('requests_for_database',database-id)
```

   The database-id can be obtained from **connection_property('DBNumber')** when connected to that database. Filtering remains in effect until explicitly reset, or until the server is shut down.

❖ To reset filtering

1. Use either of the following two statements, to reset either by connection or by database:

```
call sa_server_option('requests_for_connection',-1)
```

```
call sa_server_option('requests_for_database',-1)
```

Outputting host variables to request-level logs

Host variable values can be output to a request log.

❖ To include host variable values

1. To include host variable values in the request-level log:
   - use the -zr server command line option with a value of **sql+hostvars**
   - execute the following:

```
call sa_server_option('request_level_
         logging','sql+host')
```

The request log analysis procedure, **sa_get_request_times** recognizes host variables in the log and adds them to the global temporary table **satmp_request_hostvar**. For database versions before 9.0.0 where this temporary table does not exist, host variable values are ignored.

Index Consultant

The Index Consultant recommends indexes that can help improve performance for large workloads or complex queries. It takes as input either a single query or a workload of queries, and recommends indexes to add to the database as well as unused indexes to drop.

The Index Consultant creates a set of virtual indexes in the database. It estimates query execution costs using those indexes to see which indexes lead to improved execution plans. The Index Consultant evaluates multiple column indexes as well as single-column indexes, and also investigates the impact of clustered or unclustered indexes.

☞ For more information about the Index Consultant, see "Index Consultant overview" on page 63.

Procedure profiling

Procedure profiling shows you how long it takes your stored procedures, functions, events, and triggers to execute. You can also view the execution time for each line of a procedure. Using the database profiling information, you can determine which procedures can be fine-tuned to improve performance within your database.

Procedure profiling can help you analyze specific database procedures (including stored procedures, functions, events and triggers) found to be expensive via request level logging. It can also help you discover expensive, hidden, procedures, for example triggers, events, and nested stored procedure calls. As well, it can help pin-point potential problem areas within the body of a procedure

You can use stored procedures to view procedure profiling information that has been gathered by the server. The **sa_procedure_profile_summary** stored procedure provides information about all of the procedures within the database. You can use this procedure to view the profiling data for stored procedures, functions, events, and triggers within the same result set. However, a better way to examine this information is to use Sybase Central.

Profiling can be enabled/disabled dynamically and the data it generates is transient, stored in memory by the server. You can view it using the Profile tab in Sybase Central. Once profiling is enabled, the database gathers profiling information until you disable profiling or until the server is shut down. Profiling information is cumulative, and accurate to 1 ms.

Graphical plan

The graphical plan feature in Interactive SQL displays the execution plan for a query. It is useful for diagnosing performance issues with specific queries. For example, the information in the plan may help you decide where to add an index to your database.

The graphical plan provides a great deal more information than the short or long plans. You can choose to see the graphical plan either with or without statistics. Both allow you to quickly view which parts of the plan have been estimated as the most expensive. The graphical plan with statistics, though more expensive to view, also provides the actual query execution statistics as monitored by the server when the query is executed, and permits direct comparison between the estimates used by the query optimizer in constructing the access plan with the actual statistics monitored during execution. Note, however, that the optimizer is often unable to precisely estimate a query's cost, so expect there to be differences. The graphical plan is the default format for access plans.

You can obtain detailed information about the nodes in the plan by clicking the node in the graphical diagram. The graphical plan with statistics shows you all the estimates that are provided with the graphical plan, but also shows actual runtime costs of executing the statement. To do this, the statement must actually be executed. This means that there may be a delay in accessing the plan for expensive queries. It also means that any parts of your query such as deletes or updates are actually executed, although you can perform a rollback to undo these changes.

Use the graphical plan with statistics when you are having performance problems, and the estimated row count or run time differs from your expectations. The graphical plan with statistics provides estimates and actual statistics for you to compare. A large difference between actual and estimate is a warning sign that the optimizer might not have sufficient information to prepare correct estimates.

Following are some of the key statistics you can check in the graphical plan with statistics, and some possible remedies:

- Row count measures the rows in the result set. If the estimated row count is significantly different from the actual row count, the selectivity of underlying predicates is probably incorrect.
- Accurate selectivity estimates are critical for the proper operation of the query optimizer. For example, if the optimizer mistakenly estimates a predicate to be highly selective (with, say, a selectivity of 5%), but in reality, the predicate is much less selective (for example, 50%), then performance may suffer. In general, estimates may not be precise. However, a significantly large error does indicate a possible problem. If the predicate is over a base column for which there does not exist a histogram, executing a CREATE STATISTICS statement to create a histogram may correct the problem. If selectivity error remains a problem then, as a last resort, you may wish to consider specifying a user estimate of selectivity along with the predicate in the query text.
- Runtime measures the time to execute the query. If the runtime is incorrect for a table scan or index scan, you may improve performance by executing the REORGANIZE TABLE statement. You can use the sa_table_fragmentation and the sa_index_density function to determine whether the table or index are fragmented.
- When the source of the estimate is Guess, the optimizer has no information to use, which may indicate a problem. If the estimate source is Index and the selectivity estimate is incorrect, your problem may be that the index is skewed: you may benefit from defragmenting the index with the REORGANIZE INDEX statement.
- If the number of cache reads and cache hits are exactly the same, then your entire database is in cache—an excellent thing. When reads are greater than hits, it means that the server is attempting to go to cache but failing, and that it must read from disk. In some cases, such as hash joins, this is expected. In other cases, such as nested loops joins, a poor cache-hit ratio may indicate a performance problem, and you may benefit from increasing your cache size.

Performance Monitor

The Performance Monitor is useful for tracking detailed information about database server actions, including disk and memory access.

With the Sybase Central Performance Monitor, you can graph a variety of statistics of any Adaptive Server Anywhere database server that you can connect to in Sybase Central. All statistics in Sybase Central are shown in the Statistics folder.

Features of the Performance Monitor include:

- Real-time updates (at adjustable intervals)
- A color-coded and resizable legend
- Configurable appearance properties

When you're using the Sybase Central Performance Monitor, note that it uses actual queries against the server to gather its statistics, so the monitor itself affects some statistics (such as Cache Reads/sec). As a more precise alternative, you can graph server statistics using the Windows Performance Monitor.

The Windows monitor has two advantages:

- It offers more performance statistics (mainly those concerned with network communications).
- Unlike the Sybase Central monitor, the Windows monitor is non-intrusive. It uses a shared-memory scheme instead of performing queries against the server, so it does not affect the statistics themselves.

If you run multiple versions of Adaptive Server Anywhere simultaneously, it is also possible to run multiple versions of the Performance Monitor simultaneously

Timing utilities

Some performance testing utilities, including fetchtst, instest, and trantest, are available in the <installation dir>\samples\asa\directory. Complete documentation can be found in the *Readme.txt* file in the same folder as the utility. These tools will give you more accurate timings than the graphical plan with statistics. These utilities can provide an indication of the best achievable performance (for example, throughput) for a given server and database configuration.

Fetchtst measures fetch rates for an arbitrary query. Instest determines the time required for rows to be inserted into a table. Trantest measures the load that can be handled by a given server configuration given a database design and a set of transactions.

Concurrency

When the database server processes a transaction, it can lock one or more rows of a table. The locks maintain the reliability of information stored in the database by preventing concurrent access by other transactions. They also improve the accuracy of result queries by identifying information which is in the process of being updated.

The database server places these locks automatically and needs no explicit instruction. It holds all the locks acquired by a transaction until the transaction is completed. The transaction that has access to the row is said to hold the lock. Depending on the type of lock, other transactions may have limited access to the locked row, or none at all.

Performance can be compromised if a row or rows are frequently accessed by a number of users simultaneously. If you suspect locking problems, consider using the **sa_locks** procedure to obtain information on locks in the database. If lock issues are identified, information on the connection processes involved can be found using the AppInfo connection property.

Top performance tips

Adaptive Server Anywhere provides excellent performance automatically. However, the following tips will help you achieve the most from the product.

Always use a transaction log

You might think that Adaptive Server Anywhere would run faster without a transaction log because it would have to maintain less information on disk. Yet, the opposite is actually true. Not only does a transaction log provide a large amount of protection, it can dramatically improve performance.

Operating without a transaction log, Adaptive Server Anywhere must perform a checkpoint at the end of every transaction. Writing these changes consumes considerable resources.

With a transaction log, however, Adaptive Server Anywhere need only write notes detailing the changes as they occur. It can choose to write the new database pages all at once, at the most efficient time. **Checkpoints** make sure information enters the database file, and that it is consistent and up to date.

> **Tip**
> Always use a transaction log. It helps protect your data *and* it greatly improves performance.

If you can store the transaction log on a different physical device than the one containing the main database file, you can further improve performance. The extra drive head does not generally have to seek to get to the end of the transaction log.

Increase the cache size

Adaptive Server Anywhere stores recently used pages in a cache. Should a request need to access the page more than once, or should another connection require the same page, it may find it already in memory and hence avoid having to read information from disk. This is especially an issue for encrypted databases, which require a larger cache than unencrypted.

If your cache is too small, Adaptive Server Anywhere cannot keep pages in memory long enough to reap these benefits.

On UNIX, Windows NT/2000/XP, and Windows 95/98/Me, the database server dynamically changes cache size as needed. However, the cache is still limited by the amount of memory that is physically available, and by the amount used by other applications.

On Windows CE and Novell NetWare, the size of the cache is set on the command line when you launch the database server. Be sure to allocate as much memory to the database cache as possible, given the requirements of the other applications and processes that run concurrently. In particular, databases using Java objects benefit greatly from larger cache sizes. If you use Java in your database, consider a cache of at least 8 Mb.

> **Tip**
> Increasing the cache size can often improve performance dramatically, since retrieving information from memory is many times faster than reading it from disk. You may find it worthwhile to purchase more RAM to allow a larger cache.

☞ For more information, see "Using the cache to improve performance" on page 176.

Normalize your table structure

In general, the information in each column of a table should depend solely on the value of the primary key. If this is not the case, then one table may contain multiple copies of the same information, and your table may need to be normalized.

Normalization reduces duplication in a relational database. For example, suppose the people in your company work at a number of offices. To normalize the database, consider placing information about the offices (such as its address and main telephone numbers) in a separate table, rather than duplicating all this information for every employee.

You can, however, take the generally good notion of normalization too far. If the amount of duplicate information is small, you may find it better to duplicate the information and maintain its integrity using triggers or other constraints.

Use indexes effectively

When executing a query, Adaptive Server Anywhere chooses how to access each table. Indexes greatly speed up the access. When the database server cannot find a suitable index, it instead resorts to scanning the table sequentially—a process that can take a long time.

For example, suppose you need to search a large database for people, but you only know either their first or their last name, but not both. If no index exists, Adaptive Sever Anywhere scans the entire table. If however, you created two indexes (one that contains the last names first, and a second that contains the first names first), Adaptive Sever Anywhere scans the indexes first, and can generally return the information to you faster.

Using indexes

Although indexes let Adaptive Server Anywhere locate information very efficiently, exercise some caution when adding them. Each index creates extra work every time you insert, delete, or update a row because Adaptive Server Anywhere must also update all affected indexes.

Consider adding an index when it will allow Adaptive Server Anywhere to access data more efficiently. In particular, add an index when it eliminates unnecessarily accessing a large table sequentially. If, however, you need better performance when you add rows to a table, and finding information quickly is not an issue, use as few indexes as possible.

You may wish to use the Index Consultant to guide you through the selection of an effective set of indexes for your database. For more information, see "Index Consultant overview" on page 63.

Clustered indexes

Using clustered indexes stores rows in a table in approximately the same order as they appear in the index.

☞ For more information, see "Indexes" on page 395 and "Using clustered indexes" on page 59.

Place different files on different devices

Disk drives operate much more slowly than modern processors or RAM. Often, simply waiting for the disk to read or write pages is the reason that a database server is slow.

You almost always improve database performance when you put different physical database files on different physical devices. For example, while one disk drive is busy swapping database pages to and from the cache, another device can be writing to the log file.

Notice that to gain these benefits, the devices must be independent. A single disk, partitioned into smaller logical drives, is unlikely to yield benefits.

Adaptive Server Anywhere uses four types of files:

1. database (*.db*)
2. transaction log (*.log*)
3. transaction log mirror (*.mlg*)
4. temporary file (*.tmp*)

The **database file** holds the entire contents of your database. A single file can contain a single database, or you can add up to 12 dbspaces, which are additional files holding the same database. You choose a location for it, appropriate to your needs.

The **transaction log file** is required for recovery of the information in your database in the event of a failure. For extra protection, you can maintain a duplicate in a third type of file called a **transaction log mirror file**. Adaptive Server Anywhere writes the same information at the same time to each of these files.

> **Tip**
> By placing the transaction log mirror file (if you use one) on a physically separate drive, you gain better protection against disk failure, and Adaptive Server Anywhere runs faster because it can efficiently write to the log and log mirror files. To specify the location of the transaction log and transaction log mirror files, use the *dblog* command line utility, or the Change Log File Settings utility in Sybase Central.

Adaptive Server Anywhere may need more space than is available to it in the cache for such operations as sorting and forming unions. When it needs this space, it generally uses it intensively. The overall performance of your database becomes heavily dependent on the speed of the device containing the fourth type of file, the **temporary file**.

> **Tip**
> If the temporary file is on a fast device, physically separate from the one holding the database file, Adaptive Server Anywhere will run faster. This is because many of the operations that necessitate using the temporary file also require retrieving a lot of information from the database. Placing the information on two separate disks allows the operations to take place simultaneously.

Choose the location of your temporary file carefully. Adaptive Server Anywhere examines the following environment variables, in the order shown, to determine the directory in which to place the temporary file.

1. ASTMP

2. TMP

3. TMPDIR

4. TEMP

If none of these is defined, Adaptive Server Anywhere places its temporary file in the current directory—not a good location for the best performance.

If an environment variable is not defined, Adaptive Server Anywhere places its temporary file in the */tmp/.SQLAnywhere* directory for UNIX, and in the current directory for Windows.

If your machine has a sufficient number of fast devices, you can gain even more performance by placing each of these files on a separate device. You can even divide your database into multiple dbspaces, located on separate devices. In such a case, group tables in the separate dbspaces so that common join operations read information from different files.

A similar strategy involves placing the temporary and database files on a RAID device or a Windows NT stripe set. Although such devices act as a logical drive, they dramatically improve performance by distributing files over many physical drives and accessing the information using multiple heads.

☞ For more information about work tables, see "Use of work tables in query processing" on page 185.

☞ For information about data recovery, see "Backup and Data Recovery" [*ASA Database Administration Guide,* page 337].

☞ For information about transaction logs and the *dbcc* utility, see "Transaction log utility options" [*ASA Database Administration Guide,* page 529].

Turn off autocommit mode

If your application runs in **autocommit mode**, then Adaptive Server Anywhere treats each of your statements as a separate transaction. In effect, it is equivalent to appending a COMMIT statement to the end of each of your commands.

Instead of running in autocommit mode, consider grouping your commands so each group performs one logical task. If you do disable autocommit, you must execute an explicit commit after each logical group of commands. Also, be aware that if logical transactions are large, blocking and deadlock can happen.

The cost of using autocommit mode is particularly high if you are not using a transaction log file. Every statement forces a checkpoint—an operation that can involve writing numerous pages of information to disk.

Each application interface has its own way of setting autocommit behavior. For the Open Client, ODBC, and JDBC interfaces, Autocommit is the default behavior.

☞ For more information about autocommit, see "Setting autocommit or manual commit mode" [*ASA Programming Guide*, page 47].

Use bulk operations methods

If you find yourself loading huge amounts of information into your database, you can benefit from the special tools provided for these tasks.

If you are loading large files, it is more efficient to create indexes on the table after the data is loaded.

☞ For information on improving bulk operation performance, see "Performance considerations of moving data" on page 522.

Use the WITH EXPRESS CHECK option when validating tables

If you find that validating large databases with a small cache takes a long time, you can use one of two options to reduce the amount of time it takes. Using the WITH EXPRESS CHECK option with the VALIDATE TABLE statement, or the `-fx` option with the Validation utility can significantly increase the speed at which your tables validate.

☞ For information on improving performance when validating databases, see "Improving performance when validating databases" [*ASA Database Administration Guide*, page 365].

Try using Adaptive Server Anywhere's compression features

Enabling compression for one connection or for all connections, and adjusting the minimum size limit at which packets are compressed can offer significant improvements to Adaptive Server Anywhere performance under some circumstances.

To determine if enabling compression will help in your particular situation, we recommend that you conduct a performance analysis on your particular network and using your particular application before using communication compression in a production environment.

☞ Enabling compression increases the quantity of information stored in data packets, thereby reducing the number of packets required to transmit a particular set of data. By reducing the number of packets, the data can be transmitted more quickly.

☞ Specifying the compression threshold allows you to choose the minimum size of data packets that you want compressed. The optimal value for the compression threshold may be affected by a variety of factors, including the type and speed of network you are using.

☞ For information about using compression to improve performance, see "Adjusting communication compression settings to improve performance" [*ASA Database Administration Guide*, page 102].

☞ For more information about compression settings, see the "Compress connection parameter [COMP]" [*ASA Database Administration Guide*, page 181] and the "CompressionThreshold connection parameter [COMPTH]" [*ASA Database Administration Guide*, page 182].

Reduce the number of requests between client and server

If you find yourself in a situation where your:

- network exhibits poor latency
- application sends many cursor open and close requests

you can use the LazyClose and PrefetchOnOpen network communication parameters to reduce the number of requests between the client and server and thereby improve performance.

☞ For information about these parameters, see the "LazyClose connection parameter [LCLOSE]" [*ASA Database Administration Guide*, page 193] and the "PreFetchOnOpen communication parameter" [*ASA Database Administration Guide*, page 214].

Reduce table widths

Tables with a large number of columns are known as wide tables. When the number of columns in a table causes the size of individual rows to exceed the database page size, each row is split across two or more database pages. The more pages a row takes up, the longer it takes to read each row. If you find performance lacking, and you know you have tables with many columns, consider normalizing your tables to reduce the number of columns. If that is not possible, a larger database page size may be helpful, especially if most tables are wide.

Reduce primary key width

Wide primary keys are composed of two or more columns. The more columns contained in your primary key, the more demand there is on the server. Reducing the number of columns in your primary keys can improve performance.

Declare constraints

Undeclared primary key-foreign key relationships exist between tables when there is an implied relationship between the values of columns in different tables. It is true that not declaring the relationship can save time on index maintenance, however, declaring the relationship can improve performance of queries when joins take place because the cost model is able to do a better job of estimation.

Use appropriate data types

Data types store information about specific sets of data, including ranges of values, the operations that can be performed on those values, and how the values are stored in memory. You can improve performance by using the appropriate data type for your data. For instance, avoid assigning a data type of char or string to values that only contain numeric data. And whenever possible, choose economical data types over the more expensive numeric and string types.

Use AUTOINCREMENT to create primary keys

Primary key values must be unique. Although there are a variety of ways to create unique values for primary keys, the most efficient method is setting the default column value to be AUTOINCREMENT ON. You can use this default for any column in which you want to maintain unique values. Using the AUTOINCREMENT feature to generate primary key values is faster than other methods because the value is generated by the server.

Replace expensive triggers

Evaluate the use of triggers to see if some of the triggers could be replaced by features available in the server. For instance, triggers to update columns with the latest update time and user information can be replaced with the corresponding special values in the server. As well, using the default settings on existing triggers can also improve performance.

Minimize cascading referential actions

Cascading referential actions are costly in terms of performance, because they cause updates to multiple tables for every transaction. For example, if the foreign key from *employee* to *department* were defined with ON UPDATE CASCADE, then updating the department ID would automatically update the employee table. While cascading referential actions are convenient, sometimes it might be more efficient to implement them in application logic.

Pay attention to the order of columns

Columns in a row are accessed in a sequential manner in the order of their creation. For example, in order to access columns at the end of a row, Adaptive Server Anywhere has to skip over any columns that appear earlier in the row. Primary key columns are always stored at the beginning of rows. For this reason, it is important to create tables such that small and/or frequently accessed columns are placed before seldom accessed columns in the table.

Upgrade to take advantage of new features

Adaptive Server Anywhere is constantly being evaluated and enhanced in terms of performance features and usability. With each subsequent release, you can take advantage of new features and behavior changes that will help you optimize performance.

While you can simply run a database created with an older version of Adaptive Server Anywhere on a newer release, many of the new features are only available if the database is upgraded. Running the Upgrade utility adds and modifies system tables, system procedures and database options to upgrade a database from an older version of Adaptive Server Anywhere to a newer version.

Rebuild your database

Rebuilding your database is the process of unloading and reloading your entire database. It is sometimes called upgrading your database file format.

Rebuilding removes all the information, including data and schema, and puts it all back in a uniform fashion, thus filling space and improving performance much like defragmenting your disk drive. It also gives you the opportunity to change certain settings. In comparison, using the upgrade utility is quicker than rebuilding, and it does not affect the storage of your files.

When you upgrade your database, rebuilding also gives you access to all new features and performance enhancements in the latest version of the software.

Examine your database and server configurations

Go over your database/server configuration, and make sure that your hardware and file space are appropriate for your usage.

Use an appropriate page size

The page size you choose can affect the performance of your database. Adaptive Server Anywhere supports page sizes of (in bytes) 1024, 2048, 4096, 8192, 16384, or 32768, with 2048 being the default. There are advantages and disadvantages to whichever page size you choose.

While smaller pages hold less information and may force less efficient use of space, particularly if you insert rows that are slightly more than half a page in size. However, small page sizes allow Adaptive Server Anywhere to run with fewer resources because it can store more pages in a cache of the same size. Small pages are particularly useful if your database must run on small machines with limited memory. They can also help in situations when you use your database primarily to retrieve small pieces of information from random locations.

By contrast, a larger page sizes help Adaptive Server Anywhere read databases more efficiently. Large page sizes also tend to benefit large databases, and queries that perform sequential table scans. Often, the physical design of disks permits them to retrieve fewer large blocks more efficiently than many small ones. Other benefits of large page sizes include improving the fan-out of your indexes, thereby reducing the number of index levels, and allowing tables to include more columns.

Keep in mind that larger page sizes have additional memory requirements. And since the maximum number of rows stored on a page is 255, tables with small rows will not fill each page and therefore use space inefficiently. As well, extremely large page sizes (16 kb or 32 kb) are not recommended for most applications unless you can be sure that a large database server cache is always available. Investigate the effects of increased memory and disk space on performance characteristics before using 16 kb or 32 kb page sizes.

The server's memory usage is proportional to the number of databases loaded, and the page size of the databases. It is strongly recommended that you do performance testing (and testing in general) when choosing a page size. Then choose the smallest page size (>= 4K) that gives satisfactory results. It is particularly important to pick the correct (and reasonable) page size if a large number of databases are going to be started on the same server.

You cannot change the page size of an existing database. Instead you must create a new database and use the `-p` option of *dbinit* to specify the page size. For example, the following command creates a database with 4K pages.

```
dbinit -p 4096 new.db
```

☞ For more information about larger page sizes, see "Setting a maximum

page size” [*ASA Database Administration Guide*, page 12].

Scattered reads If you are working with a Windows NT Service Patch 2 or higher system, or with a Windows 2000/XP system, a page size of at least 4K allows the database server to read a large contiguous region of database pages on disk directly into the appropriate place in cache, bypassing the 64K buffer entirely. This feature can significantly improve performance.

Examine file, table, and index fragmentation

Fragmentation occurs naturally as you make changes to your database. Performance can suffer if your files, tables, or indexes are excessively fragmented. This becomes more important as your database increases in size. Adaptive Server Anywhere contains stored procedures that generate information about the fragmentation of files, tables, and indexes.

If the decrease in performance is significant, consider

- rebuilding your database to reduce table and/or index fragmentation
- putting the database on a disk partition by itself to reduce file fragmentation
- running one of the available Windows utilities periodically to reduce file fragmentation
- reorganizing your tables to reduce database fragmentation
- rebuilding your database if you have performed extensive delete/update/insert activity on a number of tables
- using the REORGANIZE TABLE statement to defragment rows in a table, or to compress indexes which may have become sparse due to DELETEs. Reorganizing tables can reduce the total number of pages used to store a table and its indexes, and it may reduce the number of levels in an index tree as well.

☞ For more information about detecting and fixing file, table, and index fragmentation, see “Fragmentation” on page 193.

Eliminate operating system file fragmentation To eliminate operating system file fragmentation problems, periodically run one of the available disk defragmentation utilities. File fragmentation can have a detrimental impact on performance.

The database server determines the number of file fragments in the database file when you start a database on Windows NT/2000/XP, and displays the following information in the server message window when the number of fragments is greater than one:

```
Database file "mydatabase.db" consists of nnn fragments
```

You can also obtain the number of database file fragments using the DBFileFragments database property.

Minimize index fragmentation

Indexes are designed to speed up searches on particular columns, but they can become fragmented if many DELETEs are performed on the indexed table. This may result in reduced performance if the index is accessed frequently and the cache is not large enough to hold all of the index.

The **sa_index_density** stored procedure provides information about the degree of fragmentation in a database's indexes. You must have DBA authority to run this procedure. The following statement calls the **sa_index_density** stored procedure:

```
CALL sa_index_density (['table_name'[,'owner_name']])
```

If your index is highly fragmented, you can run REORGANIZE TABLE. You can also drop the index and recreate it. However, if the index is a primary key, you will also have to drop and recreate the foreign key indexes.

As well, you can improve performance by creating a clustered index on a table. Clustered indexes cause table rows to be stored in approximately the same order as they appear in the index.

Minimize table fragmentation

Table fragmentation occurs when rows are not stored contiguously, or when rows are split between multiple pages. Performance decreases because these rows require additional page accesses.

Adaptive Server Anywhere reserves extra room on each page to allow rows to grow slightly. When an update to a row causes it to grow beyond the space available on the current page reserve, the row is split and the initial row location contains a pointer to another page where the continuous row is stored. For example, filling empty rows with UPDATE statements or inserting new columns into a table can lead to severe row splitting. As more rows are stored on separate pages, more time is required to access the additional pages.

You can use the **sa_table_fragmentation** stored procedure to obtain information about the degree of fragmentation of your database tables. The following statement calls the **sa_table_fragmentation** stored procedure:

```
CALL sa_table_fragmentation (['table_name' [,'owner_name']])
```

There are three ways to minimize table fragmentation:

- ♦ You can specify the percentage of space in a table page that should be reserved for future updates. This PCTFREE specification can be set with

CREATE TABLE, ALTER TABLE, DECLARE LOCAL TEMPORARY TABLE, or LOAD TABLE.

- ♦ You can reorganize specific tables. To defragment particular tables or parts of tables, you can run REORGANIZE TABLE. Reorganizing tables does not disrupt database access.
- ♦ You can rebuild the entire the database. Rebuilding is more comprehensive in that it defragments all tables, including system tables. Additionally, it rearranges the table rows so they appear in the order specified by the clustered index and primary keys

Acquire adequate hardware

When running on a PC, make sure your server meets Adaptive Server Anywhere's minimum CPU, memory and disk requirements:

- ♦ Adaptive Server Anywhere can run with as little as 4 Mb of memory. If you use Java in the database, Adaptive Server Anywhere requires 8 Mb of memory. If you are using the administration tools, Adaptive Server Anywhere requires at least 32 Mb of RAM. Your computer must have this much memory in addition to the requirements for the operating system.
- ♦ Enough disk space to hold your database and log files.
- ♦ Keep in mind that these are the minimums. If you are meeting only the minimum hardware requirements, and find that performance is suffering, consider upgrading some or all of your hardware. In general, evaluate the hardware configuration to see if it is adequate for the kind of work load being placed on the server.

Choose the Optimizer's priority

The OPTIMIZATION_GOAL option controls whether Adaptive Server Anywhere optimizes SQL statements for response time (first-row) or for total resource consumption (all-rows). In simpler terms, you can pick whether to optimize query processing towards returning the first row quickly, or towards minimizing the cost of returning the complete result set.

If the option is set to first-row, Adaptive Server Anywhere chooses an access plan that is intended to reduce the time to fetch the first row of the query's result, possibly at the expense of total retrieval time. In particular, the Adaptive Server Anywhere optimizer will typically avoid, if possible, access plans that require the materialization of results in order to reduce the time to return the first row. With this setting, for example, the optimizer favors access plans that utilize an index to satisfy a query's ORDER BY clause, rather than plans that require an explicit sorting operation.

You can use the FASTFIRSTROW table hint in a query's FROM clause to set the optimization goal for a specific query to first-row, without having to change the OPTIMIZATION_GOAL setting.

If the option is set to all-rows (the default), then Adaptive Server Anywhere optimizes a query so as to choose an access plan with the minimal estimated total retrieval time. Setting OPTIMIZATION_GOAL to all-rows may be appropriate for applications that intend to process the entire result set, such as PowerBuilder DataWindow applications.

Specify the correct cursor type

Specifying the correct cursor type can improve performance. For example, if a cursor is read-only, then declaring it as read-only allows for faster optimization and execution, since there is less material to build (no check constraints, and so on). If the cursor is updateable, some rewrites can be skipped. Also, if a query is updateable, then depending on the execution plan chosen by the optimizer, the execution engine must use a keyset driven approach. Keep in mind that key-set cursors are more expensive.

Consider collecting statistics on small tables

Adaptive Server Anywhere uses statistical information to determine the most efficient strategy for executing each statement. Adaptive Server Anywhere automatically gathers and updates these statistics, and stores them permanently in the database. Statistics gathered while processing one statement are available when searching for efficient ways to execute subsequent statements.

To avoid collecting statistics when they may not be very useful, Adaptive Server Anywhere does not, by default, collect statistics on small tables. The definition of a small table is governed by the min_table_size_for_histogram database option, whose default value is 1000. Sometimes it is useful to collect statistics on a small table. In order to create statistics on a small table, use the CREATE STATISTICS statement. Once created, the statistics are automatically maintained by Adaptive Server Anywhere. It is also possible to get Adaptive Server Anywhere to automatically create statistics on all small tables by setting the option min_table_size_for_histogram to a smaller value. However, it is not necessary—and not recommended—to do so.

Use user-estimates sparingly

Occasionally, statistics may become inaccurate. This condition is most likely to arise when only a few queries have been executed since a large amount of data was added, updated, or deleted. Inaccurate or unavailable statistics can impede performance. If Adaptive Server Anywhere is taking too long to update the statistics, try executing CREATE STATISTICS or DROP STATISTICS to refresh them. As well, in newer versions of the server (version 9.0 or later), Adaptive Server Anywhere will try to update statistics not only on LOAD TABLE and during query execution, but also on update DML statement.

In unusual circumstances, however, these measures may prove ineffective. If you know that a condition has a success rate that differs from the optimizer's estimate, you can explicitly supply a user estimate in the search condition.

Although user defined estimates can sometimes improve performance, avoid supplying explicit user-defined estimates in statements that are to be used on an ongoing basis. Should the data change, the explicit estimate may become inaccurate and may force the optimizer to select poor plans.

If you have used selectivity estimates that are inaccurate as a workaround to performance problems where the software-selected access plan was poor, you can set USER_ESTIMATES to OFF to ignore the values.

Reduce expensive user-defined functions

Reducing expensive user-defined functions in queries where they have to be executed many times can improve performance.

Using the cache to improve performance

The database cache is an area of memory used by the database server to store database pages for repeated fast access. The more pages that are accessible in the cache, the fewer times the database server needs to read data from disk. As reading data from disk is a slow operation, the amount of cache available is often a key factor in determining performance.

You can control the size of the database cache on the database server command line when the database is started.

Dynamic cache sizing

Adaptive Server Anywhere provides automatic resizing of the database cache. The capabilities are different on different operating systems. On Windows NT/2000/XP, Windows 95/98/Me, and UNIX operating systems, the cache grows and shrinks. Details are provided in the following sections.

Full **dynamic cache sizing** helps to ensure that the performance of your database server is not impacted by allocating inadequate memory. The cache grows when the database server can usefully use more, as long as memory is available, and shrinks when cache memory is required by other applications, so that the database server does not unduly impact other applications on the system. The effectiveness of dynamic cache sizing is limited, of course, by the physical memory available on your system.

Generally, dynamic cache sizing assesses cache requirements at the rate of approximately once per minute. However, after a new database is started or when a file grows significantly, statistics are sampled and the cache may be resized every five seconds for thirty seconds. After the initial thirty second period, the sampling rate drops back down to once per minute. Significant growth of a file is defined as a 1/8 growth since the database started or since the last growth that triggered an increase in the sampling rate. This change improves performance further, by adapting the cache size more quickly when databases are started dynamically and when a lot of data is inserted.

Dynamic cache sizing removes the need for explicit configuration of database cache in many situations, making Adaptive Server Anywhere even easier to use.

There is no dynamic cache resizing on Windows CE or Novell NetWare. When an Address Windowing Extensions (AWE) cache is used, dynamic cache sizing is disabled.

☞ For more information about AWE caches, see “-cw server option” [*ASA Database Administration Guide,* page 138].

Limiting the memory used by the cache

The initial, minimum, and maximum cache sizes are all controllable from the database server command line.

- **Initial cache size** You can change the initial cache size by specifying the database server `-c` command-line option. The default value is as follows:
  - **Windows CE** The formula is as follows:

    ```
    max( 600K, min( dbsize , physical-memory ) )
    ```

    where *dbsize* is the total size of the database file or files started, and *physical-memory* is 25% of the physical memory on the machine.
  - **Windows NT/2000/XP, Windows 95/98/Me, NetWare** The formula is as follows:

    ```
    max( 2M, min( dbsize , physical-memory ) )
    ```

    where *dbsize* is the total size of the database file or files started, and *physical-memory* is 25% of the physical memory on the machine.

    If an AWE cache is used on Windows 2000, Windows XP, or Windows Server 2003 the formula is as follows:

    ```
    min( 100% of available memory-128MB, dbsize )
    ```

    An AWE cache is not used if this value is smaller than 2 Mb.

    ☞ For information about AWE caches, see "-cw server option" [*ASA Database Administration Guide*, page 138].
  - **UNIX** At least 8 Mb.

    ☞ For information about UNIX initial cache size, see "Dynamic cache sizing (UNIX)" on page 178.
- **Maximum cache size** You can control the maximum cache size by specifying the database server `-ch` command-line option. The default is based on an heuristic that depends on the physical memory in your machine. On non-UNIX machines, this is usually approximately 90% of total physical memory, but not more than 256 Mb. On UNIX machines, this is the greater of the following:

  ```
  (25% total physical-memory,
     25%(available-physical-memory + available-swap-space),
     sum-of-file-sizes-on-the-command-line)
  ```

  but is no more than 256 Mb and is no less than 24 Mb.
- **Minimum cache size** You can control the minimum cache size by specifying the database server `-cl` command-line option. By default, the minimum cache size is the same as the initial cache size.

You can also disable dynamic cache sizing by using the `-ca` command-line option.

☞ For more information on command-line options, see “The database server” [*ASA Database Administration Guide,* page 124].

Dynamic cache sizing (Windows NT/2000/XP, Windows 95/98/Me)

On Windows NT/2000/XP and Windows 95/98/Me, the database server evaluates cache and operating statistics once per minute and computes an optimum cache size. The server computes a target cache size that uses all physical memory currently not in use, except for approximately 5 Mb that is to be left free for system use. The target cache size is never smaller than the specified or implicit minimum cache size. The target cache size never exceeds the specified or implicit maximum cache size, or the sum of the sizes of all open database and temporary files.

To avoid cache size oscillations, the database server increases the cache size incrementally. Rather than immediately adjusting the cache size to the target value, each adjustment modifies the cache size by 75% of the difference between the current and target cache size.

Windows 2000, Windows XP, and Windows Server 2003 can use Address Windowing Extensions (AWE) to support large cache sizes by specifying the `-cw` command-line option when starting the database server. AWE caches do not support dynamic cache sizing.

☞ For more information, see “-cw server option” [*ASA Database Administration Guide,* page 138].

Dynamic cache sizing (UNIX)

On UNIX, the database server uses swap space and memory to manage the cache size. The swap space is a system-wide resource on most UNIX operating systems, but not on all. In this section, the sum of memory and swap space is called the **system resources**. See your operating system documentation for details.

On startup, the database allocates the specified maximum cache size from the system resources. It loads some of this into memory (the initial cache size) and keeps the remainder as swap space.

The total amount of system resources used by the database server is constant until the database server shuts down, but the proportion loaded into memory changes. Each minute, the database server evaluates cache and operating statistics. If the database server is busy and demanding of resources, it may move cache pages from swap space into memory. If the server is quiet, it may move them out from memory to swap space.

Initial cache size By default, the initial cache size is assigned using an heuristic based on the available system resources. The initial cache size is always less than 1.1 times the total database size.

If the initial cache size is greater than 3/4 of the available system resources, the database server exits with a `Not Enough Memory` error.

You can change the initial cache size using the -c option.

Maximum cache size The maximum cache must be less than the available system resources on the machine. By default, the maximum cache size is assigned using an heuristic based on the available system resources and the total physical memory on the machine.

If you specify a maximum cache size greater than the available system resources, the server exits with a `Not Enough Memory` error. If you specify a maximum cache size greater than the available memory, the server warns of performance degradation, but does not exit.

The database server allocates all the *maximum* cache size from the system resources, and does not relinquish it until the server exits. You should be sure that you choose a maximum cache size that gives good Adaptive Server Anywhere performance while leaving space for other applications. The formula for the default maximum cache size is an heuristic that attempts to achieve this balance. You only need to tune the value if the default value is not appropriate on your system.

If you specify a maximum cache size less than 8 Mb, you will not be able to run Java applications. Low maximum cache sizes will impact performance.

☞ You can use the `-ch` server option to set the maximum cache size, and limit automatic cache growth. For more information, see “-ch server option” [*ASA Database Administration Guide*, page 136]

Minimum cache size If the -c option is specified, the minimum cache size is the same as the initial cache size. If no -c option is specified, the minimum cache size on UNIX is 8 Mb.

You can use the `-cl` server option to adjust the minimum cache size For more information, see “-cl server option” [*ASA Database Administration Guide*, page 136].

Monitoring cache size

The following statistics have been added to the Windows Performance Monitor and to the database’s property functions.

- **CurrentCacheSize** The current cache size in kilobytes
- **MinCacheSize** The minimum allowed cache size in kilobytes
- **MaxCacheSize** The maximum allowed cache size in kilobytes
- **PeakCacheSize** The peak cache size in kilobytes

Note: Windows Performance Monitor is available in Windows NT, Windows 2000, and Windows XP.

☞ For more information on these properties, see "Server-level properties" [*ASA Database Administration Guide*, page 657].

☞ For information on monitoring performance, see "Monitoring database performance" on page 187.

Using indexes to improve performance

Proper selection of indexes can make a large performance difference. Creating and managing indexes is described in "Working with indexes" on page 58.

Using keys to improve query performance

Primary keys and foreign keys, while used primarily for validation purposes, can also improve database performance.

Example

The following example illustrates how primary keys can make queries execute more quickly.

```
SELECT *
FROM employee
WHERE emp_id = 390
```

The simplest way for the server to execute this query would be to look at all 75 rows in the **employee** table and check the employee ID number in each row to see if it is 390. This does not take very long since there are only 75 employees, but for tables with many thousands of entries a sequential search can take a long time.

The referential integrity constraints embodied by each primary or foreign key are enforced by Adaptive Server Anywhere through the help of an index, implicitly created with each primary or foreign key declaration. The emp_id column is the primary key for the employee table. The corresponding primary key index permits the retrieval of employee number 390 quickly. This quick search takes almost the same amount of time whether there are 100 rows or 1,000,000 rows in the employee table.

Using primary keys to improve query performance

A primary key improves performance on the following statement:

```
SELECT *
FROM employee
WHERE emp_id = 390
```

Information on the Plan tab

The Plan tab in the Results pane contains the following information:

```
employee <employee>
```

Whenever the name inside the parentheses on the Plan tab PLAN description is the same as the name of the table, it means that the primary key for the table is used to improve performance.

Using foreign keys to improve query performance

The following query lists the orders from the customer with customer ID 113:

```
SELECT *
FROM sales_order
WHERE cust_id = 113
```

Information on the Plan tab

The Plan tab in the Results pane contains the following information:

```
sales_order <ky_so_customer>
```

Here ky_so_customer refers to the foreign key that the sales_order table has for the customer table.

Separate primary and foreign key indexes

Separate indexes are created automatically for primary and foreign keys. This arrangement allows Adaptive Server Anywhere to perform many operations more efficiently. This feature was introduced in version 7.0.

Sorting query results

Many queries have an ORDER BY clause that ensures that the rows appear in a predictable order. Indexes order the information quickly. For example, the following query can use the index on the lname column of the customer table to access the rows of the customer table in alphabetical order by last name:

```
SELECT *
FROM customer
ORDER BY customer.lname
```

Queries with WHERE and ORDER BY clauses

A potential problem arises when a query has both a WHERE clause and an ORDER BY clause.

```
SELECT *
FROM customer
WHERE id > 300
ORDER BY company_name
```

Adaptive Server Anywhere must decide between two strategies:

1. Go through the entire customer table in order by company name, checking each row to see if the customer id is greater than 300.

2. Use the key on the id column to read only the companies with id greater than 300. The results would then need to be sorted by company name.

If there are very few id values greater than 300, the second strategy is better because only a few rows need to be scanned and quickly sorted. If most of the id values are greater than 300, the first strategy is much better because it requires no sorting.

☞ For more information about sorting, see "The ORDER BY clause: sorting query results" on page 244, or "The GROUP BY clause: organizing query results into groups" on page 237.

Use of work tables in query processing

Work tables are materialized temporary result sets that are created during the execution of a query. Work tables are used when Adaptive Server Anywhere determines that the cost of using one is less than alternative strategies. Generally, the time to fetch the first few rows is higher when a work table is used, but the cost of retrieving all rows may be substantially lower in some cases if a work table can be used. Because of this difference, Adaptive Server Anywhere chooses different strategies based on the OPTIMIZATION_GOAL setting. The default is all-rows. When it is set to first-row, Adaptive Server Anywhere tries to avoid work tables. When it is set to all-rows, Adaptive Server Anywhere uses work tables when they reduce the total execution cost of a query.

Work tables are used in the following cases:

When work tables occur

- When a query has an ORDER BY, GROUP BY, OR DISTINCT clause and Adaptive Server Anywhere does not use an index for sorting the rows. If a suitable index exists and the OPTIMIZATION_GOAL setting is first-row, Adaptive Server Anywhere avoids using a work table. However, when OPTIMIZATION_GOAL is set to all-rows, it may be more expensive to fetch all the rows of a query using an index than it is to build a work table and sort the rows. Adaptive Server Anywhere chooses the cheaper strategy if the optimization goal is set to all-rows. For GROUP BY and DISTINCT, the hash-based algorithms use work tables, but are generally more efficient when fetching all the rows out of a query.

- When a hash join algorithm is chosen, work tables are used to store interim results (if the input doesn't fit into memory) and a work table is used to store the results of the join.

- When a cursor is opened with sensitive values, a work table is created to hold the row identifiers and primary keys of the base tables. This work table is filled in as rows are fetched from the query in the forward direction. However, if you fetch the last row from the cursor, the entire table is filled in.

- When a cursor is opened with insensitive semantics, a work table is populated with the results of the query when the query is opened.

- When a multiple-row UPDATE is being performed and the column being updated appears in the WHERE clause of the update or in an index being used for the update.

- When a multiple-row UPDATE or DELETE has a subquery in the WHERE clause that references the table being modified.

- When performing an INSERT from a SELECT statement and the SELECT statement references the insert table.
- When performing a multiple row INSERT, UPDATE, or DELETE, and a corresponding trigger is defined on the table that may fire during the operation.

In these cases, the records affected by the operation go into the work table. In certain circumstances, such as keyset-driven cursors, a temporary index is built on the work table. The operation of extracting the required records into a work table can take a significant amount of time before the query results appear. Creating indexes that can be used to do the sorting in the first case, above, improves the time to retrieve the first few rows. However, the total time to fetch all rows may be lower if work tables are used, since these permit query algorithms based on hashing and merge sort. These algorithms use sequential I/O, which is faster than the random I/O used with an index scan.

The query optimizer in the database server analyzes each query to determine whether a work table will give the best performance. Enhancements to the optimizer in new releases of Adaptive Server Anywhere may improve the access plan for queries. No user action is required to take advantage of these optimizations.

Notes

The INSERT, UPDATE and DELETE cases above are usually not a performance problem since they are usually one-time operations. However, if problems occur, you may be able to rephrase the command to avoid the conflict and avoid building a work table. This is not always possible.

Monitoring database performance

Adaptive Server Anywhere provides a set of statistics you can use to monitor database performance. Accessible from Sybase Central, client applications can access the statistics as functions. In addition, the server makes these statistics available to the Windows Performance Monitor.

This section describes how to access performance and related statistics from client applications, how to monitor database performance using Sybase Central, how to monitor database performance using the Windows Performance Monitor, and how to detect file, table, and index fragmentation.

Obtaining database statistics from a client application

Adaptive Server Anywhere provides a set of system functions that can access information on a per-connection, per-database, or server-wide basis. The kind of information available ranges from static information (such as the server name) to detailed performance-related statistics (such as disk and memory usage).

Functions that retrieve system information

The following functions retrieve system information:

- **property function** Provides the value of a given property on an engine-wide basis.
- **connection_property function** Provides the value of a given property for a given connection, or by default, for the current connection.
- **db_property function** Provides the value of a given property for a given database, or by default, for the current database.

Supply as an argument only the name of the property you wish to retrieve. The functions return the value for the current server, connection, or database.

☞ For more information, see “PROPERTY function [System]” [*ASA SQL Reference*, page 172], “CONNECTION_PROPERTY function [System]” [*ASA SQL Reference*, page 106], and “DB_PROPERTY function [System]” [*ASA SQL Reference*, page 122].

For a complete list of the properties available from the system functions, see “System functions” [*ASA SQL Reference*, page 92].

Examples

The following statement sets a variable named server_name to the name of the current server:

```
SET server_name = property( 'name' )
```

The following query returns the user ID for the current connection:

```
SELECT connection_property( 'userid' )
```

The following query returns the filename for the root file of the current database:

```
SELECT db_property( 'file' )
```

Improving query efficiency

For better performance, a client application monitoring database activity should use the property_number function to identify a named property, and then use the number to repeatedly retrieve the statistic. The following set of statements illustrates the process from Interactive SQL:

```
CREATE VARIABLE propnum INT ;
CREATE VARIABLE propval INT ;
SET propnum = property_number( 'cacheread' );
SET propval = property( propnum )
```

Property names obtained in this way are available for many different database statistics, from the number of transaction log page write operations and the number of checkpoints carried out, to the number of reads of index leaf pages from the memory cache.

You can view many of these statistics in graph form from the Sybase Central database management tool.

Monitoring database statistics from Sybase Central

With the Sybase Central Performance Monitor, you can graph the statistics of any Adaptive Server Anywhere database server that you can connect to in Sybase Central. All statistics in Sybase Central are shown in the Statistics folder.

Features of the Performance Monitor include:

- Real-time updates (at adjustable intervals)
- A color-coded and resizable legend
- Configurable appearance properties

When you're using the Sybase Central Performance Monitor, note that it uses actual queries against the server to gather its statistics, so the monitor itself affects some statistics (such as Cache Reads/sec). As a more precise alternative, you can graph server statistics using the Windows Performance Monitor.

☞ For information on setting properties, see "Setting properties for database objects" on page 32.

Opening the Sybase Central Performance Monitor

You can display the Performance Monitor in the right pane of Sybase Central when you have the Statistics folder open.

❖ To open the Performance Monitor

1. In the left pane, select the desired server.

2. In the right pane, click the Performance Monitor tab.

> **Note**
> The Performance Monitor only graphs statistics that you have added to it ahead of time.

☞ See also

- ♦ "Adding and removing statistics" on page 189
- ♦ "Configuring the Sybase Central Performance Monitor" on page 190
- ♦ "Monitoring database statistics from Windows Performance Monitor" on page 190

Adding and removing statistics

❖ To add statistics to the Sybase Central Performance Monitor

1. In the left pane, select the desired server.

2. In the right pane, click the Statistics tab.

3. Right-click a statistic that is not currently being graphed and choose Add to Performance Monitor from the popup menu.

❖ To remove statistics from the Sybase Central Performance Monitor

1. Do one of the following:
   - ♦ If you are working on the Statistic tab in the right pane, right-click a statistic that is currently being graphed.
   - ♦ If you are working in the Performance Monitor tab in the right pane, right-click the desired statistic in the legend.

2. From the popup menu, choose Remove from Performance Monitor.

> **Tip**
> You can also add a statistic to or remove one from the Performance Monitor on the statistic's property sheet.

☞ See also

- ♦ "Opening the Sybase Central Performance Monitor" on page 189
- ♦ "Configuring the Sybase Central Performance Monitor" on page 190
- ♦ "Monitoring database statistics from Windows Performance Monitor" on page 190

Configuring the Sybase Central Performance Monitor

The Sybase Central Performance Monitor is configurable; you can choose the type of graph it uses and the amount of time between updates to the graph.

❖ To choose a graph type

1. Choose Tools ➤ Options.
2. On the Options dialog, click the Chart tab.
3. Choose a type of graph.

❖ To set the update interval

1. Choose Tools ➤ Options.
2. On the Options dialog, click the Chart tab.
3. Move the slider to reflect a new time value (or type the value directly in the text box provided).

☞ See also

- ♦ "Opening the Sybase Central Performance Monitor" on page 189
- ♦ "Adding and removing statistics" on page 189
- ♦ "Monitoring database statistics from Windows Performance Monitor" on page 190

Monitoring database statistics from Windows Performance Monitor

As an alternative to using the Sybase Central Performance Monitor, you can use the Windows Performance Monitor.

The Windows monitor has two advantages:

- ♦ It offers more performance statistics (mainly those concerned with network communications).
- ♦ Unlike the Sybase Central monitor, the Windows monitor is non-intrusive. It uses a shared-memory scheme instead of performing queries against the server, so it does not affect the statistics themselves.

☞ For a complete list of performance statistics you can monitor, see "Performance Monitor statistics" [*ASA Database Administration Guide*, page 638].

Note: Windows Performance Monitor is available in Windows NT, Windows 2000, and Windows XP. If you run multiple versions of Adaptive Server Anywhere simultaneously, it is also possible to run multiple versions of the Performance Monitor simultaneously.

❖ To use the Windows Performance Monitor in Windows NT

1. With an Adaptive Server Anywhere engine or database running, start the Performance Monitor:
   - ♦ Choose Start ➤ Programs ➤ Administrative Tools (Common) ➤ Performance Monitor.
2. Choose Edit ➤ Add To Chart, or click the Plus sign button on the toolbar. The Add To Chart dialog appears.
3. From the Object list, select one of the following:
   - ♦ **Adaptive Server Anywhere Connection** To monitor performance for a single connection. Choose a connection to monitor from the displayed list.
   - ♦ **Adaptive Server Anywhere Database** To monitor performance for a single database. Choose a database to monitor from the displayed list.
   - ♦ **Adaptive Server Anywhere Engine** To monitor performance on a server-wide basis.

   The Counter box displays a list of the statistics you can view.
4. From the Counter list, click a statistic to view. To select multiple statistics, hold the CTRL or SHIFT keys while clicking.
5. If you selected Adaptive Server Anywhere Connection or Adaptive Server Anywhere Database, choose an instance from the Instance box.
6. For a description of the selected counter, click Explain.

7. To display the counter, click Add.
8. When you have selected all the counters you wish to display, click Done.

For more information about the Windows Performance Monitor, see the online help for the program.

Fragmentation

As you make changes to your database, the database file, tables, and indexes can become fragmented. Fragmentation can decrease performance. Adaptive Server Anywhere provides information that you can use to assess the level of fragmentation in files, tables, and indexes.

This section describes how to detect fragmentation in files, tables, and indexes, and how to defragment them.

File fragmentation

Performance can suffer if your database file is excessively fragmented. This is disk fragmentation and it becomes more important as your database increases in size.

The database server determines the number of file fragments in each dbspace when you start a database on Windows NT/2000/XP. The server displays the following information in the server message window when the number of fragments is greater than one:

```
Database file "mydatabase.db" consists of nnn fragments
```

You can also obtain the number of database file fragments using the DBFileFragments database property.

☞ For more information, see “Database-level properties” [*ASA Database Administration Guide*, page 664].

❖ To eliminate file fragmentation problems

1. Put the database on a disk partition by itself.
2. Periodically run one of the available Windows disk defragmentation utilities.

Table fragmentation

When rows are not stored contiguously, or if rows are split onto more than one page, performance decreases because these rows require additional page accesses. Table fragmentation is distinct from file fragmentation.

Adaptive Server Anywhere reserves extra room on each page to allow rows to grow slightly. When an update to a row causes it to grow beyond the original space allocated for it, the row is split and the initial row location contains a pointer to another page where the entire row is stored. For example, filling empty rows with UPDATE statements or inserting new columns into a table can lead to severe row splitting. As more rows are stored on separate pages, more time is required to access the additional pages.

You can reduce the amount of fragmentation in your tables by specifying the percentage of space in a table page that should be reserved for future updates. This PCTFREE specification can be set with CREATE TABLE, ALTER TABLE, DECLARE LOCAL TEMPORARY TABLE, or LOAD TABLE.

☞ For more information, see "CREATE TABLE statement" [*ASA SQL Reference,* page 361], "ALTER TABLE statement" [*ASA SQL Reference,* page 250], "DECLARE LOCAL TEMPORARY TABLE statement" [*ASA SQL Reference,* page 397], and "LOAD TABLE statement" [*ASA SQL Reference,* page 486].

You can use the sa_table_fragmentation stored procedure to obtain information about the degree of fragmentation of your database tables. You must have DBA authority to run this procedure. The following statement calls the sa_table_fragmentation stored procedure:

```
CALL sa_table_fragmentation (['table_name' [,'owner_name']])
```

☞ For more information, see "sa_table_fragmentation system procedure" [*ASA SQL Reference,* page 744].

Defragmenting tables

The following procedures are useful when you detect that performance is poor because a table is highly fragmented. Unloading and reloading the database is more comprehensive in that it defragments all tables, including system tables. To defragment particular tables or parts of tables, run REORGANIZE TABLE. Reorganizing tables does not disrupt database access.

❖ To defragment all the tables in a database

1. Unload the database.

2. Reload the database to reclaim disk space and improve performance.

☞ For more information about unloading a database, see "Unloading a database using the dbunload command-line utility" [*ASA Database Administration Guide,* page 534].

☞ For more information about rebuilding a database, see "The Rebuild utility" [*ASA Database Administration Guide,* page 517].

❖ To defragment individual tables

1. Execute a REORGANIZE TABLE statement.

☞ For more information, see “REORGANIZE TABLE statement” [*ASA SQL Reference*, page 522].

Index fragmentation

Indexes are designed to speed up searches on particular columns, but they can become fragmented if many DELETEs are performed on the indexed table. This may result in reduced performance if the index is accessed frequently and the cache is not large enough to hold all of the index.

The sa_index_density stored procedure provides information about the degree of fragmentation in a database’s indexes. You must have DBA authority to run this procedure. The following statement calls the sa_index_density stored procedure:

```
CALL sa_index_density (['table_name'[,'owner_name']])
```

If your index is highly fragmented, you can run REORGANIZE TABLE. You can also drop the index and recreate it. However, if the index is a primary key, you will also have to drop and recreate the foreign key indexes.

☞ For more information, see “REORGANIZE TABLE statement” [*ASA SQL Reference*, page 522].

☞ For more information about dropping an index, see “Dropping indexes” on page 62.

Monitoring query performance

Adaptive Server Anywhere includes a number of tools for testing the performance of queries. Complete documentation about each tool can be found in a *Readme.txt* file that is located in the same folder as the tool.

fetchtst

Function: Determines the time required for a result set to be retrieved.

Location: *SQL Anywhere 9\Samples\Asa\PerformanceFetch*

odbcfet

Function: Determines the time required for a result set to be retrieved. This function is similar to festchtst, but with less functionality.

Location: *SQL Anywhere 9\Samples\Asa\PerformanceFetch*

instest

Function: Determines the time required for rows to be inserted into a table.

Location: *SQL Anywhere 9\Samples\Asa\PerformanceInsert* trantest

Function: Measures the load that can be handled by a given server configuration given a database design and a set of transactions.

Location: *SQL Anywhere 9\Samples\Asa\PerformanceTransaction*

☞ For information about system procedures that measure query execution times, see "sa_get_request_profile system procedure" [*ASA SQL Reference*, page 717] and "sa_get_request_times system procedure" [*ASA SQL Reference*, page 718].

Profiling database procedures

Procedure profiling shows you how long it takes your stored procedures, functions, events, and triggers to execute. You can also view the execution time for each line of a procedure. Using the database profiling information, you can determine which procedures can be fine-tuned to increase performance within your database.

When profiling is enabled, Adaptive Server Anywhere monitors which stored procedures, functions, events, and triggers are used, keeping track of how long it takes to execute them, and how many times each one is called.

Profiling information is stored in memory by the server and can be viewed in Sybase Central via the Profile tab or in Interactive SQL. Once profiling is enabled, the database gathers profiling information until you disable profiling or until the server is shut down.

☞ For more information about obtaining profiling information in Interactive SQL, see "Viewing procedure profiling information in Interactive SQL" on page 202.

Enabling procedure profiling

You can enable profiling in either Sybase Central or Interactive SQL. You must have DBA authority to enable and use procedure profiling.

❖ To enable profiling (Sybase Central)

1. Connect to your database as a user with DBA authority.
2. Select the database in the left pane.
3. From the File menu, choose Properties.

   The Database property sheet appears.
4. On the Profiling tab, select Enable Profiling on This Database.
5. Click OK to close the property sheet.

Note

You can also right click your database in Sybase Central to enable profiling. From the popup menu, choose Profiling ➤ Start Profiling.

❖ **To enable profiling (SQL)**

1. Connect to your database as a user with DBA authority.
2. Call the sa_server_option stored procedure with the ON setting.

   For example, enter:

   ```
   CALL sa_server_option ( 'procedure_profiling', 'ON')
   ```

Resetting procedure profiling

When you reset profiling, the database clears the old information and immediately starts collecting new information about procedures, functions, events, and triggers.

The following sections assume that you are already connected to your database as a user with DBA authority and that procedure profiling is enabled.

❖ **To reset profiling (Sybase Central)**

1. Select the database in the left pane.
2. From the File menu, choose Properties.

   The Database property sheet appears.
3. On the Profiling tab, click Reset Now.
4. Click OK to close the property sheet.

Note

You can also right click your database in Sybase Central to reset profiling. From the popup menu, click Profiling ➤ Reset Profiling Information.

❖ **To reset profiling (SQL)**

1. Call the sa_server_option stored procedure with the RESET setting.

   For example, enter:

   ```
   CALL sa_server_option ('procedure_profiling', 'RESET')
   ```

Disabling procedure profiling

Once you are finished with the profiling information, you can either disable profiling or you can clear profiling. If you disable profiling, the database stops collecting profiling information and the information that it has collected to that point remains on the Profile tab in Sybase Central. If you clear profiling, the database turns profiling off and removes all the profiling data from the Profile tab in Sybase Central.

❖ To disable profiling (Sybase Central)

1. Select the database in the left pane.
2. From the File menu, choose Properties.

   The Database property sheet appears.
3. On the Profiling tab, clear the Enable Profiling on This Database option.
4. Click OK to close the property sheet.

Note

You can also right click your database in Sybase Central to disable profiling. From the popup menu, choose Profiling ➤ Stop Profiling.

❖ To disable profiling (SQL)

1. Call the sa_server_option stored procedure with the OFF setting.

   For example, enter:

   ```
   CALL sa_server_option ('procedure_profiling', 'OFF')
   ```

❖ To clear profiling (Sybase Central)

1. Select the database in the left pane.
2. From the File menu, choose Properties.

   The Database property sheet appears.
3. On the Profiling tab, click Clear Now.

   You can only clear profiling if profiling is enabled.
4. Click OK to close the property sheet.

❖ To clear profiling (SQL)

1. Call the sa_server_option stored procedure with the CLEAR setting.

   For example, enter:

   ```
   CALL sa_server_option ('procedure_profiling', 'CLEAR')
   ```

Viewing procedure profiling information in Sybase Central

Procedure profiling provides you with different information depending whether you choose to look at information for your entire database, a specific type of object, or a particular procedure. The information can be displayed in the following ways:

- details for all profiled objects within the database

- details for all stored procedures and functions
- details for all events
- details for all triggers
- details for individual profiled objects

You must be connected to your database and have profiling enabled to view profiling information.

When you view profiling information for your entire database, the following columns appear:

- **Name** lists the name of the object.
- **Owner** lists the owner of the object.
- **Object Type** lists the type of object, for example, a procedure.
- **Table** lists which table a trigger belongs to (this column only appears on the database Profile tab).
- **Milliseconds** lists the total execution time for each object.
- **Calls** lists the number times each object has been called.

These columns provide a summary of the profiling information for all of the procedures that have been executed within the database. One procedure can call other procedures, so there may be more items listed than those users call specifically.

❖ To view summary profiling information for stored procedures and functions

1. Select the Procedures & Functions folder in the left pane.
2. Click the Profile tab in the right pane.

   Profiling information about all the stored procedures and functions within your database appears on the Profile tab.

❖ To view summary profiling information for events

1. Open the Events folder in the left pane.

   A list of all the events in your database appears on the Events tab in the right pane.

2. Click the Profile tab in the right pane.

   Profiling information about all of the events within your database appears on the Profile tab.

❖ To view summary profiling information for triggers

1. Open the Triggers folder in the left pane.

   A list of all the triggers in your database appears on the Triggers tab.

2. Select the Tables folder in the left pane.

3. Click the Profile tab in the right pane.

   Profiling information about all of the triggers in your database appears on the Profile tab.

Viewing profiling information for a specific procedure

Adaptive Server Anywhere provides procedure profiling information about individual stored procedures, functions, events, and triggers. Sybase Central displays different information about individual procedures than it does about all of the stored procedures, functions, events, or triggers within a database.

When you look at the profiling information for a specific procedure, the following columns appear:

- **Calls** lists the number of times the object has been called.
- **Milliseconds** lists the total execution time for each object.
- **Line** lists the line number beside each line of the procedure.
- **Source** displays the SQL procedure, line by line.

The procedure is broken down line by line and you can examine it to see which lines have longer execution times and therefore might benefit from changes to improve the procedure's performance. You must be connected to the database, have profiling enabled, and have DBA authority to access procedure profiling information.

❖ To view the profiling information for a stored procedure or function

1. Expand the database in the left pane.

2. Select the Procedures and Functions folder in the left pane.

   A list of all the stored procedures and functions within your database appears on the Procedures & Functions tab in the right pane.

3. Click the stored procedure or function you want to profile in the left pane.

4. Click the Profile tab in the right pane.

   Profiling information about the specific stored procedure or function appears on the Profile tab in the right pane.

❖ To view profiling information for an event

1. Expand the database in the left pane.
2. Select the Events folder in the left pane.

   A list of all the events within your database appears on the Events tab in the right pane.
3. Click the event you want to profile in the left pane.
4. Click the Profile tab in the right pane.

   Profiling information about the specific event appears on the Profile tab in the right pane.

❖ To view profiling information for triggers

1. Expand the database in the left pane.
2. Open the Triggers folder in the left pane.

   A list of all the triggers within the table appears on the Triggers tab in the right pane.
3. Click the trigger you want to profile in the left pane.
4. Click the Profile tab in the right pane.

   Profiling information about the specific trigger appears on the Profile tab in the right pane.

Viewing procedure profiling information in Interactive SQL

You can use stored procedures to view procedure profiling information. The profiling information is the same whether you view it in Sybase Central or in Interactive SQL.

The sa_procedure_profile_summary stored procedure provides information about all of the procedures within the database. You can use this procedure to view the profiling data for stored procedures, functions, events, and triggers within the same result set. The following parameters restrict the rows the procedure returns.

- ♦ **p_object_name**   specify the name of an object to profile.
- ♦ **p_owner_name**   specify the owner whose objects you want to profile.
- ♦ **p_table_name**   specify which table you want to profile triggers for.

- **p_object_type** specify the type of object to profile. You can choose from the following four options. Choosing one of these values restricts the result set to only objects of the specified type.
  - **P** stored procedure
  - **F** function
  - **T** trigger
  - **E** event
- **p_ordering** specify the sort order of the result set.

Keep in mind that there may be more items listed than those called specifically by users because one procedure can call another procedure.

The following sections assume that you are already connected to your database as a user with DBA authority and that you have procedure profiling enabled.

❖ To view summary profiling information for all procedures

1. Execute the sa_procedure_profile_summary stored procedure.

   For example, enter:

   ```
   CALL sa_procedure_profile_summary
   ```

2. From the SQL menu, choose Execute.

   A result set with information about all of the procedures in your database appears on the Results tab in the Results pane.

☞ For more information about the sa_procedure_profile_summary stored procedure, see "sa_procedure_profile_summary system procedure" [*ASA SQL Reference*, page 736].

Viewing profiling information for a specific procedure in Interactive SQL

The sa_procedure_profile stored procedure provides information about individual lines within specific procedures. The result set includes the line number, execution time, and percentage of total execution time for lines within procedures. You can use the following parameters to restrict the rows the procedure returns:

- **p_object_name** specify the name of an object to profile.
- **p_owner_name** specify the owner whose objects you want to profile.
- **p_table_name** specify which table you want to profile triggers for.

If you do not include any parameters in your query, the procedure returns profiling information for all the procedures that have been called.

❖ To view profiling information for specific lines within procedures

1. Execute the sa_procedure_profile stored procedure.

   For example, enter:

   ```
   CALL sa_procedure_profile
   ```

2. From the SQL menu, choose Execute.

   A result set with profiling information for individual procedure lines appears on the Results tab in the Results pane.

☞ For more information about the sa_procedure_profile stored procedure, see “sa_procedure_profile system procedure” [*ASA SQL Reference*, page 735].

Part II

Querying and Modifying Data

This part describes how to query and modify data. It includes several chapters on queries, from simple to complex, as well as material on inserting, deleting, and updating data.

CHAPTER 6

Queries: Selecting Data from a Table

About this chapter

The SELECT statement retrieves data from the database. You can use it to retrieve a subset of the rows in one or more tables and to retrieve a subset of the columns in one or more tables.

This chapter focuses on the basics of single-table SELECT statements. Advanced uses of SELECT are described later in this manual.

Contents

Topic:	page
Query overview	208
The SELECT list: specifying columns	211
The FROM clause: specifying tables	218
The WHERE clause: specifying rows	219

Query overview

A query requests data from the database and receives the results. This process is also known as data retrieval. All SQL queries are expressed using the SELECT statement.

Queries are made up of clauses

You construct SELECT statements from clauses. In the following SELECT syntax, each new line is a separate clause. Only the more common clauses are listed here.

SELECT *select-list*
[**FROM** *table-expression*]
[**WHERE** *search-condition*]
[**GROUP BY** *column-name*]
[**HAVING** *search-condition*]
[**ORDER BY** { *expression* | *integer* }]

The clauses in the SELECT statement are as follows:

- The SELECT clause specifies the columns you want to retrieve. It is the only required clause in the SELECT statement.

- The FROM clause specifies the tables from which columns are pulled. It is required in all queries that retrieve data from tables. SELECT statements without FROM clauses have a different meaning, and this chapter does not discuss them.

  Although most queries operate on tables, queries may also retrieve data from other objects that have columns and rows, including views, other queries (derived tables) and stored procedure result sets. For more information, see “FROM clause” [*ASA SQL Reference*, page 445].

- The ON clause specifies how tables in the FROM clause are to be joined. It is used only for multi-table queries and is not discussed in this chapter.

  ☞ For information on multi-table queries, see “Joins: Retrieving Data from Several Tables” on page 261.

- The WHERE clause specifies the rows in the tables you want to see.

- The GROUP BY clause allows you to aggregate data.

- The HAVING clause specifies rows on which aggregate data is to be collected.

- The ORDER BY clause sorts the rows in the result set. (By default, rows are returned from relational databases in an order that has no meaning.)

For information on GROUP BY, HAVING, and ORDER BY clauses, see "Summarizing, Grouping and Sorting Query Results" on page 231.

Most of the clauses are optional, but if they are included then they must appear in the correct order.

☞ For more information about the SELECT statement syntax, see "SELECT statement" [*ASA SQL Reference*, page 541].

SQL queries

In this manual, SELECT statements and other SQL statements appear with each clause on a separate row, and with the SQL keywords in upper case. This is not a requirement. You can type SQL keywords in any case, and you can break lines at any point.

Keywords and line breaks

For example, the following SELECT statement finds the first and last names of contacts living in California from the Contact table.

```
SELECT first_name, last_name
FROM Contact
WHERE state = 'CA'
```

It is equally valid, though not as readable, to enter this statement as follows:

```
SELECT first_name,
last_name from contact
wHere state
 = 'CA'
```

Case sensitivity of strings and identifiers

Identifiers (that is, table names, column names, and so on) are case insensitive in Adaptive Server Anywhere databases.

Strings are case insensitive by default, so that 'CA', 'ca', 'cA', and 'Ca' are equivalent, but if you create a database as case-sensitive then the case of strings is significant. The sample database is case insensitive.

Qualifying identifiers

You can qualify the names of database identifiers if there is ambiguity about which object is being referred to. For example, the sample database contains several tables with a column called city, so you may have to qualify references to city with the name of the table. In a larger database you may also have to use the name of the owner of the table to identify the table.

```
SELECT DBA.contact.city
FROM contact
WHERE state = 'CA'
```

Since the examples in this chapter involve single-table queries, column names in syntax models and examples are usually not qualified with the names of the tables or owners to which they belong.

These elements are left out for readability; it is never wrong to include qualifiers.

The remaining sections in this chapter analyze the syntax of the SELECT statement in more detail.

The SELECT list: specifying columns

The select list

The select list commonly consists of a series of column names separated by commas, or an asterisk as shorthand to represent all columns.

More generally, the select list can include one or more expressions, separated by commas. The general syntax for the select list looks like this:

SELECT *expression* [, *expression*]. . .

If any table or column name in the list does not conform to the rules for valid identifiers, you must enclose the identifier in double quotes.

The select list expressions can include * (all columns), a list of column names, character strings, column headings, and expressions including arithmetic operators. You can also include aggregate functions, which are discussed in "Summarizing, Grouping and Sorting Query Results" on page 231.

☞ For more information about what expressions can consist of, see "Expressions" [*ASA SQL Reference*, page 15].

The following sections provide examples of the kinds of expressions you can use in a select list.

Selecting all columns from a table

The asterisk (*) has a special meaning in SELECT statements. It stands for all the column names in all the tables specified in the FROM clause. You can use it to save typing time and errors when you want to see all the columns in a table.

When you use SELECT *, the columns are returned in the order in which they were defined when the table was created.

The syntax for selecting all the columns in a table is:

```
SELECT *
FROM table-expression
```

SELECT * finds all the columns currently in a table, so that changes in the structure of a table such as adding, removing, or renaming columns automatically modify the results of SELECT *. Listing the columns individually gives you more precise control over the results.

Example

The following statement retrieves all columns in the department table. No WHERE clause is included; and so this statement retrieves every row in the table:

```
SELECT *
FROM department
```

The results look like this:

dept_id	dept_name	dept_head_id
100	R & D	501
200	Sales	902
300	Finance	1293
400	Marketing	1576
…	…	…

You get exactly the same results by listing all the column names in the table in order after the SELECT keyword:

```
SELECT dept_id, dept_name, dept_head_id
FROM department
```

Like a column name, “*” can be qualified with a table name, as in the following query:

```
SELECT department.*
FROM department
```

Selecting specific columns from a table

To SELECT only specific columns in a table, use this syntax:

SELECT *column_name* [, *column_name*]. . .
FROM *table-name*

You must separate each column name from the column name that follows it with a comma. For example:

```
SELECT emp_lname, emp_fname
FROM employee
```

Rearranging the order of columns

The order in which you list the column names determines the order in which the columns are displayed. The two following examples show how to specify column order in a display. Both of them find and display the department names and identification numbers from all five of the rows in the department table, but in a different order.

```
SELECT dept_id, dept_name
FROM department
```

dept_id	dept_name
100	R & D
200	Sales
300	Finance
400	Marketing
…	…

```
SELECT dept_name, dept_id
FROM department
```

dept_name	dept_id
R & D	100
Sales	200
Finance	300
Marketing	400
…	…

Renaming columns in query results

Query results consist of a set of columns. By default, the heading for each column is the expression supplied in the select list.

When query results are displayed, each column's default heading is the name given to it when it was created. You can specify a different column heading, or **alias**, in one of the following ways:

SELECT *column-name* **AS** *alias*

SELECT *column-name alias*

SELECT *alias* = *column-name*

Providing an alias can produce more readable results. For example, you can change dept_name to Department in a listing of departments as follows:

```
SELECT dept_name AS Department,
   dept_id AS "Identifying Number"
FROM department
```

Department	Identifying Number
R & D	100
Sales	200
Finance	300
Marketing	400
…	…

Using spaces and keywords in alias

The Identifying Number alias for dept_id is enclosed in double quotes because it is an identifier. You also use double quotes if you wish to use keywords in aliases. For example, the following query is invalid without the quotation marks:

```
SELECT dept_name AS Department,
   dept_id AS "integer"
FROM department
```

If you wish to ensure compatibility with Adaptive Server Enterprise, you should use quoted aliases of 30 bytes or less.

Character strings in query results

The SELECT statements you have seen so far produce results that consist solely of data from the tables in the FROM clause. Strings of characters can also be displayed in query results by enclosing them in single quotation marks and separating them from other elements in the select list with commas.

To enclose a quotation mark in a string, you precede it with another quotation mark.

For example:

```
SELECT 'The department''s name is' AS "Prefix",
   Department = dept_name
FROM department
```

Prefix	Department
The department's name is	R & D
The department's name is	Sales
The department's name is	Finance
The department's name is	Marketing
The department's name is	Shipping

Computing values in the SELECT list

The expressions in the select list can be more complicated than just column names or strings. For example, you can perform computations with data from numeric columns in a select list.

Arithmetic operations

To illustrate the numeric operations you can carry out in the select list, we start with a listing of the names, quantity in stock, and unit price of products in the sample database.

```
SELECT name, quantity, unit_price
FROM product
```

name	quantity	unit_price
Tee Shirt	28	9
Tee Shirt	54	14
Tee Shirt	75	14
Baseball Cap	112	9
...	...	...

Suppose the practice is to replenish the stock of a product when there are ten items left in stock. The following query lists the number of each product that must be sold before re-ordering:

```
SELECT name, quantity - 10
   AS "Sell before reorder"
FROM product
```

name	Sell before reorder
Tee Shirt	18
Tee Shirt	44
Tee Shirt	65
Baseball Cap	102
...	...

You can also combine the values in columns. The following query lists the total value of each product in stock:

```
SELECT name,
   quantity * unit_price AS "Inventory value"
FROM product
```

name	Inventory value
Tee Shirt	252
Tee Shirt	756
Tee Shirt	1050
Baseball Cap	1008
...	...

Arithmetic operator precedence

When there is more than one arithmetic operator in an expression, multiplication, division, and modulo are calculated first, followed by subtraction and addition. When all arithmetic operators in an expression have the same level of precedence, the order of execution is left to right. Expressions within parentheses take precedence over all other operations.

For example, the following SELECT statement calculates the total value of each product in inventory, and then subtracts five dollars from that value.

```
SELECT name, quantity * unit_price - 5
FROM product
```

To avoid misunderstandings, it is recommended that you use parentheses. The following query has the same meaning and gives the same results as the previous one, but some may find it easier to understand:

```
SELECT name, ( quantity * unit_price ) - 5
FROM product
```

☞ For more information on operator precedence, see “Operator precedence” [*ASA SQL Reference*, page 13].

String operations

You can concatenate strings using a string concatenation operator. You can use either || (SQL/92 compliant) or + (supported by Adaptive Server Enterprise) as the concatenation operator.

The following example illustrates the use of the string concatenation operator in the select list:

```
SELECT emp_id, emp_fname || ’ ’ || emp_lname AS Name
FROM employee
```

emp_id	Name
102	Fran Whitney
105	Matthew Cobb
129	Philip Chin
148	Julie Jordan
...	...

Date and time operations

Although you can use operators on date and time columns, this typically involves the use of functions. For information on SQL functions, see "SQL Functions" [*ASA SQL Reference*, page 83].

Eliminating duplicate query results

The optional DISTINCT keyword eliminates duplicate rows from the results of a SELECT statement.

If you do not specify DISTINCT, you get all rows, including duplicates. Optionally, you can specify ALL before the select list to get all rows. For compatibility with other implementations of SQL, Adaptive Server syntax allows the use of ALL to explicitly ask for all rows. ALL is the default.

For example, if you search for all the cities in the contact table without DISTINCT, you get 60 rows:

```
SELECT city
FROM contact
```

You can eliminate the duplicate entries using DISTINCT. The following query returns only 16 rows.:

```
SELECT DISTINCT city
FROM contact
```

NULL values are not distinct

The DISTINCT keyword treats NULL values as duplicates of each other. In other words, when DISTINCT is included in a SELECT statement, only one NULL is returned in the results, no matter how many NULL values are encountered.

The FROM clause: specifying tables

The FROM clause is required in every SELECT statement involving data from tables, views, or stored procedures.

☞ The FROM clause can include JOIN conditions linking two or more tables, and can include joins to other queries (derived tables). For information on these features, see "Joins: Retrieving Data from Several Tables" on page 261.

Qualifying table names

In the FROM clause, the full naming syntax for tables and views is always permitted, such as:

```
SELECT select-list
FROM owner.table_name
```

Qualifying table, view, and procedure names is necessary only when the object is owned by a user ID that is not the same as the user ID of the current connection, or is not the name of a group to which the user iD Of the current connection belongs.

Using correlation names

You can give a table name a correlation name to save typing. You assign the correlation name in the FROM clause by typing it after the table name, like this:

```
SELECT d.dept_id, d.dept_name
FROM Department d
```

All other references to the Department table, for example in a WHERE clause, *must* use the correlation name. Correlation names must conform to the rules for valid identifiers.

☞ For more information about the FROM clause, see "FROM clause" [*ASA SQL Reference*, page 445].

Querying from objects other than tables

The most common elements in a FROM clause are table names. It is also possible to query rows from other database objects that have a table-like structure—that is, a well-defined set of rows and columns. In addition to querying from tables and views, you can use derived tables (which are SELECT statements) or stored procedures that return result sets.

For example, the following query operates on the result set of a stored procedure.

```
SELECT *
FROM sp_customer_products( 149 )
```

☞ For more information, see "FROM clause" [*ASA SQL Reference*, page 445].

The WHERE clause: specifying rows

The WHERE clause in a SELECT statement specifies the search conditions for exactly which rows are retrieved. The general format is:

SELECT *select_list*
FROM *table_list*
WHERE *search-condition*

Search conditions, also called qualifications or predicates, in the WHERE clause include the following:

- **Comparison operators** (=, <, >, and so on) For example, you can list all employees earning more than $50,000:

  ```
  SELECT emp_lname
  FROM employee
  WHERE salary > 50000
  ```

- **Ranges** (BETWEEN and NOT BETWEEN) For example, you can list all employees earning between $40,000 and $60,000:

  ```
  SELECT emp_lname
  FROM employee
  WHERE salary BETWEEN 40000 AND 60000
  ```

- **Lists** (IN, NOT IN) For example, you can list all customers in Ontario, Quebec, or Manitoba:

  ```
  SELECT company_name , state
  FROM customer
  WHERE state IN( 'ON', 'PQ', 'MB')
  ```

- **Character matches** (LIKE and NOT LIKE) For example, you can list all customers whose phone numbers start with 415. (The phone number is stored as a string in the database):

  ```
  SELECT company_name , phone
  FROM customer
  WHERE phone LIKE '415%'
  ```

- **Unknown values** (IS NULL and IS NOT NULL) For example, you can list all departments with managers:

  ```
  SELECT dept_name
  FROM Department
  WHERE dept_head_id IS NOT NULL
  ```

- **Combinations** (AND, OR) For example, you can list all employees earning over $50,000 whose first name begins with the letter A.

```
SELECT emp_fname, emp_lname
FROM employee
WHERE salary > 50000
AND emp_fname like 'A%'
```

In addition, the WHERE keyword can introduce the following:

- **Transact-SQL join conditions** Joins are discussed in "Joins: Retrieving Data from Several Tables" on page 261.

☞ For more information about search conditions, see "Search conditions" [*ASA SQL Reference*, page 22].

☞ The following sections describe how to use WHERE clauses.

Using comparison operators in the WHERE clause

You can use comparison operators in the WHERE clause. The operators follow the syntax:

WHERE *expression comparison-operator expression*

☞ For more information about comparison operators, see "Comparison operators" [*ASA SQL Reference*, page 10]. For a description of what an expression can consist of, see "Expressions" [*ASA SQL Reference*, page 15].

Notes on comparisons

- **Sort orders** In comparing character data, < means earlier in the sort order and > means later in the sort order. The sort order is determined by the collation chosen when the database is created. You can find out the collation by running the *dbinfo* command-line utility against the database:

  ```
  dbinfo -c "uid=DBA;pwd=SQL"
  ```

  You can also find the collation from Sybase Central. It is on the Extended Information tab of the database property sheet.

- **Trailing blanks** When you create a database, you indicate whether trailing blanks are to be ignored or not for the purposes of comparison.

  By default, databases are created with trailing blanks not ignored. For example, 'Dirk' is not the same as 'Dirk '. You can create databases with blank padding, so that trailing blanks are ignored. Trailing blanks are ignored by default in Adaptive Server Enterprise databases.

- **Comparing dates** In comparing dates, < means earlier and > means later.

- **Case sensitivity** When you create a database, you indicate whether string comparisons are case sensitive or not.

By default, databases are created case insensitive. For example, 'Dirk' is the same as 'DIRK'. You can create databases to be case sensitive, which is the default behavior for Adaptive Server Enterprise databases.

Here are some SELECT statements using comparison operators:

```
SELECT *
FROM product
WHERE quantity < 20
SELECT E.emp_lname, E.emp_fname
FROM employee E
WHERE emp_lname > 'McBadden'
SELECT id, phone
FROM contact
WHERE state  != 'CA'
```

The NOT operator

The NOT operator negates an expression. Either of the following two queries will find all Tee shirts and baseball caps that cost $10 or less. However, note the difference in position between the negative logical operator (NOT) and the negative comparison operator (!>).

```
SELECT id, name, quantity
FROM product
WHERE (name = 'Tee Shirt' OR name = 'BaseBall Cap')
AND NOT unit_price > 10
SELECT id, name, quantity
FROM product
WHERE (name = 'Tee Shirt' OR name = 'BaseBall Cap')
AND unit_price !> 10
```

Using ranges (between and not between) in the WHERE clause

The BETWEEN keyword specifies an inclusive range, in which the lower value and the upper value are searched for as well as the values they bracket.

❖ To list all the products with prices between $10 and $15, inclusive

1. Type the following query:

```
SELECT name, unit_price
FROM product
WHERE unit_price BETWEEN 10 AND 15
```

name	unit_price
Tee Shirt	14
Tee Shirt	14
Baseball Cap	10
Shorts	15

You can use NOT BETWEEN to find all the rows that are not inside the range.

❖ To list all the products cheaper than $10 or more expensive than $15

1. Execute the following query:

```
SELECT name, unit_price
FROM product
WHERE unit_price NOT BETWEEN 10 AND 15
```

name	unit_price
Tee Shirt	9
Baseball Cap	9
Visor	7
Visor	7
…	…

Using lists in the WHERE clause

The IN keyword allows you to select values that match any one of a list of values. The expression can be a constant or a column name, and the list can be a set of constants or, more commonly, a subquery.

For example, without in, if you want a list of the names and states of all the contacts who live in Ontario, Manitoba, or Quebec, you can type this query:

```
SELECT company_name , state
FROM customer
WHERE state = 'ON' OR state = 'MB' OR state = 'PQ'
```

However, you get the same results if you use IN. The items following the IN keyword must be separated by commas and enclosed in parentheses. Put single quotes around character, date, or time values. For example:

```
SELECT company_name , state
FROM customer
WHERE state IN( 'ON', 'MB', 'PQ')
```

Perhaps the most important use for the IN keyword is in nested queries, also called subqueries.

Matching character strings in the WHERE clause

The LIKE keyword indicates that the following character string is a matching pattern. LIKE is used with character, binary, or date and time data.

The syntax for LIKE is:

{ **WHERE** | **HAVING** } *expression* [**NOT**] **LIKE** *match-expression*

The expression to be matched is compared to a match-expression that can include these special symbols:

Symbols	Meaning
%	Matches any string of 0 or more characters
_	Matches any one character
[specifier]	The specifier in the brackets may take the following forms: ♦ **Range** A range is of the form *rangespec1-rangespec2*, where *rangespec1* indicates the start of a range of characters, the hyphen indicates a range, and *rangespec2* indicates the end of a range of characters ♦ **Set** A set can be comprised of any discrete set of values, in any order. For example, [a2bR]. Note that the range [a-f], and the sets [abcdef] and [fcbdae] return the same set of values.
[^specifier]	The caret symbol (^) preceding a specifier indicates non-inclusion. [^a-f] means not in the range a-f; [^a2bR] means not a, 2, b, or R.

You can match the column data to constants, variables, or other columns that contain the wildcard characters displayed in the table. When using constants, you should enclose the match strings and character strings in single quotes.

Examples

All the following examples use LIKE with the last_name column in the Contact table. Queries are of the form:

```
SELECT last_name
FROM contact
WHERE last_name LIKE match-expression
```

The first example would be entered as

```
SELECT last_name
FROM contact
WHERE last_name LIKE 'Mc%'
```

Match expression	Description	Returns
‘Mc%’	Search for every name that begins with the letters **Mc**	McEvoy
‘%er’	Search for every name that ends with **er**	Brier, Miller, Weaver, Rayner
‘%en%’	Search for every name containing the letters **en**.	Pettengill, Lencki, Cohen
‘_ish’	Search for every four-letter name ending in **ish**.	Fish
‘Br[iy][ae]r’	Search for Brier, Bryer, Briar, or Bryar.	Brier
‘[M-Z]owell’	Search for all names ending with **owell** that begin with a single letter in the range M to Z.	Powell
‘M[^c]%’	Search for all names beginning with M’ that do not have c as the second letter	Moore, Mulley, Miller, Masalsky

Wildcards require LIKE

Wildcard characters used without LIKE are interpreted as **literals** rather than as a pattern: they represent exactly their own values. The following query attempts to find any phone numbers that consist of the four characters 415% only. It does not find phone numbers that start with 415.

```
SELECT phone
FROM Contact
WHERE phone = ’415%’
```

Using LIKE with date and time values

You can use LIKE on date and time fields as well as on character data. When you use LIKE with date and time values, the dates are converted to the standard DATETIME format, and then to VARCHAR.

One feature of using LIKE when searching for DATETIME values is that, since date and time entries may contain a variety of date parts, an equality test has to be written carefully in order to succeed.

For example, if you insert the value 9:20 and the current date into a column named arrival_time, the clause:

```
WHERE arrival_time = ’9:20’
```

fails to find the value, because the entry holds the date as well as the time. However, the clause below would find the 9:20 value:

```
WHERE arrival_time LIKE ’%09:20%’
```

Using NOT LIKE

With NOT LIKE, you can use the same wildcard characters that you can use with LIKE. To find all the phone numbers in the Contact table that do not have 415 as the area code, you can use either of these queries:

```
SELECT phone
FROM Contact
WHERE phone NOT LIKE '415%'
SELECT phone
FROM Contact
WHERE NOT phone LIKE '415%'
```

Character strings and quotation marks

When you enter or search for character and date data, you must enclose it in single quotes, as in the following example.

```
SELECT first_name, last_name
FROM contact
WHERE first_name = 'John'
```

If the quoted_identifier database option is set to OFF (it is ON by default), you can also use double quotes around character or date data.

Interactive SQL automatically sets quoted_identifier to ON for the duration of the Interactive SQL session.

❖ To set the quoted_identifier option off for the current user ID

1. Type the following command:

   ```
   SET OPTION quoted_identifier = 'OFF'
   ```

The quoted_identifier option is provided for compatibility with Adaptive Server Enterprise. By default, the Adaptive Server Enterprise option is quoted_identifier OFF and the Adaptive Server Anywhere option is quoted_identifier ON.

Quotation marks in strings

There are two ways to specify literal quotations within a character entry. The first method is to use two consecutive quotation marks. For example, if you have begun a character entry with a single quotation mark and want to include a single quotation mark as part of the entry, use two single quotation marks:

```
'I don''t understand.'
```

With double quotation marks (quoted_identifier OFF):

```
"He said, ""It is not really confusing."""
```

The second method, applicable only with quoted_identifier OFF, is to enclose a quotation in the other kind of quotation mark. In other words, surround an entry containing double quotation marks with single quotation marks, or vice versa. Here are some examples:

```
'George said, "There must be a better way."'
"Isn't there a better way?"
'George asked, "Isn''t there a better way?"'
```

Unknown Values: NULL

A NULL in a column means that the user or application has made no entry in that column. A data value for the column is unknown or not available.

NULL does not mean the same as zero (numerical values) or blank (character values). Rather, NULL values allow you to distinguish between a deliberate entry of zero for numeric columns or blank for character columns and a non-entry, which is NULL for both numeric and character columns.

Entering NULL

NULL can be entered in a column where NULL values are permitted, as specified in the create table statement, in two ways:

- **Default** If no data is entered, and the column has no other default setting, NULL is entered.
- **Explicit entry** You can explicitly enter the value NULL by typing the word NULL (without quotation marks).

  If the word NULL is typed in a character column with quotation marks, it is treated as data, not as a null value.

For example, the dept_head_id column of the department table allows nulls. You can enter two rows for departments with no manager as follows:

```
INSERT INTO department (dept_id, dept_name)
VALUES (201, 'Eastern Sales')
INSERT INTO department
VALUES (202, 'Western Sales', null)
```

When NULLs are retrieved

When NULLS are retrieved, displays of query results in Interactive SQL show (NULL) in the appropriate position:

```
SELECT *
FROM department
```

dept_id	dept_name	dept_head_id
100	R & D	501
200	Sales	904
300	Finance	1293
400	Marketing	1576
500	Shipping	703
201	Eastern Sales	(NULL)
202	Western Sales	(NULL)

Testing a column for NULL

You can use IS NULL in search conditions to compare column values to NULL and to select them or perform a particular action based on the results of the comparison. Only columns that return a value of TRUE are selected or result in the specified action; those that return FALSE or UNKNOWN do not.

The following example selects only rows for which unit_price is less than $15 or is NULL:

```
SELECT quantity , unit_price
FROM product
WHERE unit_price < 15
OR unit_price IS NULL
```

The result of comparing any value to NULL is UNKNOWN, since it is not possible to determine whether NULL is equal (or not equal) to a given value or to another NULL.

There are some conditions that never return true, so that queries using these conditions do not return result sets. For example, the following comparison can never be determined to be true, since NULL means having an unknown value:

```
WHERE column1 > NULL
```

This logic also applies when you use two column names in a WHERE clause, that is, when you join two tables. A clause containing the condition

```
WHERE column1 = column2
```

does not return rows where the columns contain NULL.

You can also find NULL or non-NULL with this pattern:

```
WHERE column_name IS [NOT] NULL
```

For example:

```
WHERE advance < $5000
OR advance IS NULL
```

☞ For more information, see “NULL value” [*ASA SQL Reference*, page 48].

Properties of NULL

The following list expands on the properties of NULL.

- **The difference between FALSE and UNKNOWN** Although neither FALSE nor UNKNOWN returns values, there is an important logical difference between FALSE and UNKNOWN, because the opposite of false (“not false”) is true. For example,

  ```
  1 = 2
  ```

  evaluates to false and its opposite,

  ```
  1 != 2
  ```

  evaluates to true. But “not unknown” is still unknown. If null values are included in a comparison, you cannot negate the expression to get the opposite set of rows or the opposite truth value.

- **Substituting a value for NULLs** Use the ISNULL built-in function to substitute a particular value for nulls. The substitution is made only for display purposes; actual column values are not affected. The syntax is:

  ISNULL(*expression*, *value*)

  For example, use the following statement to select all the rows from test, and display all the null values in column t1 with the value unknown.

  ```
  SELECT ISNULL(t1, 'unknown')
  FROM test
  ```

- **Expressions that evaluate to NULL** An expression with an arithmetic or bitwise operator evaluates to NULL if any of the operands are null. For example:

  ```
  1 + column1
  ```

  evaluates to NULL if column1 is NULL.

- **Concatenating strings and NULL** If you concatenate a string and NULL, the expression evaluates to the string. For example:

  ```
  SELECT 'abc' || NULL || 'def'
  ```

returns the string **abcdef**.

Connecting conditions with logical operators

The logical operators AND, OR, and NOT are used to connect search conditions in WHERE clauses.

Using AND

The AND operator joins two or more conditions and returns results only when all of the conditions are true. For example, the following query finds only the rows in which the contact's last name is Purcell and the contact's first name is Beth. It does not find the row for Beth Glassmann.

```
SELECT *
FROM contact
WHERE first_name = 'Beth'
   AND last_name = 'Purcell'
```

Using OR

The OR operator also connects two or more conditions, but it returns results when *any* of the conditions is true. The following query searches for rows containing variants of Elizabeth in the first_name column.

```
SELECT *
FROM contact
WHERE first_name = 'Beth'
   OR first_name = 'Liz'
```

Using NOT

The NOT operator negates the expression that follows it. The following query lists all the contacts who do not live in California:

```
SELECT *
FROM contact
WHERE NOT state = 'CA'
```

When more than one logical operator is used in a statement, AND operators are normally evaluated before OR operators. You can change the order of execution with parentheses. For example:

```
SELECT *
FROM contact
WHERE ( city = 'Lexington'
        OR city = 'Burlington' )
   AND state = 'MA'
```

CHAPTER 7

Summarizing, Grouping and Sorting Query Results

About this chapter

Aggregate functions display summaries of the values in specified columns. You can also use the GROUP BY clause, HAVING clause, and ORDER BY clause to group and sort the results of queries using aggregate functions, and the UNION operator to combine the results of queries.

This chapter describes how to group and sort query results.

Contents

Topic:	page
Summarizing query results using aggregate functions	232
The GROUP BY clause: organizing query results into groups	237
Understanding GROUP BY	238
The HAVING clause: selecting groups of data	242
The ORDER BY clause: sorting query results	244
The ROLLUP operation: adding summary information to GROUP BY queries	247
Performing set operations on query results with UNION, INTERSECT, and EXCEPT	251
Standards and compatibility	258

Summarizing query results using aggregate functions

You can apply aggregate functions to all the rows in a table, to a subset of the table specified by a WHERE clause, or to one or more groups of rows in the table. From each set of rows to which an aggregate function is applied, Adaptive Server Anywhere generates a single value.

The following are among the available aggregate functions:

- **avg(expression)** The mean of the supplied expression over the returned rows.
- **count(expression)** The number of rows in the supplied group where the expression is not NULL.
- **count(*)** The number of rows in each group.
- **list(string-expr)** A string containing a comma-separated list composed of all the values for *string-expr* in each group of rows.
- **max(expression)** The maximum value of the expression, over the returned rows.
- **min(expression)** The minimum value of the expression, over the returned rows.
- **stddev(expression)** The standard deviation of the expression, over the returned rows.
- **sum(expression)** The sum of the expression, over the returned rows.
- **variance(expression)** The variance of the expression, over the returned rows.

☞ For a complete list of aggregate functions, see "Aggregate functions" [*ASA SQL Reference*, page 84].

You can use the optional keyword DISTINCT with AVG, SUM, LIST, and COUNT to eliminate duplicate values before the aggregate function is applied.

The expression to which the syntax statement refers is usually a column name. It can also be a more general expression.

For example, with this statement you can find what the average price of all products would be if one dollar were added to each price:

```
SELECT AVG (unit_price + 1)
FROM product
```

Example

The following query calculates the total payroll from the annual salaries in the employee table:

```
SELECT SUM(salary)
FROM employee
```

To use aggregate functions, you must give the function name followed by an expression on whose values it will operate. The expression, which is the salary column in this example, is the function's argument and must be specified inside parentheses.

Where you can use aggregate functions

The aggregate functions can be used in a select list, as in the previous examples, or in the HAVING clause of a select statement that includes a GROUP BY clause.

☞ For more information about the HAVING clause, see "The HAVING clause: selecting groups of data" on page 242.

You cannot use aggregate functions in a WHERE clause or in a JOIN condition. However, a SELECT statement with aggregate functions in its select list often includes a WHERE clause that restricts the rows to which the aggregate is applied.

If a SELECT statement includes a WHERE clause, but not a GROUP BY clause, an aggregate function produces a single value for the subset of rows that the WHERE clause specifies.

Whenever an aggregate function is used in a SELECT statement that does not include a GROUP BY clause, it produces a single value. This is true whether it is operating on all the rows in a table or on a subset of rows defined by a where clause.

You can use more than one aggregate function in the same select list, and produce more than one scalar aggregate in a single SELECT statement.

Aggregate functions and outer references

Adaptive Server Anywhere version 8 and later follows SQL/99 standards for clarifying the use of aggregate functions when they appear in a subquery. These changes affect the behavior of statements written for previous versions of the software: previously correct queries may now produce error messages, and result sets may change.

When an aggregate function appears in a subquery, and the column referenced by the aggregate function is an outer reference, the entire aggregate function itself is now treated as an outer reference. This means that the aggregate function is now computed in the outer block, not in the subquery, and becomes a constant within the subquery.

The following restrictions now apply to the use of outer reference aggregate functions in subqueries:

- The outer reference aggregate function can only appear in subqueries that are in the SELECT list or HAVING clause, and these clauses must be in the immediate outer block.
- Outer reference aggregate functions can only contain one outer column reference.
- Local column references and outer column references cannot be mixed in the same aggregate function.

Some problems related to the new standards can be circumvented by rewriting the aggregate function so that it only includes local references. For example, the subquery `(SELECT MAX(S.y + R.y) FROM S)` contains both a local column reference (S.y) and an outer column reference (R.y), which is now illegal. It can be rewritten as `(SELECT MAX(S.y) + R.y FROM S)`. In the rewrite, the aggregate function has only a local column reference. The same sort of rewrite can be used when an outer reference aggregate function appears in clauses other than SELECT or HAVING.

Example

The following query produced the following results in Adaptive Server Anywhere version 7.

```
SELECT name, (SELECT SUM(p.quantity)
              FROM sales_order_items)
FROM product p
```

name	**sum(p.quantity)**
Tee shirt	30,716
Tee shirt	59,238

In later versions, the same query produces the error message `ASA Error -149: Function or column reference to 'name' must also appear in a GROUP BY`. The reason that the statement is no longer valid is that the outer reference aggregate function `sum(p.quantity)` is now computed in the outer block. In later versions, the query is semantically equivalent to the following (except that Z does not appear as part of the result set):

```
SELECT name,
       SUM(p.quantity) as Z,
       (SELECT Z FROM sales_order_items)
FROM product p
```

Since the outer block now computes an aggregate function, the outer block is treated as a grouped query and column name must appear in a GROUP BY clause in order to appear in the SELECT list.

Aggregate functions and data types

Some aggregate functions have meaning only for certain kinds of data. For example, you can use SUM and AVG with numeric columns only.

However, you can use MIN to find the lowest value—the one closest to the beginning of the alphabet—in a character type column:

```
SELECT MIN(last_lname)
FROM  contact
```

Using COUNT(*)

The COUNT(*) function does not require an expression as an argument because, by definition, it does not use information about any particular column. The COUNT(*) function finds the total number of rows in a table. This statement finds the total number of employees:

```
SELECT COUNT(*)
FROM employee
```

COUNT(*) returns the number of rows in the specified table without eliminating duplicates. It counts each row separately, including rows that contain NULL.

Like other aggregate functions, you can combine count(*) with other aggregates in the select list, with where clauses, and so on:

```
SELECT count(*), AVG(unit_price)
FROM product
WHERE  unit_price > 10
```

count(*)	AVG(product.unit_price)
5	18.2

Using aggregate functions with DISTINCT

The DISTINCT keyword is optional with SUM, AVG, and COUNT. When you use DISTINCT, duplicate values are eliminated before calculating the sum, average, or count.

For example, to find the number of different cities in which there are contacts, type:

```
SELECT count(DISTINCT city)
FROM contact
```

count(distinct contact.city)
16

You can use more than one aggregate function with DISTINCT in a query. Each DISTINCT is evaluated independently. For example:

```
SELECT count( DISTINCT first_name ) "first names",
       count( DISTINCT last_name ) "last names"
FROM contact
```

first names	last names
48	60

Aggregate functions and NULL

Any NULLS in the column on which the aggregate function is operating are ignored for the purposes of the function except COUNT(*), which includes them. If all the values in a column are NULL, COUNT(column_name) returns 0.

If no rows meet the conditions specified in the WHERE clause, COUNT returns a value of 0. The other functions all return NULL. Here are examples:

```
SELECT COUNT (DISTINCT name)
FROM product
WHERE unit_price > 50
```

count(DISTINCT name)
0

```
SELECT AVG(unit_price)
FROM product
WHERE unit_price > 50
```

AVG(product.unit_price)
(NULL)

The GROUP BY clause: organizing query results into groups

The GROUP BY clause divides the output of a table into groups. You can GROUP BY one or more column names, or by the results of computed columns using numeric data types in an expression.

Using GROUP BY with aggregate functions

A GROUP BY clause almost always appears in statements that include aggregate functions, in which case the aggregate produces a value for each group. These values are called **vector aggregates**. (Remember that a scalar aggregate is a single value produced by an aggregate function without a GROUP BY clause.)

Example

The following query lists the average price of each kind of product:

```
SELECT name, AVG(unit_price) AS Price
FROM product
GROUP BY name
```

name	Price
Tee Shirt	12.333333333
Baseball Cap	9.5
Visor	7
Sweatshirt	24
…	…

The summary values (vector aggregates) produced by SELECT statements with aggregates and a GROUP BY appear as columns in each row of the results. By contrast, the summary values (scalar aggregates) produced by queries with aggregates and no GROUP BY also appear as columns, but with only one row. For example:

```
SELECT AVG(unit_price)
FROM product
```

AVG(product.unit_price)
13.3

Understanding GROUP BY

Understanding which queries are valid and which are not can be difficult when the query involves a GROUP BY clause. This section describes a way to think about queries with GROUP BY so that you may understand the results and the validity of queries better.

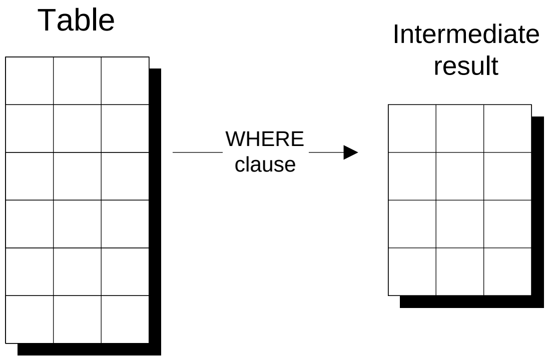
How queries with GROUP BY are executed

Consider a single-table query of the following form:

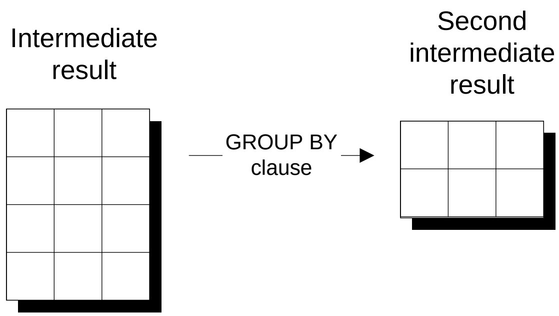
SELECT *select-list*
FROM *table*
WHERE *where-search-condition*
GROUP BY [*group-by-expression* | **ROLLUP** *(group-by-expression)*]
HAVING *having-search-condition*

This query can be thought of as being executed in the following manner:

1. **Apply the WHERE clause** This generates an intermediate result that contains only some of the rows of the table.



2. **Partition the result into groups** This action generates an intermediate result with one row for each group as dictated by the GROUP BY clause. Each generated row contains the *group-by-expression* for each group, and the computed aggregate functions in the *select-list* and *having-search-condition.*

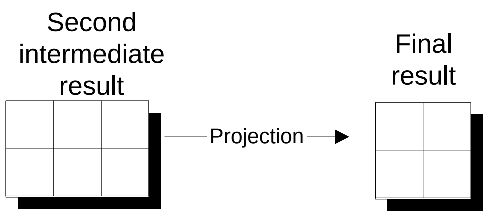


3. **Apply any ROLLUP operation** Subtotal rows computed as part of a ROLLUP operation are added to the result set.

   ☞ For more information, see "The ROLLUP operation: adding summary information to GROUP BY queries" on page 247.

4. **Apply the HAVING clause** Any rows from this second intermediate result that do not meet the criteria of the HAVING clause are removed at this point.

5. **Project out the results to display** This action takes from step 3 only those columns that need to be displayed in the result set of the query–that is, it takes only those columns corresponding to the expressions from the *select-list*.



This process makes requirements on queries with a GROUP BY clause:

- The WHERE clause is evaluated first. Therefore, any aggregate functions are evaluated only over those rows that satisfy the WHERE clause.
- The final result set is built from the second intermediate result, which holds the partitioned rows. The second intermediate result holds rows corresponding to the *group-by-expression*. Therefore, if an expression that is not an aggregate function appears in the *select-list*, then it must also appear in the *group-by-expression*. No function evaluation can be carried out during the projection step.
- An expression can be included in the *group-by-expression* but not in the *select-list*. It is projected out in the result.

GROUP BY with multiple columns

You can list more than one expression in the GROUP BY clause in order to nest groups—that is, you can group a table by any combination of expressions.

The following query lists the average price of products, grouped first by name and then by size:

```
SELECT name, size, AVG(unit_price)
FROM product
GROUP BY name, size
```

name	size	AVG(product.unit_price)
Tee Shirt	Small	9
Tee Shirt	Medium	14
Tee Shirt	One size fits all	14
Baseball Cap	One size fits all	9.5
…	…	…

Columns in GROUP BY that are not in the select list

A Sybase extension to the SQL/92 standard that is supported by both Adaptive Server Enterprise and Adaptive Server Anywhere is to allow expressions to the GROUP BY clause that are not in the select list. For example, the following query lists the number of contacts in each city:

```
SELECT state, count(id)
FROM contact
GROUP BY state, city
```

WHERE clause and GROUP BY

You can use a WHERE clause in a statement with GROUP BY. The WHERE clause is evaluated before the GROUP BY clause. Rows that do not satisfy the conditions in the WHERE clause are eliminated before any grouping is done. Here is an example:

```
SELECT  name, AVG(unit_price)
FROM product
WHERE id > 400
GROUP BY name
```

Only the rows with id values of more than 400 are included in the groups that are used to produce the query results.

Example

The following query illustrates the use of WHERE, GROUP BY, and

HAVING clauses in one query:

```
SELECT name, SUM(quantity)
FROM product
WHERE name LIKE '%shirt%'
GROUP BY name
HAVING SUM(quantity) > 100
```

name	SUM(product.quantity)
Tee Shirt	157

In this example:

- The WHERE clause includes only rows that have a name including the word *shirt* (Tee Shirt, Sweatshirt).
- The GROUP BY clause collects the rows with a common name.
- The SUM aggregate calculates the total quantity of products available for each group.
- The HAVING clause excludes from the final results the groups whose inventory totals do not exceed 100.

The HAVING clause: selecting groups of data

The HAVING clause restricts the rows returned by a query. It sets conditions for the GROUP BY clause similar to the way in which WHERE sets conditions for the SELECT clause.

The HAVING clause search conditions are identical to WHERE search conditions except that WHERE search conditions cannot include aggregates, while HAVING search conditions often do. The example below is legal:

```
HAVING AVG(unit_price) > 20
```

But this example is not legal:

```
WHERE AVG(unit_price) > 20
```

Using HAVING with aggregate functions

The following statement is an example of simple use of the HAVING clause with an aggregate function.

To list those products available in more than one size or color, you need a query to group the rows in the product table by name, but eliminate the groups that include only one distinct product:

```
SELECT name
FROM product
GROUP BY name
HAVING COUNT(*) > 1
```

name
Tee Shirt
Baseball Cap
Visor
Sweatshirt

☞ For information about when you can use aggregate functions in HAVING clauses, see "Where you can use aggregate functions" on page 233.

Using HAVING without aggregate functions

The HAVING clause can also be used without aggregates.

The following query groups the products, and then restricts the result set to only those groups for which the name starts with B.

```
SELECT name
FROM product
GROUP BY name
HAVING name LIKE 'B%'
```

name
Baseball Cap

More than one condition in HAVING

More than one condition can be included in the HAVING clause. They are combined with the AND, OR, or NOT operators, as in the following example.

To list those products available in more than one size or color, for which one version costs more than $10, you need a query to group the rows in the product table by name, but eliminate the groups that include only one distinct product, and eliminate those groups for which the maximum unit price is under $10.

```
SELECT name
FROM product
GROUP BY name
HAVING COUNT(*) > 1
AND MAX(unit_price) > 10
```

name
Tee Shirt
Sweatshirt

The ORDER BY clause: sorting query results

The ORDER BY clause allows sorting of query results by one or more columns. Each sort can be ascending (ASC) or descending (DESC). If neither is specified, ASC is assumed.

A simple example

The following query returns results ordered by name:

```
SELECT id, name
FROM product
ORDER BY name
```

id	name
400	Baseball Cap
401	Baseball Cap
700	Shorts
600	Sweatshirt
…	…

Sorting by more than one column

If you name more than one column in the ORDER BY clause, the sorts are nested.

The following statement sorts the shirts in the product table first by name in ascending order, then by quantity (descending) within each name:

```
SELECT id, name, quantity
FROM product
WHERE name like '%shirt%'
ORDER BY name, quantity DESC
```

id	name	quantity
600	Sweatshirt	39
601	Sweatshirt	32
302	Tee Shirt	75
301	Tee Shirt	54
…	…	…

Using the column position

You can use the position number of a column in a select list instead of the column name. Column names and select list numbers can be mixed. Both of the following statements produce the same results as the preceding one.

```
SELECT id, name, quantity
FROM product
WHERE name like '%shirt%'
ORDER BY 2, 3 DESC
SELECT id, name, quantity
FROM product
WHERE name like '%shirt%'
ORDER BY 2, quantity DESC
```

Most versions of SQL require that ORDER BY items appear in the select list, but Adaptive Server Anywhere has no such restriction. The following query orders the results by quantity, although that column does not appear in the select list:

```
SELECT id, name
FROM product
WHERE name like '%shirt%'
ORDER BY 2, quantity DESC
```

ORDER BY and NULL

With ORDER BY, NULL sorts before all other values in ascending sort order.

ORDER BY and case sensitivity

The effects of an ORDER BY clause on mixed-case data depend on the database collation and case sensitivity specified when the database is created.

Explicitly limiting the number of rows returned by a query

You can use the FIRST or TOP keywords to limit the number of rows included in the result set of a query. These keywords are for use with queries that include an ORDER BY clause.

Examples

The following query returns information about the employee that appears first when employees are sorted by last name:

```
SELECT FIRST *
FROM employee
ORDER BY emp_lname
```

The following query returns the first five employees as sorted by last name:

```
SELECT TOP 5 *
FROM employee
ORDER BY emp_lname
```

When you use TOP, you can also use START AT to provide an offset. The following statement lists the fifth and sixth employees sorted in descending order by last name:

```
SELECT TOP 2 START AT 5 *
FROM employee
ORDER BY emp_lname DESC
```

FIRST and TOP should be used only in conjunction with an ORDER BY clause to ensure consistent results. Use of FIRST or TOP without an ORDER BY triggers a syntax warning, and will likely yield unpredictable results.

ORDER BY and GROUP BY

You can use an ORDER BY clause to order the results of a GROUP BY in a particular way.

Example

The following query finds the average price of each product and orders the results by average price:

```
SELECT name, AVG(unit_price)
FROM product
GROUP BY name
ORDER BY AVG(unit_price)
```

name	AVG(product.unit_price)
Visor	7
Baseball Cap	9.5
Tee Shirt	12.333333333
Shorts	15
...	...

The ROLLUP operation: adding summary information to GROUP BY queries

The ROLLUP operation is a simple online analytical processing feature. The term OnLine Analytical Processing (OLAP) describes a large set of data analysis features, of which ROLLUP is one.

ROLLUP adds subtotal rows into the result sets of queries with GROUP BY clauses.

ROLLUP example

The following query illustrates a ROLLUP operation and its result set. The subtotal rows are highlighted in the result set. Each subtotal row has a NULL in the column or columns over which the subtotal is computed. One row is an aggregate over all rows, and has NULL in both Year and Quarter columns.

```
SELECT year(order_date) Year,
       quarter( order_date) Quarter,
       count(*) Orders
FROM sales_order
GROUP BY ROLLUP (Year, Quarter)
ORDER BY Year, Quarter
```

Year	Quarter	Orders
(NULL)	**(NULL)**	**648**
2000	**(NULL)**	**380**
2000	1	87
2000	2	77
2000	3	91
2000	4	125
2001	**(NULL)**	**268**
2001	1	139
2001	2	119
2001	3	10

Understanding subtotal rows

Much of the purpose of ROLLUP operations can be understood from the example above or by running your own examples. This section gives a formal description of ROLLUP operations for those cases where examples are not sufficient.

ROLLUP is equivalent to a UNION of a set of GROUP BY queries. The result sets of the following queries are identical:

```
-- A ROLLUP query
SELECT A, B, C , SUM( D )
FROM T1
GROUP BY ROLLUP A, B, C;
-- Equivalent query without ROLLUP
SELECT * FROM (
 ( SELECT A, B, C, SUM( D )
   GROUP BY A, B, C )
  UNION ALL
 ( SELECT A, B, NULL, SUM( D )
   GROUP BY A, B )
  UNION ALL
 ( SELECT A, NULL, NULL, SUM( D )
   GROUP BY A )
  UNION ALL
 ( SELECT NULL, NULL, NULL, SUM( D ) )
)
```

The result set of GROUP BY A, B consists of subtotals over all those rows in which A and B are held constant. To make a union possible, column C is assigned NULL.

The ROLLUP operation can be thought of as follows:

- A list of **prefixes** is constructed for the query. A prefix is a subset of the items in the *group-by-list*.

  A prefix is constructed by excluding one or more rightmost items from those in the query's *group-by-list*. The remaining columns are called the **prefix columns**. For example, in the example above the **group-by-list** includes two items (Year and Quarter).

  ```
  GROUP BY ROLLUP (Year, Quarter)
  ```

  There are two prefixes for this query:

  - Exclude Quarter. The set of prefix columns contains the single column Year.
  - Exclude both Quarter and Year. There are no prefix columns.

  There are the same number of prefixes as there are items in the *group-by-list*.

- For each prefix, a subtotal row is constructed corresponding to all those rows in which the prefix columns have the same value.

  For example, in the query above, the prefix containing the Year column leads to a summary row for Year=2000 and a summary row for Year=2001. There is a single summary row for the prefix that has no columns, which is a subtotal over all rows in the intermediate result set.

The value of each column in a subtotal row is as follows:

- **Column included in the prefix** The value of the column. For example, in the query above, the value of the Year column for the subtotal over rows with Year=2000 is 2000.
- **Column excluded from the prefix** NULL. For example, the Quarter column has a value of NULL for the subtotal rows generated by the prefix consisting of the Year column.
- **Aggregate function** An aggregate over the values of the excluded columns.

  Subtotal values are computed over the rows in the underlying data, not over the aggregated rows. In many cases, such as SUM or COUNT, the result is the same, but the distinction is important in the case of statistical functions such as AVG, STDDEV, and VARIANCE, for which the result differs.

The ROLLUP operation and NULL

When rows in the input to a GROUP BY operation contain NULL, there is the possibility of confusion between subtotal rows added by the ROLLUP operation and NULL-containing rows that are part of the GROUP BY result set.

The GROUPING function distinguishes subtotal rows from others. The GROUPING function takes a column of the result set as its argument, and returns 1 if the column is NULL because the row is a subtotal row, and 0 otherwise.

The following example includes GROUPING columns in the result set. The query is an outer join between the employee table and the sales_order table. NULL appears in the columns corresponding to those employees who are not sales representatives (and therefore have no sales).

```
SELECT year(order_date) Year,
       employee.emp_id Employee,
       count(*) Orders,
       grouping( Year ) as GY,
       grouping( Employee ) as GE
FROM employee left outer join sales_order
ON employee.emp_id = sales_order.sales_rep
GROUP BY ROLLUP (Year, Employee)
ORDER BY Year, Employee
```

Year	Employee	Orders	GY	GE
(NULL)	(NULL)	64	0	1
(NULL)	(NULL)	712	1	1
(NULL)	102	1	0	0

Year	Employee	Orders	GY	GE
…	…	…	…	…

☞ For more information, see “GROUPING function [Aggregate]” [*ASA SQL Reference*, page 138].

Performing set operations on query results with UNION, INTERSECT, and EXCEPT

The operators described in this section carry out set operations on the results of two or more queries. While many of the operations can also be carried out using operations in the WHERE clause or HAVING clause, there are some operations that are very difficult to carry out in any way other than using these set-based operators. For example:

- When data is held in an unnormalized manner, you may wish to assemble seemingly disparate information into a single result set, even though the tables are unrelated.
- NULL is treated differently by set operators than in the WHERE clause or HAVING clause. In the WHERE clause or HAVING clause, two null-containing rows with identical non-null entries are not seen as identical, as the two NULL values are not defined to be identical. The set operators see two such rows as the same.

  For more information on NULL and set operations, see "Set operators and NULL" on page 254.

For more information, see "EXCEPT operation" [*ASA SQL Reference*, page 423], "INTERSECT operation" [*ASA SQL Reference*, page 482], and "UNION operation" [*ASA SQL Reference*, page 586].

Combining sets with the UNION operation

The UNION operator combines the results of two or more queries into a single result set.

By default, the UNION operator removes duplicate rows from the result set. If you use the ALL option, duplicates are not removed. The columns in the result set have the same names as the columns in the first table referenced. Any number of union operators may be used. For example:

```
x UNION y UNION z
```

By default, a statement containing multiple UNION operators is evaluated from left to right. Parentheses may be used to specify the order of evaluation.

For example, the following two expressions are not equivalent, due to the way that duplicate rows are removed from result sets:

```
x UNION ALL (y UNION z)
(x UNION ALL y) UNION z
```

In the first expression, duplicates are eliminated in the UNION between y and z. In the UNION between that set and x, duplicates are not eliminated. In the second expression, duplicates are included in the union between x and y, but are then eliminated in the subsequent union with z.

Using EXCEPT and INTERSECT

The EXCEPT operation lists the differences between two result sets. The following general construction lists all those rows that appear in the result set of query-1, but not in the result set of query-2.

query-1
EXCEPT
query-2

The INTERSECT operation lists the rows that appear in each of two result sets. The following general construction lists all those rows that appear in the result set of both query-1 and query-2.

query-1
INTERSECT
query-2

Like the UNION operation, both EXCEPT and INTERSECT take the ALL modifier, which prevents the elimination of duplicate rows from the result set.

For more information, see "EXCEPT operation" [*ASA SQL Reference,* page 423], and "INTERSECT operation" [*ASA SQL Reference,* page 482].

Rules for set operations

The following rules apply to UNION, EXCEPT, and INTERSECT operations:

- **Same number of items in the select lists** All select lists in the queries must have the same number of expressions (such as column names, arithmetic expressions, and aggregate functions). The following statement is invalid because the first select list is longer than the second:

```
-- This is an example of an invalid statement
SELECT store_id, city, state
FROM stores
UNION
SELECT store_id, city
FROM stores_east
```

- **Data types must match** Corresponding expressions in the SELECT lists must be of the same data type, or an implicit data conversion must be possible between the two data types, or an explicit conversion should be supplied.

For example, a UNION, INTERSECT, or EXCEPT is not possible between a column of the CHAR data type and one of the INT data type, unless an explicit conversion is supplied. However, a set operation is possible between a column of the MONEY data type and one of the INT data type.

- **Column ordering** You must place corresponding expressions in the individual queries of a set operation in the same order, because the set operators compare the expressions one to one in the order given in the individual queries in the SELECT clauses.

- **Multiple set operations** You can string several set operations together, as in the following example:

```
SELECT city AS Cities
FROM contact
UNION
SELECT city
FROM customer
UNION
SELECT city
FROM employee
```

  For UNION operations, the order of queries is not important. For INTERSECT, the order is important when there are two or more queries. For EXCEPT, the order is always important.

- **Column headings** The column names in the table resulting from a UNION are taken from the first individual query in the statement. If you want to define a new column heading for the result set, you can do so in the select list of the first query, as in the following example:

```
SELECT city AS Cities
FROM contact
UNION
SELECT city
FROM customer
```

  In the following query, the column heading remains as city, as it is defined in the first query of the UNION statement.

```
SELECT city
FROM contact
UNION
SELECT city AS Cities
FROM customer
```

  Alternatively, you can use the WITH clause to define the column names. For example:

```
WITH V( Cities )
AS ( SELECT city
     FROM contact
     UNION
     SELECT city
     FROM customer )
SELECT * FROM V
```

- **Ordering the results** You can use the WITH clause of the SELECT statement to order the column names in the select list . For example:

  ```
  WITH V( cityname )
  AS ( SELECT Cities = city
       FROM contact
       UNION
       SELECT city
       FROM customer )
  SELECT * FROM V
  ORDER BY cityname
  ```

  Alternatively, you can use a single ORDER BY clause at the end of the list of queries, but you must use integers rather than column names, as in the following example:

  ```
  SELECT Cities = city
  FROM contact
  UNION
  SELECT city
  FROM customer
  ORDER BY 1
  ```

Set operators and NULL

NULL is treated differently by the set operators UNION, EXCEPT, and INTERSECT than it is in search conditions. This difference is one of the main reasons to use set operators.

When comparing rows, set operators treat NULL values as equal to each other. In contrast, when NULL is compared to NULL in a search condition the result is unknown (not true).

One particularly useful consequence of this difference is that the number of rows in the result set for `query-1 EXCEPT ALL query-2` is *always* the difference in the number of rows in the result sets of the individual queries.

For example, consider two tables T1 and T2, each with the following columns:

```
col1 INT,
col2 CHAR(1)
```

The data in the tables is as follows:

- Table T1.

col1	col2
1	a
2	b
3	(NULL)
3	(NULL)
4	(NULL)
4	(NULL)

- Table T2

col1	col2
1	a
2	x
3	(NULL)

One query that asks for rows in T1 that also appear in T2 is as follows:

```
SELECT T1.col1, T1.col2
FROM T1 JOIN T2
ON T1.col1 = T2.col2
AND T1.col2 = T2.col2
```

T1.col1	T1.col2
1	a

The row (3, NULL) does not appear in the result set, as the comparison between NULL and NULL is not true. In contrast, approaching the problem using the INTERSECT operator includes a row with NULL:

```
SELECT col1, col2
FROM T1
INTERSECT
SELECT col1, col2
FROM T2
```

col1	col2
1	a
3	(NULL)

The following query uses search conditions to list rows in T1 that do not appear in T2:

```
SELECT col1, col2
FROM T1
WHERE col1 NOT IN (
    SELECT col1
    FROM t2
    WHERE t1.col2 = t2.col2 )
OR col2 NOT IN (
    SELECT col2
    FROM t2
    WHERE t1.col1 = t2.col1 )
```

col1	col2
2	b
3	(NULL)
4	(NULL)
3	(NULL)
4	(NULL)

The NULL-containing rows from T1 are not excluded by the comparison. In contrast, approaching the problem using EXCEPT ALL excludes NULL-containing rows that appear in both tables. In this case, the (3, NULL) row in T2 is identified as the same as the (3, NULL) row in T1.

```
SELECT col1, col2
FROM T1
EXCEPT ALL
SELECT col1, col2
FROM T2
```

col1	col2
2	b
3	(NULL)
4	(NULL)
4	(NULL)

The EXCEPT operator is more restrictive still. It eliminates both (3, NULL) rows from T1 and excludes one of the (4, NULL) rows as a duplicate.

```
SELECT col1, col2
FROM T1
EXCEPT
SELECT col1, col2
FROM T2
```

col1	col2
2	b
4	(NULL)

Standards and compatibility

This section describes standards and compatibility aspects of the Adaptive Server Anywhere GROUP BY clause.

GROUP BY and the SQL/92 standard

The SQL/92 standard for GROUP BY requires the following:

- A column used in an expression of the SELECT clause must be in the GROUP BY clause. Otherwise, the expression using that column is an aggregate function.
- A GROUP BY expression can only contain column names from the select list, but not those used only as arguments for vector aggregates.

The results of a standard GROUP BY with vector aggregate functions produce one row with one value per group.

Adaptive Server Anywhere and Adaptive Server Enterprise support extensions to HAVING that allow aggregate functions not in the select list and not in the GROUP BY clause.

Compatibility with Adaptive Server Enterprise

Adaptive Server Enterprise supports several extensions to the GROUP BY clause that are not supported in Adaptive Server Anywhere. These include the following:

- **Non-grouped columns in the select list** Adaptive Server Enterprise permits column names in the select list that do not appear in the group by clause. For example, the following is valid in Adaptive Server Enterprise:

  ```
  SELECT name, unit_price
  FROM product
  GROUP BY name
  ```

  This syntax is not supported in Adaptive Server Anywhere.

- **Nested aggregate functions** The following query, which nests a vector aggregate inside a scalar aggregate, is valid in Adaptive Server Enterprise but not in Adaptive Server Anywhere:

  ```
  SELECT MAX(AVG(unit_price))
  FROM product
  GROUP BY name
  ```

- **GROUP BY and ALL** Adaptive Server Anywhere does not support the use of ALL in the GROUP BY clause.

- **HAVING with no GROUP BY** Adaptive Server Anywhere does not support the use of HAVING with no GROUP BY clause unless all the expressions in the select and having clauses are aggregate functions. For example, the following query is valid in Adaptive Server Enterprise, but is not supported in Adaptive Server Anywhere:

  ```
  --unsupported syntax
  SELECT unit_price
     FROM product
     HAVING COUNT(*) > 8
  ```

  However, the following statement is valid in Adaptive Server Anywhere, because the functions MAX and COUNT are aggregate functions:

  ```
  SELECT MAX(unit_price)
  FROM product
  HAVING COUNT(*) > 8
  ```

- **HAVING conditions** Adaptive Server Enterprise supports extensions to HAVING that allow non-aggregate functions not in the select list and not in the GROUP BY clause. Only aggregate functions of this type are allowed in Adaptive Server Anywhere.

- **DISTINCT with ORDER BY or GROUP BY** Adaptive Server Enterprise permits the use of columns in the ORDER BY or GROUP BY clause that do not appear in the select list, even in SELECT DISTINCT queries. This can lead to repeated values in the SELECT DISTINCT result set. Adaptive Server Anywhere does not support this behavior.

- **Column names in UNIONS** Adaptive Server Enterprise permits the use of columns in the ORDER BY clause in unions of queries. In Adaptive Server Anywhere, the ORDER BY clause must use an integer to mark the column by which the results are being ordered.

CHAPTER 8

Joins: Retrieving Data from Several Tables

About this chapter

When you create a database, you normalize the data by placing information specific to different objects in different tables, rather than in one large table with many redundant entries.

A join operation recreates a larger table using the information from two or more tables (or views). Using different joins, you can construct a variety of these virtual tables, each suited to a particular task.

Before your start

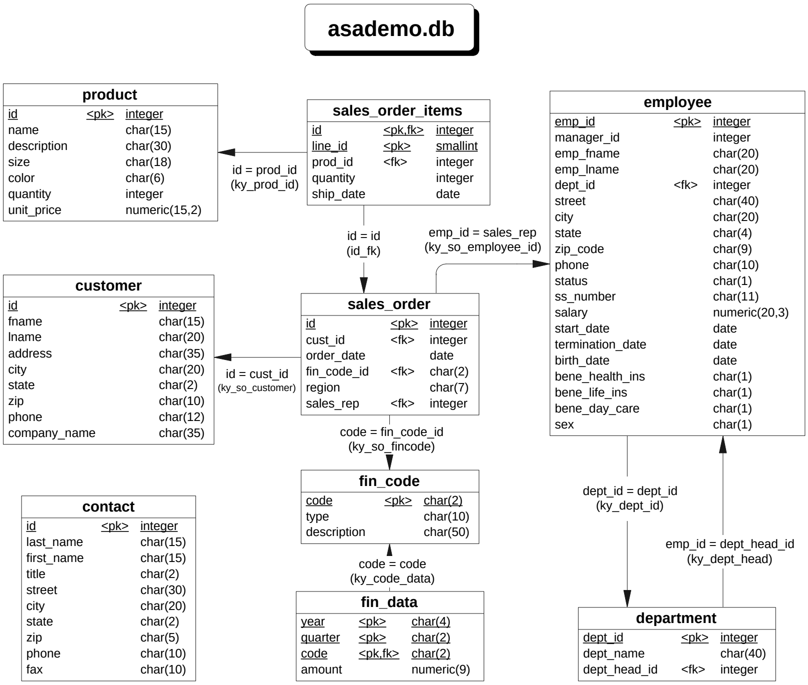
This chapter assumes some knowledge of queries and the syntax of the select statement. Information about queries appears in "Queries: Selecting Data from a Table" on page 207.

Contents

Topic:	page
Sample database schema	262
How joins work	263
Joins overview	264
Explicit join conditions (the ON phrase)	269
Cross joins	272
Inner and outer joins	274
Specialized joins	281
Natural joins	288
Key joins	292

Sample database schema

This chapter makes frequent reference to the sample database. In the following diagram, the sample database is shown with the names of the foreign keys that relate the tables. The sample database is held in a file called *asademo.db*, and is located in your installation directory.



How joins work

A relational database stores information about different types of objects in different tables. For example, information particular to employees appears in one table, and information that pertains to departments in another. The employee table contains information such as employee names and addresses. The department table contains information about one department, such as the name of the department and who the department head is.

Most questions can only be answered using a combination of information from the various tables. For example, you may want to answer the question "Who manages the Sales department?" To find the name of this person, you must identify the correct person using information from the department table, then look up that person's name in the employee table.

Joins are a means of answering such questions by forming a new virtual table that includes information from multiple tables. For example, you could create a list of the department heads by combining the information contained in the employee table and the department table. You specify which tables contain the information you need using the FROM clause.

To make the join useful, you must combine the correct columns of each table. To list department heads, each row of the combined table should contain the name of a department and the name of the employee who manages it. You control how columns are matched in the composite table by either specifying a particular type of join operation or using the ON phrase.

Joins overview

A **join** is an operation that combines the rows in tables by comparing the values in specified columns. This section is an overview of Adaptive Server Anywhere join syntax. All of the concepts are explored in greater detail in later sections.

The FROM clause

Use the FROM clause to specify which base tables, temporary tables, views or derived tables to join. The FROM clause can be used in SELECT or UPDATE statements. An abbreviated syntax for the FROM clause is as follows:

FROM *table_expression*, . . .

where:

table_expression:
table | *view* | *derived table* | *joined table* | **(** *table_expression*, . . . **)**

table or view:
[*userid*.] *table-or-view-name* [[**AS**] *correlation-name*]

derived table:
(*select-statement* **)** [**AS**] *correlation-name* [**(** *column-name*, . . . **)**]

joined table:
table_expression join_operator table_expression [**ON** *join_condition*]

join_operator:
[**KEY** | **NATURAL**] [*join_type*] **JOIN** | **CROSS JOIN**

join_type:
INNER | **FULL** [**OUTER**] | **LEFT** [**OUTER**] | **RIGHT** [**OUTER**]

Notes

You cannot use an ON phrase with CROSS JOIN.

☞ For the complete syntax, see “FROM clause” [*ASA SQL Reference,* page 445].

☞ For the syntax of the ON phrase, see “Search conditions” [*ASA SQL Reference,* page 22].

Join conditions

Tables can be joined using **join conditions**. A join condition is simply a search condition. It chooses a subset of rows from the joined tables based on the relationship between values in the columns. For example, the following query retrieves data from the product and sales_order_items tables.

```
SELECT *
FROM product JOIN sales_order_items
   ON product.id = sales_order_items.prod_id
```

The join condition in this query is

```
product.id = sales_order_items.prod_id
```

This join condition means that rows can be combined in the result set only if they have the same product ID in both tables.

Join conditions can be explicit or generated. An **explicit join condition** is a join condition that is put in an ON phrase or a WHERE clause. The following query uses an ON phrase. It produces a cross product of the two tables (all combinations of rows), but with rows excluded if the id numbers do not match. The result is a list of customers with details of their orders.

```
SELECT *
FROM customer JOIN sales_order
  ON sales_order.cust_id = customer.id
```

A **generated join condition** is a join condition that is automatically created when you specify KEY JOIN or NATURAL JOIN. In the case of a key join, the generated join condition is based on the foreign key relationships between the tables. In the case of a natural join, the generated join condition is based on columns that have the same name.

> *Tip:* Both key join syntax and natural join syntax are shortcuts: you get identical results from using the keyword JOIN *without* KEY or NATURAL, and then explicitly stating the same join condition in an ON phrase.

When you use an ON phrase with a key join or natural join, the join condition that is used is the **conjunction** of the explicitly specified join condition with the generated join condition. This means that the join conditions are combined with the keyword AND.

Joined tables

Adaptive Server Anywhere supports the following classes of joined tables.

- **CROSS JOIN** A cross join of two tables produces all possible combinations of rows from the two tables. The size of the result set is the number of rows in the first table multiplied by the number of rows in the second table. A cross join is also called a cross product or Cartesian product. You cannot use an ON phrase with a cross join.
- **KEY JOIN (default)** A join condition is automatically generated based on the foreign key relationships that have been built into the

database. Key join is the default when the JOIN keyword is used without specifying a join type and there is no ON phrase.

- **NATURAL JOIN** A join condition is automatically generated based on columns having the same name.
- **Join using an ON phrase** You specify an explicit join condition. When used with a key join or natural join, the join condition contains both the generated join condition and the explicit join condition. When used with the keyword JOIN without the keywords KEY or NATURAL, there is no generated join condition. You cannot use an ON clause with a cross join.

Inner and outer joins

Key joins, natural joins and joins with an ON clause may be qualified by specifying INNER, LEFT OUTER, RIGHT OUTER, or FULL OUTER. The default is INNER. When using the keywords LEFT, RIGHT or FULL, the keyword OUTER is optional.

In an inner join, each row in the result satisfies the join condition.

In a left or right outer join, all rows are preserved for one of the tables, and for the other table nulls are returned for rows that do not satisfy the join condition. For example, in a right outer join the right side is preserved and the left side is null-supplying.

In a full outer join, all rows are preserved for both of the tables, and nulls are supplied for rows that do not satisfy the join condition.

Joining two tables

To understand how a simple inner join is computed, consider the following query. It answers the question: which product sizes have been ordered in the same quantity as the quantity in stock?

```
SELECT DISTINCT name, size,
    sales_order_items.quantity
FROM product JOIN sales_order_items
ON product.id = sales_order_items.prod_id
  AND product.quantity = sales_order_items.quantity
```

name	size	quantity
Baseball Cap	One size fits all	12
Visor	One size fits all	36

You can interpret the query as follows. Note that this is a conceptual explanation of the processing of this query, used to illustrate the semantics of a query involving a join. It does not represent how Adaptive Server Anywhere actually computes the result set.

- Create a cross product of the product table and sales_order_items table. A cross product contains every combination of rows from the two tables.
- Exclude all rows where the product IDs are not identical (because of the join condition `product.id = sales_order_items.prod_id`).
- Exclude all rows where the quantity is not identical (because of the join condition `product.quantity = sales_order_items.quantity`).
- Create a result table with three columns: product.name, product.size, and sales_order_items.quantity.
- Exclude all duplicate rows (because of the DISTINCT keyword).

☞ For a description of how outer joins are computed, see "Outer joins" on page 274.

Joining more than two tables

With Adaptive Server Anywhere, there is no fixed limit on the number of tables you can join.

When joining more than two tables, parentheses are optional. If you do not use parentheses, Adaptive Server Anywhere evaluates the statement from left to right. Therefore, `A JOIN B JOIN C` is equivalent to `(A JOIN B) JOIN C`. Another example:

```
SELECT *
FROM A JOIN B JOIN C JOIN D
```

is equivalent to

```
SELECT *
FROM ((A JOIN B) JOIN C) JOIN D
```

Whenever more than two tables are joined, the join involves table expressions. In the example `A JOIN B JOIN C`, the table expression `A JOIN B` is joined to C. This means, conceptually, that A and B are joined, and then the result is joined to C.

The order of joins is important if the table expression contains outer joins. For example, `A JOIN B LEFT OUTER JOIN C` is interpreted as `(A JOIN B) LEFT OUTER JOIN C`. This means that the table expression `A JOIN B` is joined to C. The table expression `A JOIN B` is preserved and table C is null-supplying.

☞ For more information about outer joins, see "Outer joins" on page 274.

☞ For more information about how Adaptive Server Anywhere performs a key join of table expressions, see "Key joins of table expressions" on page 295.

☞ For more information about how Adaptive Server Anywhere performs a natural join of table expressions, see "Natural joins of table expressions" on page 289.

Join compatible data types

When you join two tables, the columns you compare must have the same or compatible data types.

☞ For more information about data type conversion in joins, see "Conversion when using comparison operators" [*ASA SQL Reference*, page 76].

Using joins in delete, update, and insert statements

You can use joins in DELETE, UPDATE and INSERT statements, as well as in SELECT statements. You can update some cursors that contain joins if the ANSI_UPDATE_CONSTRAINTS option is set to OFF. This is the default for databases created before Adaptive Server Anywhere version 7. For databases created in version 7 or later, the default is ON.

☞ For more information, see "ANSI_UPDATE_CONSTRAINTS option [compatibility]" [*ASA Database Administration Guide*, page 576].

Non-ANSI joins

☞ Adaptive Server Anywhere supports ISO/ANSI standards for joins. It also supports the following non-standard joins:

- "Transact-SQL outer joins (*= or =*)" on page 278
- "Duplicate correlation names in joins (star joins)" on page 282
- "Key joins" on page 292
- "Natural joins" on page 288

☞ You can use the REWRITE function to see the ANSI equivalent of a non-ANSI join.

☞ For more information, see "REWRITE function [Miscellaneous]" [*ASA SQL Reference*, page 177].

Explicit join conditions (the ON phrase)

Instead of, or along with, a key or natural join, you can specify a join using an explicit join condition. You specify a join condition by inserting an ON phrase immediately after the join. The join condition always refers to the join immediately preceding it.

Example

In the following query, the first ON phrase is used to join sales_order to customer. The second ON phrase is used to join the table expression (sales_order JOIN customer) to the base table sales_order_item.

```
SELECT *
FROM sales_order JOIN customer
    ON sales_order.cust_id = customer.id
  JOIN sales_order_items
    ON sales_order_items.id = sales_order.id
```

Tables that can be referenced

The tables that are referenced in an ON phrase must be part of the join that the ON phrase modifies. For example, the following is invalid:

```
FROM (A KEY JOIN B) JOIN (C JOIN D ON A.x = C.x)
```

The problem is that the join condition `A.x = C.x` references table A, which is not part of the join it modifies (in this case, `C JOIN D`).

However, as of the ANSI/ISO standard SQL99 and Adaptive Server Anywhere 7.0, there is an exception to this rule: if you use commas between table expressions, an ON condition of a join can reference a table that precedes it syntactically in the FROM clause. Therefore, the following is valid:

```
FROM (A KEY JOIN B) , (C JOIN D ON A.x = C.x)
```

☞ For more information about commas, see "Commas" on page 272.

Generated joins and the ON phrase

Key joins are the default if the keyword JOIN is used and no join type is specified—unless you use an ON phrase. If you use an ON phrase with an unspecified JOIN, key join is not the default and no generated join condition is applied.

For example, the following is a key join, because key join is the default when the keyword JOIN is used and there is no ON phrase:

```
SELECT *
FROM A JOIN B
```

The following is a join between table A and table B with the join condition

`A.x = B.y`. It is *not* a key join.

```
SELECT *
FROM A JOIN B ON A.x = B.y
```

If you specify a KEY JOIN or NATURAL JOIN *and* use an ON phrase, the final join condition is the conjunction of the generated join condition and the explicit join condition(s). For example, the following statement has two join conditions: one generated because of the key join, and one explicitly stated in the ON phrase.

```
SELECT *
FROM A KEY JOIN B ON A.x = B.y
```

If the join condition generated by the key join is `A.w = B.z`, then the following statement is equivalent:

```
SELECT *
FROM A JOIN B
  ON A.x = B.y
  AND A.w = B.z
```

☞ For more information about key joins, see "Key joins" on page 292.

Types of explicit join conditions

Most join conditions are based on equality, and so are called **equijoins**. For example,

```
SELECT *
FROM department JOIN employee
   ON department.dept_id = employee.dept_id
```

However, you do not have to use equality (=) in a join condition. You can use any search condition, such as conditions containing LIKE, SOUNDEX, BETWEEN, > (greater than), and != (not equal to).

Example

The following example answers the question: For which products has someone ordered more than the quantity in stock?

```
SELECT DISTINCT product.name
FROM product JOIN sales_order_items
ON product.id = sales_order_items.prod_id
   AND product.quantity > sales_order_items.quantity
```

For more information about search conditions, see "Search conditions" [*ASA SQL Reference*, page 22].

Using the WHERE clause for join conditions

Except when using outer joins, you can specify join conditions in the

WHERE clause instead of the ON phrase. However, you should be aware that there may be semantic differences between the two if the query contains outer joins.

The ON phrase is part of the FROM clause, and so is processed before the WHERE clause. This does not make a difference to results except in the case of outer joins, where using the WHERE clause can convert the join to an inner join.

When deciding whether to put join conditions in an ON phrase or WHERE clause, keep the following rules in mind:

- When you specify an outer join, putting a join condition in the WHERE clause may convert the outer join to an inner join.

  ☞ For more information about the WHERE clause and outer joins, see "Outer joins and join conditions" on page 276.

- Conditions in an ON phrase can only refer to tables that are in the table expressions joined by the associated JOIN. However, conditions in a WHERE clause can refer to any tables, even if they are not part of the join.

- You cannot use an ON phrase with the keywords CROSS JOIN, but you can always use a WHERE clause.

- When join conditions are in an ON phrase, key join is not the default. However, key join can be the default if join conditions are put in a WHERE clause.

  ☞ For more information about the conditions under which key join is the default, see "When key join is the default" on page 292.

In the examples in this documentation, join conditions are put in an ON phrase. In examples using outer joins, this is necessary. In other cases it is done to make it obvious that they are join conditions and not general search conditions.

Cross joins

A cross join of two tables produces all possible combinations of rows from the two tables. A cross join is also called a cross product or Cartesian product.

Each row of the first table appears once with each row of the second table. Hence, the number of rows in the result set is the product of the number of rows in the first table and the number of rows in the second table, minus any rows that are omitted because of restrictions in a WHERE clause.

You cannot use an ON phrase with cross joins. However, you can put restrictions in a WHERE clause.

Inner and outer modifiers do not apply to cross joins

Except in the presence of additional restrictions in the WHERE clause, all rows of both tables always appear in the result set of cross joins. Thus, the keywords INNER, LEFT OUTER and RIGHT OUTER are not applicable to cross joins.

For example, the following statement joins two tables.

```
SELECT *
FROM A CROSS JOIN B
```

The result set from this query includes all columns in A and all columns in B. There is one row in the result set for each combination of a row in A and a row in B. If A has *n* rows and B has *m* rows, the query returns *n* x *m* rows.

Commas

A comma works like a join operator, but is not one. A comma creates a cross product exactly as the keyword CROSS JOIN does. However, join keywords create table expressions, and commas create lists of table expressions.

In the following simple inner join of two tables, a comma and the keywords CROSS JOIN are equivalent:

```
Select *
FROM A CROSS JOIN B CROSS JOIN C
WHERE A.x = B.y
```

and

```
Select *
FROM A, B, C
WHERE A.x = B.y
```

Generally, you can use a comma instead of the keywords CROSS JOIN. The comma syntax is equivalent to cross join syntax, except in the case of generated join conditions in table expressions using commas.

☞ For information about how commas work with generated join conditions, see “Key joins of table expressions” on page 295.

☞ In the syntax of star joins, commas have a special use. For more information, see “Duplicate correlation names in joins (star joins)” on page 282.

Inner and outer joins

The keywords INNER, LEFT OUTER, RIGHT OUTER, and FULL OUTER may be used to modify key joins, natural joins, and joins with an ON phrase. The default is INNER. The keyword OUTER is optional. These modifiers do not apply to cross joins.

Inner joins

By default, joins are **inner joins**. This means that rows are included in the result set only if they satisfy the join condition.

Example

For example, each row of the result set of the following query contains the information from one customer row and one sales_order row, satisfying the key join condition. If a particular customer has placed no orders, the condition is not satisfied and the result set does not contain the row corresponding to that customer.

```
SELECT fname, lname, order_date
FROM customer KEY INNER JOIN sales_order
ORDER BY order_date
```

fname	lname	order_date
Hardy	Mums	1/2/00
Aram	Najarian	1/3/00
Tommie	Wooten	1/3/00
Alfredo	Margolis	1/6/00
...	...	...

Because inner joins and key joins are the defaults, you obtain the same result using the following FROM clause.

```
FROM customer JOIN sales_order
```

Outer joins

A left or right **outer join** of two tables preserves all the rows in one table, and supplies nulls for the other table when it does not meet the join condition. A **left outer join** preserves every row in the left-hand table, and a **right outer join** preserves every row in the right-hand table. In a **full outer join**, all rows from both tables are preserved.

The table expressions on either side of a left or right outer join are referred to as **preserved** and **null-supplying**. In a left outer join, the left-hand table expression is preserved and the right-hand table expression is null-supplying.

☞ For information about creating outer joins with Transact-SQL syntax, see "Transact-SQL outer joins (*= or =*)" on page 278.

Example

For example, the following statement includes all customers, whether or not they have placed an order. If a particular customer has placed no orders, each column in the result that corresponds to order information contains the NULL value.

```
SELECT lname, order_date, city
FROM customer LEFT OUTER JOIN sales_order
    ON customer.id = sales_order.cust_id
WHERE customer.state = 'NY'
ORDER BY order_date
```

lname	order_date	city
Thompson	(NULL)	Bancroft
Reiser	2000-01-22	Rockwood
Clarke	2000-01-27	Rockwood
Mentary	2000-01-30	Rockland
...	...	...

You can interpret the outer join in this statement as follows. Note that this is a conceptual explanation, and does not represent how Adaptive Server Anywhere actually computes the result set.

- ♦ Return one row for every sales order placed by a customer. More than one row is returned when the customer placed two or more sales orders, because a row is returned for each sales order. This is the same result as an inner join. The ON condition is used to match customer and sales order rows. The WHERE clause is not used for this step.
- ♦ Include one row for every customer who has not placed any sales orders. This ensures that every row in the customer table is included. For all of these rows, the columns from sales_order are filled with nulls. These rows are added because the keyword OUTER is used, and would not have appeared in an inner join. Neither the ON condition nor the WHERE clause is used for this step.
- ♦ Exclude every row where the customer does not live in New York, using the WHERE clause.

Outer joins and join conditions

A common mistake with outer joins is the placement of the join condition. In most cases, if you place restrictions on the null-supplying table in a WHERE clause, the join is equivalent to an inner join.

The reason for this is that most search conditions cannot evaluate to TRUE when any of their inputs are NULL. The WHERE clause restriction on the null-supplying table compares values to null, resulting in the elimination of the row from the result set. The rows in the preserved table are not preserved and so the join is an inner join.

The exception to this is comparisons that can evaluate to true when any of their inputs are NULL. These include IS NULL, IS UNKNOWN, IS FALSE, IS NOT TRUE, and expressions involving ISNULL or COALESCE.

Example

For example, the following statement computes a left outer join.

```
SELECT *
FROM customer KEY LEFT OUTER JOIN sales_order
   ON sales_order.order_date < '2000-01-03'
```

In contrast, the following statement creates an inner join.

```
SELECT lname, order_date
FROM customer KEY LEFT OUTER JOIN sales_order
   WHERE sales_order.order_date < '2000-01-03'
```

The first of these two statements can be thought of as follows: First, left-outer join the customer table to the sales_order table. The result set includes every row in the customer table. For those customers who have no orders prior to January 3 2000, fill the sales order fields with nulls.

In the second statement, first left-outer join customer and sales_order. The result set includes every row in the customer table. For those customers who have no orders, fill the sales order fields with nulls. Next, apply the WHERE condition by selecting only those rows in which the customer has placed an order since January 3 2000. For those customers who have not placed orders, these values are NULL. Comparing any value to NULL evaluates to UNKNOWN. Hence, these rows are eliminated and the statement reduces to an inner join.

☞ For more information about search conditions, see “Search conditions” [*ASA SQL Reference*, page 22].

Understanding complex outer joins

The order of joins is important when a query includes table expressions using outer joins. For example, `A JOIN B LEFT OUTER JOIN C` is interpreted as `(A JOIN B) LEFT OUTER JOIN C`. This means that the table expression `(A JOIN B)` is joined to C. The table expression `(A JOIN B)` is preserved and table C is null-supplying.

Consider the following statement, in which A, B and C are tables:

```
SELECT *
FROM A LEFT OUTER JOIN B RIGHT OUTER JOIN C
```

To understand this statement, first remember that Adaptive Server Anywhere evaluates statements from left to right, adding parentheses. This results in

```
SELECT *
FROM (A LEFT OUTER JOIN B) RIGHT OUTER JOIN C
```

Next, you may want to convert the right outer join to a left outer join so that both joins are the same type. To do this, simply reverse the position of the tables in the right outer join, resulting in:

```
SELECT *
FROM C LEFT OUTER JOIN (A LEFT OUTER JOIN B)
```

A is the preserved table and B is the null-supplying table for the nested outer join. C is the preserved table for the first outer join.

You can interpret this join as follows:

- Join A to B, preserving all rows in A.
- Next, join C to the results of the join of A and B, preserving all rows in C.

The join does not have an ON phrase, and so is by default a key join. The way Adaptive Server Anywhere generates join conditions for this type of join is explained in "Key joins of table expressions that do not contain commas" on page 296.

In addition, the join condition for an outer join must only include tables that have previously been referenced in the FROM clause. This restriction is according to the ANSI/ISO standard, and is enforced to avoid ambiguity. For example, the following two statements are syntactically incorrect, because C is referenced in the join condition before the table itself is referenced.

```
SELECT *
FROM (A LEFT OUTER JOIN B ON B.x = C.x) JOIN C
```

and

```
SELECT *
FROM A LEFT OUTER JOIN B ON A.x = C.x, C
```

Outer joins of views and derived tables

Outer joins can also be specified for views and derived tables.

The statement

```
SELECT *
FROM V LEFT OUTER JOIN A ON (V.x = A.x)
```

can be interpreted as follows:

- Compute the view V.
- Join all the rows from the computed view V with A by preserving all the rows from V, using the join condition `V.x = A.x`.

Example

The following example defines a view called V that returns the employee IDs and department names of women who make over $60 000.

```
CREATE VIEW V AS
SELECT employee.emp_id, dept_name
  FROM employee JOIN department
    ON employee.dept_id = department.dept_id
  WHERE sex = 'F' and salary > 60000
```

Next, use this view to add a list of the departments where the women work and the regions where they have sold. The view V is preserved and sales_order is null-supplying.

```
SELECT DISTINCT V.emp_id, region, V.dept_name
  FROM V LEFT OUTER JOIN sales_order
    ON V.emp_id = sales_order.sales_rep
```

emp_id	region	dept_name
243	(NULL)	R & D
316	(NULL)	R & D
529	(NULL)	R & D
902	Eastern	Sales
…	…	…

Transact-SQL outer joins (*= or =*)

In accordance with ANSI/ISO SQL standards, Adaptive Server Anywhere supports the LEFT OUTER, RIGHT OUTER, and FULL OUTER keywords. For compatibility with Adaptive Server Enterprise prior to version 12, Adaptive Server Anywhere also supports the Transact-SQL counterparts of these keywords, *= and =*. However, there are some limitations and potential problems with the Transact-SQL semantics.

For a detailed discussion of Transact-SQL outer joins, see the whitepaper *Semantics and Compatibility of Transact-SQL Outer Joins* , which is available at *http://www.ianywhere.com/whitepapers/tsql.html.*

> *Warning:* When you are creating outer joins, do *not* mix *= syntax with ON phrase syntax. This also applies to views that are referenced in the query.

In the Transact-SQL dialect, you create outer joins by supplying a comma-separated list of tables in the FROM clause, and using the special operators *= or =* in the WHERE clause. In Adaptive Server Enterprise prior to version 12, the join condition must appear in the WHERE clause (ON was not supported).

Example

For example, the following left outer join lists all customers and finds their order dates (if any):

```
SELECT fname, lname, order_date
FROM customer, sales_order
WHERE customer.id *= sales_order.cust_id
ORDER BY order_date
```

This statement is equivalent to the following statement, in which ANSI/ISO syntax is used:

```
SELECT fname, lname, order_date
FROM customer LEFT OUTER JOIN sales_order
ON customer.id = sales_order.cust_id
ORDER BY order_date
```

Transact-SQL outer join limitations

There are several restrictions for Transact-SQL outer joins:

- If you specify an outer join and a qualification on a column from the null-supplying table of the outer join, the results may not be what you expect. The qualification in the query does not exclude rows from the result set, but rather affects the values that appear in the rows of the result set. For rows that do not meet the qualification, a null value appears in the null-supplying table.

- You cannot mix ANSI/ISO SQL syntax and Transact-SQL outer join syntax in a single query. If a view is defined using one dialect for an outer join, you must use the same dialect for any outer-join queries on that view.

- A null-supplying table cannot participate in both a Transact-SQL outer join and a regular join or two outer joins. For example, the following WHERE clause is not allowed, because table S violates this limitation.

  ```
  WHERE R.x *= S.x
  AND S.y = T.y
  ```

  When you cannot rewrite your query to avoid using a table in both an outer join and a regular join clause, you must divide your statement into two separate queries, or use only ANSI/ISO SQL syntax.

- You cannot use a subquery that contains a join condition involving the null-supplying table of an outer join. For example, the following WHERE clause is not allowed:

  ```
  WHERE R.x *= S.y
  AND EXISTS ( SELECT *
               FROM T
               WHERE T.x = S.x )
  ```

Using views with Transact-SQL outer joins

If you define a view with an outer join, and then query the view with a qualification on a column from the null-supplying table of the outer join, the results may not be what you expect. The query returns all rows from the null-supplying table. Rows that do not meet the qualification show a NULL value in the appropriate columns of those rows.

The following rules determine what types of updates you can make to columns through views that contain outer joins:

- INSERT and DELETE statements are not allowed on outer join views.
- UPDATE statements are allowed on outer join views. If the view is defined WITH CHECK option, the update fails if any of the affected columns appears in the WHERE clause in an expression that includes columns from more than one table.

How NULL affects Transact-SQL joins

NULL values in tables or views being joined never match each other in a Transact-SQL outer join. The result of comparing a NULL value with any other NULL value is FALSE.

Specialized joins

This section describes how to create some specialized joins such as self-joins, star joins, and joins using derived tables.

Self-joins

In a **self-join**, a table is joined to itself by referring to the same table using a different correlation name.

Example 1

The following self-join produces a list of pairs of employees. Each employee name appears in combination with every employee name.

```
SELECT a.emp_fname, a.emp_lname,
      b.emp_fname, b.emp_lname
FROM employee AS a CROSS JOIN employee AS b
```

emp_fname	emp_lname	emp_fname	emp_lname
Fran	Whitney	Fran	Whitney
Fran	Whitney	Matthew	Cobb
Fran	Whitney	Philip	Chin
Fran	Whitney	Julie	Jordan
…	…	…	…

Since the employee table has 75 rows, this join contains 75 x 75 = 5 625 rows. It includes, as well, rows that list each employee with themselves. For example, it contains the row

emp_fname	emp_lname	emp_fname	emp_lname
Fran	Whitney	Fran	Whitney

If you want to exclude rows that contain the same name twice, add the join condition that the employee IDs should not be equal to each other.

```
SELECT a.emp_fname, a.emp_lname,
      b.emp_fname, b.emp_lname
FROM employee AS a CROSS JOIN employee AS b
WHERE a.emp_id != b.emp_id
```

Without these duplicate rows, the join contains 75 x 74 = 5 550 rows.

This new join contains rows that pair each employee with every other employee, but because each pair of names can appear in two possible orders, each pair appears twice. For example, the result of the above join contains the following two rows.

emp_fname	emp_lname	emp_fname	emp_lname
Matthew	Cobb	Fran	Whitney
Fran	Whitney	Matthew	Cobb

If the order of the names is not important, you can produce a list of the (75 x 74)/2 = 2 775 unique pairs.

```
SELECT a.emp_fname, a.emp_lname,
      b.emp_fname, b.emp_lname
FROM employee AS a CROSS JOIN employee AS b
WHERE a.emp_id < b.emp_id
```

This statement eliminates duplicate lines by selecting only those rows in which the emp_id of employee a is less than that of employee b.

Example 2

The following self-join uses the correlation names report and manager to distinguish two instances of the employee table, and creates a list of employees and their managers.

```
SELECT report.emp_fname, report.emp_lname,
   manager.emp_fname, manager.emp_lname
FROM employee AS report JOIN employee AS manager
   ON (report.manager_id = manager.emp_id)
ORDER BY report.emp_lname, report.emp_fname
```

This statement produces the result shown partially below. The employee names appear in the two left-hand columns, and the names of their managers are on the right.

emp_fname	emp_lname	emp_fname	emp_lname
Alex	Ahmed	Scott	Evans
Joseph	Barker	Jose	Martinez
Irene	Barletta	Scott	Evans
Jeannette	Bertrand	Jose	Martinez
…	…	…	…

Duplicate correlation names in joins (star joins)

The reason for using duplicate table names is to create a **star join**. In a star join, one table or view is joined to several others.

To create a star join, you use the same table name, view name, or correlation name more than once in the FROM clause. This is an extension to the

ANSI/ISO SQL standard. The ability to use duplicate names does not add any additional functionality, but it makes it much easier to formulate certain queries.

The duplicate names must be in different joins for the syntax to make sense. When a table name or view name is used twice in the same join, the second instance is ignored. For example, `FROM A,A` and `FROM A CROSS JOIN A` are both interpreted as `FROM A`.

The following example, in which A, B and C are tables, is valid in Adaptive Server Anywhere. In this example, the same instance of table A is joined both to B and C. Note that a comma is required to separate the joins in a star join. The use of a comma in star joins is specific to the syntax of star joins.

```
SELECT *
FROM A LEFT OUTER JOIN B ON A.x = B.x,
     A LEFT OUTER JOIN C ON A.y = C.y
```

The next example is equivalent.

```
SELECT *
FROM A LEFT OUTER JOIN B ON A.x = B.x,
     C RIGHT OUTER JOIN A ON A.y = C.y
```

Both of these are equivalent to the following standard ANSI/ISO syntax. (The parentheses are optional.)

```
SELECT *
FROM (A LEFT OUTER JOIN B ON A.x = B.x)
LEFT OUTER JOIN C ON A.y = C.y
```

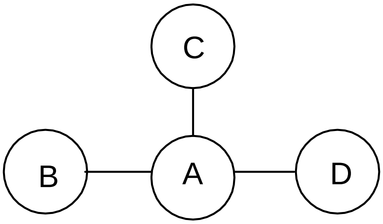
In the next example, table A is joined to three tables: B, C and D.

```
SELECT *
FROM A JOIN B ON A.x = B.x,
     A JOIN C ON A.y = C.y,
     A JOIN D ON A.w = D.w
```

This is equivalent to the following standard ANSI/ISO syntax. (The parentheses are optional.)

```
SELECT *
FROM ((A JOIN B ON A.x = B.x)
JOIN C ON A.y = C.y)
JOIN D ON A.w = D.w
```

With complex joins, it can help to draw a diagram. The previous example can be described by the following diagram, which illustrates that tables B, C and D are joined via table A.



> *Note* You can use duplicate table names only if the EXTENDED_JOIN_-SYNTAX option is ON (the default).
>
> For more information, see the "EXTENDED_JOIN_SYNTAX option [database]" [*ASA Database Administration Guide*, page 592].

Example 1

Create a list of the names of the customers who have placed orders with Rollin Overbey. Notice that one of the tables in the FROM clause, employee, does not contribute any columns to the results. Nor do any of the columns that are joined—such as customer.id or employee.id—appear in the results. Nonetheless, this join is possible only using the employee table in the FROM clause.

```
SELECT customer.fname, customer.lname,
    sales_order.order_date
FROM    sales_order KEY JOIN customer,
      sales_order KEY JOIN employee
WHERE employee.emp_fname = 'Rollin'
  AND employee.emp_lname = 'Overbey'
ORDER BY sales_order.order_date
```

fname	lname	order_date
Tommie	Wooten	1/3/00
Michael	Agliori	1/8/00
Salton	Pepper	1/17/00
Tommie	Wooten	1/23/00
…	…	…

Following is the equivalent statement in standard ANSI/ISO syntax:

```
SELECT customer.fname, customer.lname,
  sales_order.order_date
FROM sales_order JOIN customer
  ON sales_order.cust_id = customer.id
JOIN employee
  ON sales_order.sales_rep = employee.emp_id
WHERE employee.emp_fname = 'Rollin'
  AND employee.emp_lname = 'Overbey'
ORDER BY sales_order.order_date
```

Example 2

This example answers the question: How much of each product has each customer ordered, and who is the manager of the salesperson who took the order?

To answer the question, start by listing the information you need to retrieve. In this case, it is product, quantity, customer name, and manager name. Next, list the tables that hold this information. They are product, sales_order_items, customer, and employee. When you look at the structure of the sample database (see "Sample database schema" on page 262), you will notice that these tables are all related through the sales_order table. You can create a star join on the sales_order table to retrieve the information from the other tables.

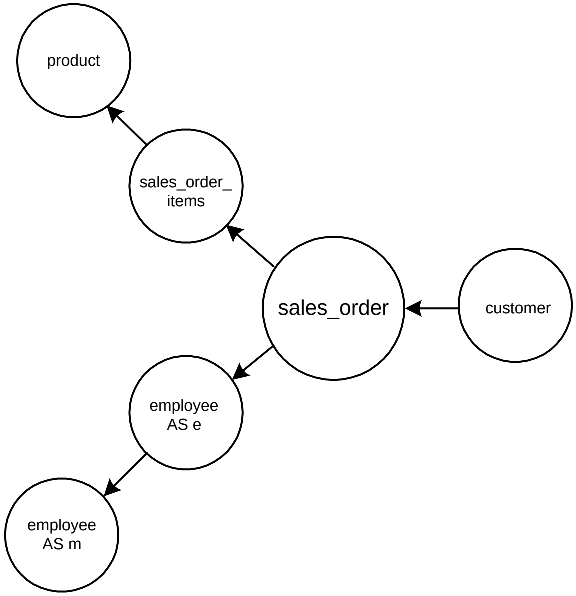
In addition, you need to create a self-join in order to get the name of the manager, because the employee table contains ID numbers for managers and the names of all employees, but not a column listing only manager names. For more information, see "Self-joins" on page 281.

The following statement creates a star join around the sales_order table. The joins are all outer joins so that the result set will include all customers. Some customers have not placed orders, so the other values for these customers are NULL. The columns in the result set are customer, product, quantity ordered, and the name of the manager of the salesperson.

```
SELECT customer.fname, product.name,
  SUM(sales_order_items.quantity), m.emp_fname
FROM   sales_order
         KEY RIGHT OUTER JOIN customer,
       sales_order
         KEY LEFT OUTER JOIN sales_order_items
         KEY LEFT OUTER JOIN product,
      sales_order
         KEY LEFT OUTER JOIN employee AS e
         LEFT OUTER JOIN employee AS m
         ON (e.manager_id = m.emp_id)
WHERE customer.state = 'CA'
GROUP BY customer.fname, product.name, m.emp_fname
ORDER BY SUM(sales_order_items.quantity) DESC, customer.fname
```

fname	name	SUM(sales_order_items.quantity)	emp_fname
Sheng	Baseball Cap	240	Moira
Laura	Tee Shirt	192	Moira
Moe	Tee Shirt	192	Moira
Leilani	Sweatshirt	132	Moira
…	…	…	…

Following is a diagram of the tables in this star join. The arrows indicate the directionality (left or right) of the outer joins. As you can see, the complete list of customers is maintained throughout all the joins.



The following standard ANSI/ISO syntax is equivalent to the star join in Example 2.

```
SELECT customer.fname, product.name,
  SUM(sales_order_items.quantity), m.emp_fname
FROM sales_order LEFT OUTER JOIN sales_order_items
    ON sales_order.id = sales_order_items.id
  LEFT OUTER JOIN product
    ON sales_order_items.prod_id = product.id
  LEFT OUTER JOIN employee as e
    ON sales_order.sales_rep = e.emp_id
  LEFT OUTER JOIN employee as m
    ON e.manager_id = m.emp_id
  RIGHT OUTER JOIN customer
    ON sales_order.cust_id = customer.id
WHERE customer.state = 'CA'
GROUP BY customer.fname, product.name, m.emp_fname
ORDER BY SUM(sales_order_items.quantity) DESC, customer.fname
```

Joins involving derived tables

Derived tables allow you to nest queries within a FROM clause. With derived tables, you can perform grouping of groups, or you can construct a join with a group, without having to create a view.

In the following example, the inner SELECT statement (enclosed in parentheses) creates a derived table, grouped by customer id values. The outer SELECT statement assigns this table the correlation name sales_order_counts and joins it to the customer table using a join condition.

```
SELECT lname, fname, number_of_orders
FROM customer JOIN
   (   SELECT cust_id, count(*)
      FROM sales_order
      GROUP BY cust_id    )
   AS sales_order_counts (cust_id, number_of_orders)
   ON (customer.id = sales_order_counts.cust_id)
WHERE number_of_orders > 3
```

The result is a table of the names of those customers who have placed more than three orders, including the number of orders each has placed.

☞ For an explanation of key joins of derived tables, see “Key joins of views and derived tables” on page 301.

☞ For an explanation of natural joins of derived tables, see “Natural joins of views and derived tables” on page 290.

☞ For an explanation of outer joins of derived tables, see “Outer joins of views and derived tables” on page 278.

Natural joins

When you specify a natural join, Adaptive Server Anywhere generates a join condition based on columns with the same name. For this to work in a natural join of base tables, there must be at least one pair of columns with the same name, with one column from each table. If there is no common column name, an error is issued.

If table A and table B have one column name in common, and that column is called x, then

```
SELECT *
FROM A NATURAL JOIN B
```

is equivalent to the following:

```
SELECT *
FROM A JOIN B
 ON A.x = B.x
```

If table A and table B have two column names in common, and they are called a and b, then `A NATURAL JOIN B` is equivalent to the following:

```
A JOIN B
 ON A.a = B.a
 AND A.b = B.b
```

Example

For example, you can join the employee and department tables using a natural join because they have a column name in common, the dept_id column.

```
SELECT emp_fname, emp_lname, dept_name
FROM employee NATURAL JOIN department
ORDER BY dept_name, emp_lname, emp_fname
```

emp_fname	emp_lname	dept_name
Janet	Bigelow	Finance
Kristen	Coe	Finance
James	Coleman	Finance
Jo Ann	Davidson	Finance
...	...	...

The following statement is equivalent. It explicitly specifies the join condition that was generated in the previous example.

```
SELECT emp_fname, emp_lname, dept_name
FROM employee JOIN department
  ON (employee.dept_id = department.dept_id)
ORDER BY dept_name, emp_lname, emp_fname
```

Natural joins with an ON phrase

When you specify a NATURAL JOIN *and* put a join condition in an ON phrase, the result is the conjunction of the two join conditions.

For example, the following two queries are equivalent. In the first query, Adaptive Server Anywhere generates the join condition `employee.dept_id = department.dept_id`. The query also contains an explicit join condition.

```
SELECT emp_fname, emp_lname, dept_name
FROM employee NATURAL JOIN department
  ON employee.manager_id = department.dept_head_id
```

The next query is equivalent. In it, the natural join condition that was generated in the previous query is specified in the ON phrase.

```
SELECT emp_fname, emp_lname, dept_name
FROM employee JOIN department
  ON employee.manager_id = department.dept_head_id
   AND employee.dept_id = department.dept_id
```

Natural joins of table expressions

When there is a multiple-table expression on at least one side of a natural join, Adaptive Server Anywhere generates a join condition by comparing the set of columns for each side of the join operator, and looking for columns that have the same name.

For example, in the statement

```
SELECT *
FROM (A JOIN B) NATURAL JOIN (C JOIN D)
```

there are two table expressions. The column names in the table expression `A JOIN B` are compared to the column names in the table expression `C JOIN D`, and a join condition is generated for each unambiguous pair of matching column names. An *unambiguous pair of matching columns* means that the column name occurs in both table expressions, but does not occur twice in the same table expression.

If there is a pair of ambiguous column names, an error is issued. However, a column name may occur twice in the same table expression, as long as it doesn't also match the name of a column in the other table expression.

Natural joins of lists

When a list of table expressions is on at least one side of a natural join, a separate join condition is generated for each table expression in the list.

Consider the following tables:

- table A consists of columns called a, b and c
- table B consists of columns called a and d
- table C consists of columns called d and c

In this case, the join `(A,B) NATURAL JOIN C` causes Adaptive Server Anywhere to generate two join conditions:

```
ON A.c = C.c
 AND B.d = C.d
```

If there is no common column name for A-C or B-C, an error is issued.

If table C consists of columns a, d, and c, then the join `(A,B) NATURAL JOIN C` is invalid. The reason is that column a appears in all three tables, and so the join is ambiguous.

Example

The following example answers the question: for each sale, provide information about what was sold and who sold it.

```
SELECT *
FROM (employee KEY JOIN sales_order)
  NATURAL JOIN (sales_order_items KEY JOIN product)
```

This is equivalent to

```
SELECT *
FROM (employee KEY JOIN sales_order)
  JOIN (sales_order_items KEY JOIN product)
    ON sales_order.id = sales_order_items.id
```

Natural joins of views and derived tables

An extension to the ANSI/ISO SQL standard is that you can specify views or derived tables on either side of a natural join. In the following statement,

```
SELECT *
FROM View1 NATURAL JOIN View2
```

the columns in View1 are compared to the columns in View2. If, for example, a column called emp_id is found to occur in both views, and there are no other columns that have identical names, then the generated join condition is `(View1.emp_id = View2.emp_id)`.

Example

The following example illustrates that a view used in a natural join can include expressions, and not just columns, and they are treated the same way in the natural join. First, create the view V with a column called x, as follows:

```
CREATE VIEW V(x) AS
SELECT R.y + 1
FROM R
```

Next, create a natural join of the view to a derived table. The derived table has a correlation name T with a column called x.

```
SELECT *
FROM V NATURAL JOIN (SELECT P.y FROM P) as T(x)
```

This join is equivalent to the following:

```
SELECT *
FROM V JOIN (SELECT P.y FROM P) as T(x) ON (V.x = T.x)
```

Key joins

When you specify a key join, Adaptive Server Anywhere generates a join condition based on the foreign key relationships in the database. To use a key join, there must be a foreign key relationship between the tables, or an error is issued.

The key join is a Sybase extension to the ANSI/ISO SQL standard. It does not provide any greater functionality, but it makes it easier to formulate certain queries.

When key join is the default

Key join is the default in Adaptive Server Anywhere when all of the following apply:

- the keyword JOIN is used.
- the keywords CROSS, NATURAL or KEY are *not* specified.
- there is no ON phrase.

Example

For example, the following query is a simple key join that joins the tables product and sales_order_items based on the foreign key relationship in the database.

```
SELECT *
FROM product KEY JOIN sales_order_items
```

The next query is equivalent. It leaves out the word KEY, but by default a JOIN without an ON phrase is a KEY JOIN.

```
SELECT *
FROM product JOIN sales_order_items
```

The next query is also equivalent, because the join condition specified in the ON phrase happens to be the same as the join condition that Adaptive Server Anywhere generates for these tables based on their foreign key relationship in the sample database.

```
SELECT *
FROM product JOIN sales_order_items
ON sales_order_items.prod_id = product.id
```

Key joins with an ON phrase

When you specify a KEY JOIN *and* put a join condition in an ON phrase, the result is the conjunction of the two join conditions. For example,

```
SELECT *
FROM A KEY JOIN B
ON A.x = B.y
```

If the join condition generated by the key join of A and B is A.w = B.z, then this query is equivalent to

```
SELECT *
FROM A JOIN B
ON A.x = B.y AND A.w = B.z
```

Key joins when there are multiple foreign key relationships

When Adaptive Server Anywhere attempts to generate a join condition based on a foreign key relationship, it sometimes finds more than one relationship. In these cases, Adaptive Server Anywhere determines which foreign key relationship to use by matching the role name of the foreign key to the correlation name of the primary key table that the foreign key references.

☞ The following sections describe how Adaptive Server Anywhere generates join conditions for key joins. This information is summarized in “Rules describing the operation of key joins” on page 303.

Correlation name and role name

A **correlation name** is the name of a table or view that is used in the FROM clause of the query—either its original name, or an alias that is defined in the FROM clause.

A **role name** is the name of the foreign key. It must be unique for a given foreign (child) table.

If you do not specify a role name for a foreign key, the name is assigned as follows:

♦ If there is no foreign key with the same name as the primary table name, the primary table name is assigned as the role name.

♦ If the primary table name is already being used by another foreign key, the role name is the primary table name concatenated with a zero-padded three-digit number unique to the foreign table.

If you don’t know the role name of a foreign key, you can find it in Sybase Central by expanding the database container in the left pane. Select the table in left pane, and then click the Foreign Keys tab in the right pane. A list of foreign keys for that table appears in the right pane.

☞ See “Sample database schema” on page 262 for a diagram that includes the role names of all foreign keys in the sample database.

Generating join conditions

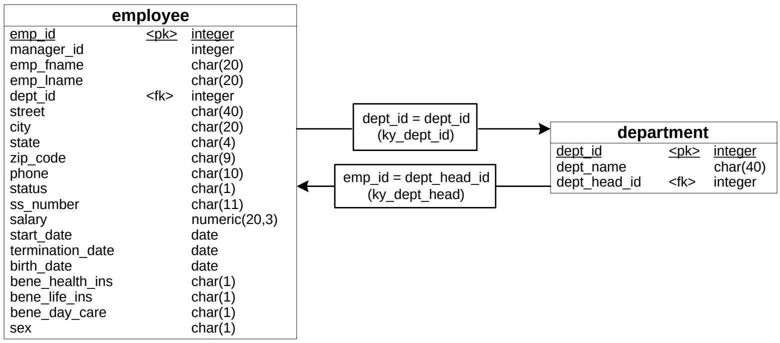
Adaptive Server Anywhere looks for a foreign key that has the same role name as the correlation name of the primary key table:

♦ If there is exactly one foreign key with the same name as a table in the join, Adaptive Server Anywhere uses it to generate the join condition.

- ♦ If there is more than one foreign key with the same name as a table, the join is ambiguous and an error is issued.
- ♦ If there is no foreign key with the same name as the table, Adaptive Server Anywhere looks for any foreign key relationship, even if the names don't match. If there is more than one foreign key relationship, the join is ambiguous and an error is issued.

Example 1

In the sample database, two foreign key relationships are defined between the tables employee and department: the foreign key ky_dept_id in the employee table references the department table; and the foreign key ky_dept_head in the department table references the employee table.



The following query is ambiguous because there are two foreign key relationships and neither has the same role name as the primary key table name. Therefore, attempting this query results in the syntax error `SQLE_AMBIGUOUS_JOIN (-147)`.

```
SELECT employee.emp_lname, department.dept_name
FROM employee KEY JOIN department
```

Example 2

This query modifies the query in Example 1 by specifying the correlation name ky_dept_id for the department table. Now, the foreign key ky_dept_id has the same name as the table it references, and so it is used to define the join condition. The result includes all the employee last names and the departments where they work.

```
SELECT employee.emp_lname, ky_dept_id.dept_name
FROM employee KEY JOIN department AS ky_dept_id
```

The following query is equivalent. It is not necessary to create an alias for the department table in this example. The same join condition that was generated above is specified in the ON phrase in this query:

```
SELECT employee.emp_lname, department.dept_name
FROM employee JOIN department
   ON department.dept_id = employee.dept_id
```

Example 3

If the intent was to list all the employees that are the head of a department, then the foreign key ky_dept_head should be used and Example 1 should be rewritten as follows. This query imposes the use of the foreign key ky_dept_head by specifying the correlation name ky_dept_head for the primary key table employee.

```
SELECT ky_dept_head.emp_lname, department.dept_name
FROM employee AS ky_dept_head KEY JOIN department
```

The following query is equivalent. The join condition that was generated above is specified in the ON phrase in this query:

```
SELECT employee.emp_lname, department.dept_name
FROM employee JOIN department
   ON department.dept_head_id = employee.emp_id
```

Example 4

A correlation name is not needed if the foreign key role name is identical to the primary key table name. For example, we can define the foreign key department for the employee table:

```
ALTER TABLE employee ADD FOREIGN KEY department (dept_id)
         REFERENCES department (dept_id)
```

Now, this foreign key relationship is the default join condition when a KEY JOIN is specified between the two tables. If the foreign key department is defined, then the following query is equivalent to Example 3.

```
SELECT employee.emp_lname, department.dept_name
FROM employee KEY JOIN department
```

Note

If you try this example in Interactive SQL, you should reverse the change to the sample database with the following statement:

```
ALTER TABLE employee DROP FOREIGN KEY department
```

Key joins of table expressions

Adaptive Server Anywhere generates join conditions for the key join of table expressions by examining the foreign key relationship of each pair of tables in the statement.

The following example joins four pairs of tables.

```
SELECT *
FROM (A NATURAL JOIN B) KEY JOIN (C NATURAL JOIN D)
```

The table-pairs are A-C, A-D, B-C and B-D. Adaptive Server Anywhere considers the relationship within each pair and then creates a generated join condition for the table expression as a whole. How Adaptive Server Anywhere does this depends on whether the table expressions use commas or not. Therefore, the generated join conditions in the following two examples are different. `A JOIN B` is a *table expression that does not contain commas* , and `(A,B)` is a *table expression list* .

```
SELECT *
FROM (A JOIN B) KEY JOIN C
```

is semantically different from

```
SELECT *
FROM (A,B) KEY JOIN C
```

The two types of join behavior are explained in the following sections:

- "Key joins of table expressions that do not contain commas" on page 296
- "Key joins of table expression lists" on page 297

Key joins of table expressions that do not contain commas

When both of the two table expressions being joined do not contain commas, Adaptive Server Anywhere examines the foreign key relationships in the pairs of tables in the statement, and generates a *single* join condition.

For example, the following join has two table-pairs, A-C and B-C.

```
(A NATURAL JOIN B) KEY JOIN C
```

Adaptive Server Anywhere generates a single join condition for joining C with `(A NATURAL JOIN B)` by looking at the foreign key relationships within the table-pairs A-C and B-C. It generates one join condition for the two pairs according to the rules for determining key joins when there are multiple foreign key relationships:

- First, it looks at both A-C and B-C for a single foreign key that has the same role name as the correlation name of one of the primary key tables it references. If there is exactly one foreign key meeting this criterion, it uses it. If there is more than one foreign key with the same role name as the correlation name of a table, the join is considered to be ambiguous and an error is issued.

- If there is no foreign key with the same name as the correlation name of a table, Adaptive Server Anywhere looks for any foreign key relationship between the tables. If there is one, it uses it. If there is more than one, the join is considered to be ambiguous and an error is issued.

- If there is no foreign key relationship, an error is issued.

☞ For more information, see "Key joins when there are multiple foreign key relationships" on page 293.

Example

The following query finds all the employees who are sales representatives, and their departments.

```
SELECT employee.emp_lname, ky_dept_id.dept_name
FROM (employee KEY JOIN department as ky_dept_id)
  KEY JOIN sales_order
```

You can interpret this query as follows.

- Adaptive Server Anywhere considers the table expression (`employee KEY JOIN department as ky_dept_id`) and generates the join condition `employee.dept_id = ky_dept_id.dept_id` based on the foreign key ky_dept_id.

- Adaptive Server Anywhere then considers the table-pairs employee-sales_order and ky_dept_id-sales_order. Note that only one foreign key can exist between the tables sales_order and employee *and* between sales_order and ky_dept_id, or the join is ambiguous. As it happens, there is exactly one foreign key relationship between the tables sales_order and employee (ky_so_employee_id), and no foreign key relationship between sales_order and ky_dept_id. Hence, the generated join condition is `sales_order.emp_id = employee.sales_rep`.

The following query is therefore equivalent to the previous query:

```
SELECT employee.emp_lname, department.dept_name
FROM (employee JOIN department
   ON ( employee.dept_id = department.dept_id ) )
JOIN sales_order
   ON (employee.emp_id = sales_order.sales_rep)
```

Key joins of table expression lists

To generate a join condition for the key join of two table expression lists, Adaptive Server Anywhere examines the pairs of tables in the statement, and generates a join condition for *each pair* . The final join condition is the conjunction of the join conditions for each pair. There must be a foreign key relationship between each pair.

The following example joins two table-pairs, A-C and B-C.

```
SELECT *
FROM (A,B) KEY JOIN C
```

Adaptive Server Anywhere generates a join condition for joining C with

(A,B) by generating a join condition for each of the two pairs A-C and B-C. It does so according to the rules for key joins when there are multiple foreign key relationships:

- For each pair, Adaptive Server Anywhere looks for a foreign key that has the same role name as the correlation name of the primary key table. If there is exactly one foreign key meeting this criterion, it uses it. If there is more than one, the join is considered to be ambiguous and an error is issued.
- For each pair, if there is no foreign key with the same name as the correlation name of the table, Adaptive Server Anywhere looks for any foreign key relationship between the tables. If there is one, it uses it. If there is more than one, the join is considered to be ambiguous and an error is issued.
- For each pair, if there is no foreign key relationship, an error is issued.
- If Adaptive Server Anywhere is able to determine exactly one join condition for each pair, it combines the join conditions using AND.

☞ For more information, see "Key joins when there are multiple foreign key relationships" on page 293.

Example

The following query returns the names of all salespeople who have sold at least one order to a specific region.

```
SELECT DISTINCT employee.emp_lname,
  ky_dept_id.dept_name, sales_order.region
FROM (sales_order, department AS ky_dept_id)
   KEY JOIN employee
```

emp_lname	dept_name	region
Chin	Sales	Eastern
Chin	Sales	Western
Chin	Sales	Central
…	…	…

This query deals with two pairs of tables: sales_order and employee; and department AS ky_dept_id and employee.

For the pair sales_order and employee, there is no foreign key with the same role name as one of the tables. However, there is a foreign key (ky_so_employee_id) relating the two tables. It is the only foreign key relating the two tables, and so it is used, resulting in the generated join condition (employee.emp_id = sales_order.sales_rep).

For the pair department AS ky_dept_id and employee, there is one foreign key that has the same role name as the primary key table. It is ky_dept_id, and it matches the correlation name given to the department table in the query. There are no other foreign keys with the same name as the correlation name of the primary key table, so ky_dept_id is used to form the join condition for the table-pair. The join condition that is generated is `(employee.dept_id = ky_dept_id.dept_id)`. Note that there is another foreign key relating the two tables, but as it has a different name from either of the tables, it is not a factor.

The final join condition adds together the join condition generated for each table-pair. Therefore, the following query is equivalent:

```
SELECT DISTINCT employee.emp_lname, department.dept_name, sales_
         order.region
FROM ( sales_order, department )
   JOIN employee
   ON employee.emp_id = sales_order.sales_rep
   AND employee.dept_id = department.dept_id
```

Key joins of lists and table expressions that do not contain commas

When table expression lists are joined via key join with table expressions that do not contain commas, Adaptive Server Anywhere generates a join condition for each table in the table expression list.

For example, the following statement is the key join of a table expression list with a table expression that does not contain commas. This example generates a join condition for table A with table expression `C NATURAL JOIN D`, and for table B with table expression `C NATURAL JOIN D`.

```
SELECT *
FROM (A,B) KEY JOIN (C NATURAL JOIN D)
```

`(A,B)` is a list of table expressions and `C NATURAL JOIN D` is a table expression. Adaptive Server Anywhere must therefore generate two join conditions: it generates one join condition for the pairs A-C and A-D, and a second join condition for the pairs B-C and B-D. It does so according to the rules for key joins when there are multiple foreign key relationships:

- For each set of table-pairs, Adaptive Server Anywhere looks for a foreign key that has the same role name as the correlation name of one of the primary key tables. If there is exactly one foreign key meeting this criterion, it uses it. If there is more than one, the join is ambiguous and an error is issued.

- For each set of table-pairs, if there is no foreign key with the same name as the correlation name of a table, Adaptive Server Anywhere looks for any foreign key relationship between the tables. If there is exactly one relationship, it uses it. If there is more than one, the join is ambiguous and an error is issued.

- For each set of pairs, if there is no foreign key relationship, an error is issued.
- If Adaptive Server Anywhere is able to determine exactly one join condition for each set of pairs, it combines the join conditions with the keyword AND.

Example 1

Consider the following join of five tables:

```
((A,B) JOIN (C NATURAL JOIN D) ON A.x = D.y) KEY JOIN E
```

☞ In this case, Adaptive Server Anywhere generates a join condition for the key join to E by generating a condition *either* between `(A,B)` and E *or* between `C NATURAL JOIN D` and E. This is as described in "Key joins of table expressions that do not contain commas" on page 296.

☞ If Adaptive Server Anywhere generates a join condition between `(A,B)` and E, it needs to create two join conditions, one for A-E and one for B-E. It must find a valid foreign key relationship within each table-pair. This is as described in "Key joins of table expression lists" on page 297.

☞ If Adaptive Server Anywhere creates a join condition between `C NATURAL JOIN D` and E, it creates only one join condition, and so must find only one foreign key relationship in the pairs C-E and D-E. This is as described in "Key joins of table expressions that do not contain commas" on page 296.

Example 2

The following is an example of a key join of a table expression and a list of table expressions. The example provides the name and department of employees who are sales representatives and also managers.

```
SELECT DISTINCT employee.emp_lname, ky_dept_id.dept_name
FROM (sales_order, department AS ky_dept_id)
  KEY JOIN (employee JOIN department AS d
    ON employee.emp_id = d.dept_head_id)
```

Adaptive Server Anywhere generates two join conditions:

- There must be exactly one foreign key relationship between the table-pairs sales_order-employee and sales_order-d. There is; it is `sales_order.sales_rep = employee.emp_id`.
- There must be exactly one foreign key relationship between the table-pairs ky_dept_id-employee and ky_dept_id-d. There is; it is `ky_dept_id.dept_id = employee.dept_id`.

This example is equivalent to the following. In the following version, it is not necessary to create the correlation name `department AS ky_dept_id`, because that was only needed to clarify which of two foreign keys should be used to join employee and department.

```
SELECT DISTINCT employee.emp_lname, department.dept_name
FROM (sales_order, department)
  JOIN (employee JOIN department AS d
      ON employee.emp_id = d.dept_head_id)
    ON sales_order.sales_rep = employee.emp_id
      AND department.dept_id = employee.dept_id
```

Key joins of views and derived tables

When you include a view or derived table in a key join, Adaptive Server Anywhere follows the same basic procedure as with tables, but with these differences:

- For each key join, Adaptive Server Anywhere considers the pairs of tables in the FROM clause of the query and the view, and generates *one* join condition for the set of all pairs, regardless of whether the FROM clause in the view contains commas or join keywords.
- Adaptive Server Anywhere joins the tables based on the foreign key that has the same role name as the correlation name of the view or derived table.
- When you include a view or derived table in a key join, the view cannot contain UNION, ORDER BY, DISTINCT, GROUP BY, or an aggregate function. If it contains any of those items, an error is issued.

A derived table works identically to a view. The only difference is that instead of referencing a predefined view, the definition for the table is included in the statement.

Example 1

For example, in the following statement, View1 is a view.

```
SELECT *
FROM View1 KEY JOIN B
```

The definition of View1 can be any of the following and result in the same join condition to B. (The result set will differ, but the join conditions will be identical.)

```
SELECT *
FROM C CROSS JOIN D
```

or

```
SELECT *
FROM C,D
```

or

```
SELECT *
FROM C JOIN D ON (C.x = D.y)
```

In each case, to generate a join condition for the key join of View1 and B, Adaptive Server Anywhere considers the table-pairs C-B and D-B, and generates a single join condition. It generates the join condition based on the rules for multiple foreign key relationships described in "Key joins of table expressions" on page 295, except that it looks for a foreign key with the same name as the correlation name of the view (rather than a table referenced in the view).

Using any of the view definitions above, you can interpret the processing of `View1 KEY JOIN B` as follows:

Adaptive Server Anywhere generates a single join condition by considering the table-pairs C-B and D-B. It generates the join condition according to the rules for determining key joins when there are multiple foreign key relationships:

- ♦ First, it looks at both C-B and D-B for a single foreign key that has the same role name as the correlation name of the view. If there is exactly one foreign key meeting this criterion, it uses it. If there is more than one foreign key with the same role name as the correlation name of the view, the join is considered to be ambiguous and an error is issued.
- ♦ If there is no foreign key with the same name as the correlation name of the view, Adaptive Server Anywhere looks for any foreign key relationship between the tables. If there is one, it uses it. If there is more than one, the join is considered to be ambiguous and an error is issued.
- ♦ If there is no foreign key relationship, an error is issued.

Assume this generated join condition is `B.y = D.z`. We can now expand the original join.

```
SELECT *
FROM View1 KEY JOIN B
```

is equivalent to

```
SELECT *
FROM View1 JOIN B ON B.y = View1.z
```

☞ For more information, see "Key joins when there are multiple foreign key relationships" on page 293.

Example 2

The following view contains all the employee information about the manager of each department.

```
CREATE VIEW V AS
SELECT department.dept_name, employee.*
FROM employee JOIN department
  ON employee.emp_id = department.dept_head_id
```

The following query joins the view to a table expression.

```
SELECT *
FROM V KEY JOIN (sales_order, department ky_dept_id)
```

This is equivalent to

```
SELECT *
FROM V JOIN (sales_order, department ky_dept_id)
ON (V.emp_id = sales_order.sales_rep
AND V.dept_id = ky_dept_id.dept_id)
```

Rules describing the operation of key joins

The following rules summarize the information provided above.

Rule 1: key join of two tables

This rule applies to `A KEY JOIN B`, where A and B are base or temporary tables.

1. Find all foreign keys from A referencing B.

   If there exists a foreign key whose role name is the correlation name of table B, then mark it as a preferred foreign key.

2. Find all foreign keys from B referencing A.

   If there exists a foreign key whose role name is the correlation name of table A, then mark it as a preferred foreign key.

3. If there is more than one preferred key, the join is ambiguous. The syntax error `SQLE_AMBIGUOUS_JOIN (-147)` is issued.

4. If there is a single preferred key, then this foreign key is chosen to define the generated join condition for this KEY JOIN expression.

5. If there is no preferred key, then other foreign keys between A and B are used:

   - If there is more than one foreign key between A and B, then the join is ambiguous. The syntax error `SQLE_AMBIGUOUS_JOIN (-147)` is issued.
   - If there is a single foreign key, then this foreign key is chosen to define the generated join condition for this KEY JOIN expression.
   - If there is no foreign key, then the join is invalid and an error is generated.

Rule 2: key join of table expressions that do not contain commas

This rule applies to `A KEY JOIN B`, where A and B are table expressions that do not contain commas.

1. For each pair of tables; one from expression A and one from expression B, list all foreign keys, and mark all preferred foreign keys between the tables. The rule for determining a preferred foreign key is given in Rule 1, above.

2. If there is more than one preferred key, then the join is ambiguous. The syntax error `SQLE_AMBIGUOUS_JOIN (-147)` is issued.

3. If there is a single preferred key, then this foreign key is chosen to define the generated join condition for this KEY JOIN expression.

4. If there is no preferred key, then other foreign keys between pairs of tables are used:
   - ♦ If there is more than one foreign key, then the join is ambiguous. The syntax error `SQLE_AMBIGUOUS_JOIN (-147)` is issued.
   - ♦ If there is a single foreign key, then this foreign key is chosen to define the generated join condition for this KEY JOIN expression.
   - ♦ If there is no foreign key, then the join is invalid and an error is generated.

Rule 3: key join of table expression lists

This rule applies to `(A1, A2, ...)  KEY JOIN ( B1, B2, ...)` where A1, B1, and so on are table expressions that do not contain commas.

1. For each pair of table expressions Ai and Bj, find a unique generated join condition for the table expression `(Ai KEY JOIN Bj)` by applying Rule 1 or 2. If any KEY JOIN for a pair of table expressions is ambiguous by Rule 1 or 2, a syntax error is generated.

2. The generated join condition for this KEY JOIN expression is the conjunction of the join conditions found in step 1.

Rule 4: key join of lists and table expressions that do not contain commas

This rule applies to `(A1, A2, ...)  KEY JOIN ( B1, B2, ...)` where A1, B1, and so on are table expressions that may contain commas.

1. For each pair of table expressions Ai and Bj, find a unique generated join condition for the table expression `(Ai KEY JOIN Bj)` by applying Rule 1, 2, or 3. If any KEY JOIN for a pair of table expressions is ambiguous by Rule 1, 2, or 3, then a syntax error is generated.

2. The generated join condition for this KEY JOIN expression is the conjunction of the join conditions found in step 1.

CHAPTER 9

Common Table Expressions

About this chapter

The WITH prefix to the SELECT statements affords you the opportunity to define common table expressions. These can be used like temporary views within your query. This chapter describes how to use them.

Contents

Topic:	page
About common table expressions	306
Typical applications of common table expressions	310
Recursive common table expressions	314
Parts explosion problems	317
Datatype declarations in recursive common table expressions	320
Least distance problem	322
Using multiple recursive common table expressions	325

About common table expressions

Common table expressions are temporary views that are known only within the scope of a single SELECT statement. They permit you to write queries more easily, and to write queries that could not otherwise be expressed.

Common table expressions are useful or may be necessary if a query involves multiple aggregate functions or defines a view within a stored procedure that references program variables. Common table expressions also provide a convenient means to temporarily store sets of values.

Recursive common table expressions permit you to query tables that represent hierarchical information, such as reporting relationships within a company. They can also be used to solve parts explosion problems and least distance problems.

☞ For information about recursive queries, see "Recursive common table expressions" on page 314.

For example, consider the problem of determining which department has the most number of employees. The employee table in the sample database lists all the employees in a fictional company and specifies in which department each works. The following query lists the department ID codes and the total number of employees in each department.

```
SELECT dept_id, count(*) AS n
FROM employee
GROUP BY dept_id
```

This query can be used to extract the department with the most employees as follows:

```
SELECT dept_id, n
FROM ( SELECT dept_id, count(*) AS n
       FROM employee GROUP BY dept_id ) AS a
WHERE a.n =
  ( SELECT max(n)
    FROM ( SELECT dept_id, count(*) AS n
           FROM employee GROUP BY dept_id ) AS b )
```

While this statement provides the correct result, it has some disadvantages. The first disadvantage is that the repeated subquery makes this statement clumsy. The second is that this statement provides no clear link between the subqueries.

One way around these problems is to create a view, then use it to re-express the query. This approach avoids the problems mentioned above.

```
CREATE VIEW CountEmployees(dept_id, n) AS
    SELECT dept_id, count(*) AS n
    FROM employee GROUP BY dept_id;
SELECT dept_id, n
FROM CountEmployees
WHERE n = ( SELECT max(n)
            FROM CountEmployees );
```

The disadvantage of this approach is that some overhead is required, as the engine must update the system tables when creating the view. If the view will be used frequently, this approach is reasonable. However, in cases where the view is used only once within a particular SELECT statement, the preferred method is to instead use a common table expression.

Using common table expressions

Common table expressions are defined using the WITH clause, which precedes the SELECT keyword in a SELECT statement. The content of the clause defines one or more temporary views that may then be referenced elsewhere in the statement. The syntax of this clause mimics that of the CREATE VIEW statement. Using common table expressions, you can express the previous query as follows.

```
WITH CountEmployees(dept_id, n) AS
  ( SELECT dept_id, count(*) AS n
    FROM employee GROUP BY dept_id )
SELECT dept_id, n
FROM CountEmployees
WHERE n = ( SELECT max(n)
            FROM CountEmployees )
```

Instead searching for the department with the fewest employees demonstrates that such queries may return multiple rows.

```
WITH CountEmployees(dept_id, n) AS
  ( SELECT dept_id, count(*) AS n
    FROM employee GROUP BY dept_id )
SELECT dept_id, n
FROM CountEmployees
WHERE n = ( SELECT min(n)
            FROM CountEmployees )
```

In the sample database, two departments share the minimum number of employees, which is 9.

Multiple correlation names

Just as when using tables, you can give different correlation names to multiple instances of a common table expression. Doing so permits you to join a common table expression to itself. For example, the query below produces pairs of departments that have the same number of employees, although there are only two departments with the same number of employees in the sample database.

```
WITH CountEmployees(dept_id, n) AS
    ( SELECT dept_id, count(*) AS n
      FROM employee GROUP BY dept_id )
SELECT a.dept_id, a.n, b.dept_id, b.n
FROM CountEmployees AS a JOIN CountEmployees AS b
ON a.n = b.n AND a.dept_id < b.dept_id
```

Multiple table expressions

A single WITH clause may define more than one common table expression. These definitions must be separated by commas. The following example lists the department that has the smallest payroll and the department that has the largest number of employees.

```
WITH
  CountEmployees(dept_id, n) AS
    ( SELECT dept_id, count(*) AS n
      FROM employee GROUP BY dept_id ),
  DeptPayroll( dept_id, amt ) AS
     ( SELECT dept_id, sum(salary) AS amt
       FROM employee GROUP BY dept_id )
SELECT count.dept_id, count.n, pay.amt
FROM CountEmployees AS count JOIN DeptPayroll AS pay
ON count.dept_id = pay.dept_id
WHERE count.n = ( SELECT max(n) FROM CountEmployees )
   OR pay.amt = ( SELECT min(amt) FROM DeptPayroll )
```

Where common table expressions are permitted

Common table expressions can be used only in three situations.

- **Top-level SELECT statement** Common table expressions are permitted within top-level SELECT statements, but not within subqueries.

  ```
  WITH DeptPayroll( dept_id, amt ) AS
    ( SELECT dept_id, sum(salary) AS amt
      FROM employee GROUP BY dept_id )
  SELECT dept_id, amt
  FROM DeptPayroll
  WHERE amt = ( SELECT max(amt)
                FROM DeptPayroll )
  ```

- **The top-level SELECT statement in a view definition** Common table expressions are permitted within the top-level SELECT statement that defines a view, but not within subqueries within the definition.

```
CREATE VIEW LargestDept (dept_id, size, pay) AS
   WITH
     CountEmployees(dept_id, n) AS
       ( SELECT dept_id, count(*) AS n
         FROM employee GROUP BY dept_id ),
     DeptPayroll( dept_id, amt ) AS
       ( SELECT dept_id, sum(salary) AS amt
         FROM employee GROUP BY dept_id )
  SELECT count.dept_id, count.n, pay.amt
  FROM CountEmployees count JOIN DeptPayroll pay
  ON count.dept_id = pay.dept_id
  WHERE count.n = ( SELECT max(n) FROM CountEmployees )
     OR pay.amt = ( SELECT max(amt) FROM DeptPayroll )
```

- **A top-level SELECT statement in an INSERT statement** Common table expressions are permitted within a top-level SELECT statement in an INSERT statement, but not within subqueries within the INSERT statement.

```
INSERT INTO LargestPayrolls (dept_id, payroll, date)
  WITH DeptPayroll( dept_id, amt ) AS
    ( SELECT dept_id, sum(salary) AS amt
      FROM employee
      GROUP BY dept_id )
  SELECT dept_id, amt, CURRENT TIMESTAMP
  FROM DeptPayroll
  WHERE amt = ( SELECT max(amt)
                FROM DeptPayroll )
```

Typical applications of common table expressions

In general, common table expressions are useful whenever a table expression must appear multiple times within a single query. The following typical situations are suited to common table expressions.

- ♦ Queries that involve multiple aggregate functions.
- ♦ Views within a procedure that must contain a reference to a program variable.
- ♦ Queries that use temporary views to store a set of values.

This list is not exhaustive. You may encounter many other situations in which common table expressions are useful.

Multiple aggregate functions

Common table expressions are useful whenever multiple levels of aggregation must appear within a single query. This is the case in the example used in the previous section. The task was to retrieve the department ID of the department that has the most employees. To do so, the count aggregate function is used to calculate the number of employees in each department and the max function is used to select the largest department.

A similar situation arises when writing a query to determine which department has the largest payroll. The sum aggregate function is used to calculate each department's payroll and the max function to determine which is largest. The presence of both functions in the query is a clue that a common table expression may be helpful.

```
WITH DeptPayroll( dept_id, amt ) AS
    ( SELECT dept_id, sum(salary) AS amt
      FROM employee GROUP BY dept_id )
SELECT dept_id, amt
FROM DeptPayroll
WHERE amt = ( SELECT max(amt)
              FROM DeptPayroll )
```

Views that reference program variables

Sometimes, it can be convenient to create a view that contains a reference to a program variable. For example, you may define a variable within a procedure that identifies a particular customer. You want to query the customer's purchase history, and as you will be accessing similar information multiple times or perhaps using multiple aggregate functions, you want to create a view that contains information about that specific customer.

You cannot create a view that references a program variable because there is no way to limit the scope of a view to that of your procedure. Once created, a view can be used by in other contexts. You can, however, use a common table expressions within the queries in your procedure. As the scope of a common table expression is limited to the statement, the variable reference creates no ambiguity and is thus permitted.

The following statement selects the gross sales of the various sales representatives in the sample database.

```
SELECT emp_fname || ' ' || emp_lname AS sales_rep_name,
       sales_rep AS sales_rep_id,
       sum( p.unit_price * i.quantity ) AS total_sales
FROM employee LEFT OUTER JOIN sales_order AS o
              INNER JOIN sales_order_items AS i
              INNER JOIN product AS p
WHERE '2000-01-01' <= order_date
                  AND order_date < '2001-01-01'
GROUP BY sales_rep, emp_fname, emp_lname
```

The above query is the basis of the common table expression that appears in the following procedure. The ID number of the sales representative and the year in question are incoming parameters. As this procedure demonstrates, the procedure parameters and any declared local variables can be referenced within the WITH clause.

```
CREATE PROCEDURE sales_rep_total (
  IN rep  INTEGER,
  IN yyyy INTEGER )
BEGIN
  DECLARE start_date DATE;
  DECLARE end_date   DATE;
  SET start_date = YMD( yyyy,  1,  1 );
  SET   end_date = YMD( yyyy, 12, 31 );
  WITH total_sales_by_rep ( sales_rep_name,
                            sales_rep_id,
                            month,
                            order_year,
                            total_sales ) AS
  ( SELECT emp_fname || ' ' || emp_lname AS sales_rep_name,
           sales_rep AS sales_rep_id, month( order_date),
           year(order_date),
           sum( p.unit_price * i.quantity ) AS total_sales
    FROM employee LEFT OUTER JOIN sales_order o
                  INNER JOIN sales_order_items i
                  INNER JOIN product p
    WHERE start_date <= order_date AND
                        order_date <= end_date AND
          sales_rep = rep
    GROUP BY year(order_date), month(order_date),
             emp_fname, emp_lname, sales_rep )
  SELECT sales_rep_name,
            monthname( YMD(yyyy, month, 1) ) AS month_name,
            order_year,
            total_sales
  FROM total_sales_by_rep
  WHERE total_sales =
    ( SELECT max( total_sales) FROM total_sales_by_rep )
  ORDER BY order_year ASC, month ASC;
END;
```

The following statement demonstrates how to call the above procedure.

```
CALL sales_rep_total(129, 2000);
```

Views that store values

Sometimes, it can be useful to store a particular set of values within a SELECT statement or within a procedure. For example, suppose a company prefers to analyze the results of its sales staff by thirds of a year, instead of by quarter. Since there is no built-in date part for thirds, as there is for quarters, it is necessary to store the dates within the procedure.

```
WITH thirds (q_name, q_start, q_end) AS
( SELECT 'T1', '2000-01-01', '2000-04-30' UNION
  SELECT 'T2', '2000-05-01', '2000-08-31' UNION
  SELECT 'T3', '2000-09-01', '2000-12-31' )
SELECT q_name,
       sales_rep,
       count(*) AS num_orders,
       sum( p.unit_price * i.quantity ) AS total_sales
FROM thirds LEFT OUTER JOIN sales_order AS o
    ON q_start <= order_date AND order_date <= q_end
                   INNER JOIN sales_order_items AS i
                   INNER JOIN product AS p
 GROUP BY q_name, sales_rep
 ORDER BY q_name, sales_rep
```

This method should be used with care, as the values may need periodic maintenance. For example, the above statement must be modified if it is to be used for any other year.

You can also apply this technique within procedures. The following example declares a procedure that takes the year in question as an argument.

```
CREATE PROCEDURE sales_by_third ( IN y INTEGER )
BEGIN
  WITH thirds (q_name, q_start, q_end) AS
  ( SELECT 'T1', YMD( y, 01, 01), YMD( y, 04, 30) UNION
    SELECT 'T2', YMD( y, 05, 01), YMD( y, 08, 31) UNION
    SELECT 'T3', YMD( y, 09, 01), YMD( y, 12, 31) )
  SELECT q_name,
         sales_rep,
         count(*) AS num_orders,
         sum(p.unit_price * i.quantity) AS total_sales
  FROM thirds JOIN sales_order AS o
    ON q_start <= order_date AND order_date <= q_end
            KEY JOIN sales_order_items AS i
            KEY JOIN product AS p
  GROUP BY q_name, sales_rep
  ORDER BY q_name, sales_rep;
END;

CALL sales_by_third (2000);
```

Recursive common table expressions

Common table expressions may be recursive. Common table expressions are recursive when the RECURSIVE keyword appears immediately after WITH. A single WITH clause may contain multiple recursive expressions, and may contain both recursive and non-recursive common table expressions.

Recursive common table expressions provide a convenient way to write queries that return relationships to an arbitrary depth. For example, given a table that represents the reporting relationships within a company, you can readily write a query that returns all the employees that report to one particular person.

Depending on how you write the query, you can either limit the number of levels of recursion or you can provide no limit. Limiting the number of levels permits you to return only the top levels of management, for example, but may exclude some employees if the chains of command are longer than you anticipated. Providing no restriction on the number of levels ensures no employees will be excluded, but can introduce infinite recursion should the graph contain any cycles; for example, if an employee directly or indirectly reports to himself. This situation could arise within a company's management hierarchy if, for example, an employee within the company also sits on the board of directors.

Recursion provides a much easier means of traversing tables that represent tree or tree-like data structures. The only way to traverse such a structure in a single statement without using recursive expressions is to join the table to itself once for each possible level. For example, if a reporting hierarchy contains at most seven levels, you must join the employee table to itself seven times. If the company reorganizes and a new management level is introduced, you must rewrite the query.

Recursive common table expressions contain an *initial subquery*, or seed, and a *recursive subquery* that during each iteration appends additional rows to the result set. The two parts can be connected only with the operator UNION ALL. The initial subquery is an ordinary non-recursive query and is processed first. The recursive portion contains a reference to the rows added during the previous iteration. Recursion stops automatically whenever an iteration generates no new rows. There is no way to reference rows selected prior to the previous iteration.

The select list of the recursive subquery must match that of the initial subquery in number and datatype. If automatic translation of datatypes cannot be performed, explicitly cast the results of one subquery so that they match those in the other subquery.

Selecting hierarchical data

The following query demonstrates how to list the employees by management level. Level 0 represents employees with no managers. Level 1 represents employees who report directly to one of the level 0 managers, level 2 represents employees who report directly to a level 1 manager, and so on.

```
WITH RECURSIVE
  manager ( emp_id, manager_id,
            emp_fname, emp_lname, mgmt_level ) AS
( ( SELECT emp_id, manager_id,        -- initial subquery
           emp_fname, emp_lname, 0
    FROM employee AS e
    WHERE manager_id = emp_id )
  UNION ALL
  ( SELECT e.emp_id, e.manager_id,    -- recursive subquery
           e.emp_fname, e.emp_lname, m.mgmt_level + 1
    FROM employee AS e JOIN manager AS m
     ON   e.manager_id =  m.emp_id
      AND e.manager_id <> e.emp_id
      AND m.mgmt_level < 20 ) )
SELECT * FROM manager
ORDER BY mgmt_level, emp_lname, emp_fname
```

The condition within the recursive query that restricts the management level to less than 20 is an important precaution. It prevents infinite recursion in the event that the table data contains a cycle.

The MAX_RECURSIVE_-ITERATIONS option

The option MAX_RECURSIVE_ITERATIONS is designed to catch runaway recursive queries. The default value of this option is 100. Recursive queries that exceed this number of levels of recursion terminate, but cause an error.

Although this option may seem to diminish the importance of a stop condition, this is not usually the case. The number of rows selected during each iteration may grow exponentially, seriously impacting database performance before the maximum is reached. Stop conditions within recursive queries provide a means of setting appropriate limits in each situation.

Restrictions on recursive common table expressions

The following restrictions apply to recursive common table expressions.

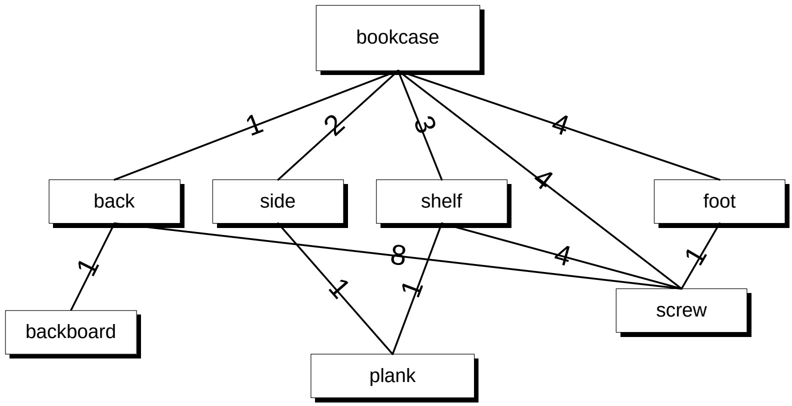
- References to other recursive common table expressions cannot appear within the definition of recursive common table expressions. Thus, recursive common table expressions cannot be mutually recursive. However, non-recursive common table expressions can contain references to recursive ones, and recursive common table expressions can contain references to non-recursive ones.

- The only set operator permitted between the initial subquery and the recursive subquery is UNION ALL. No other set operators are permitted.
- Within the definition of a recursive subquery, a self-reference to the recursive table expression can appear only within the FROM clause of the recursive subquery.
- When a self-reference appears within the FROM clause of the recursive subquery, the reference to the recursive table cannot appear on the null-supplying side of an outer join.
- The recursive subquery cannot contain DISTINCT, or a GROUP BY or an ORDER BY clause.
- The recursive subquery can not make use of any aggregate function.
- To prevent runaway recursive queries, an error is generated if the number of levels of recursion exceeds the current setting of the MAX_RECURSIVE_ITERATIONS option. The default value of this option is 100.

Parts explosion problems

The parts explosion problem is a classic application of recursion. In this problem, the components necessary to assemble a particular object are represented by a graph. The goal is to represent this graph using a database table, then to calculate the total number of the necessary elemental parts.

For example, the following graph represents the components of a simple bookshelf. The bookshelf is made up of three shelves, a back, and four feet that are held on by four screws. Each shelf is a board held on with four screws. The back is another board held on by eight screws.



The information in the table below represents the edges of the bookshelf graph. The first column names a component, the second column names one of the subcomponents of that component, and the third column specifies how many of the subcomponents are required.

component	subcomponent	quantity
bookcase	back	1
bookcase	side	2
bookcase	shelf	3
bookcase	foot	4
bookcase	screw	4
back	backboard	1

component	subcomponent	quantity
back	screw	8
side	plank	1
shelf	plank	1
shelf	screw	4

The following statements create the bookcase table and insert the data shown in the above table.

```
CREATE TABLE bookcase (
      component      VARCHAR(9),
      subcomponent   VARCHAR(9),
    quantity       integer,
    PRIMARY KEY (component, subcomponent)
);
INSERT INTO bookcase
  SELECT 'bookcase', 'back',      1 UNION
  SELECT 'bookcase', 'side',      2 UNION
  SELECT 'bookcase', 'shelf',     3 UNION
  SELECT 'bookcase', 'foot',      4 UNION
  SELECT 'bookcase', 'screw',     4 UNION
  SELECT 'back',     'backboard', 1 UNION
  SELECT 'back',     'screw',     8 UNION
  SELECT 'side',     'plank',     1 UNION
  SELECT 'shelf',    'plank',     1 UNION
  SELECT 'shelf',    'screw',     4;
```

After you have created the bookcase table, you can recreate the table of its parts, shown above, with the following query..

```
SELECT * FROM bookcase
ORDER BY component, subcomponent;
```

With this table constructed, you can generate a list of the primitive parts and the quantity of each required to construct the bookcase.

```
WITH RECURSIVE parts (component, subcomponent, quantity) AS
( SELECT component, subcomponent, quantity
  FROM bookcase WHERE component = 'bookcase'
    UNION ALL
  SELECT b.component, b.subcomponent, p.quantity * b.quantity
  FROM parts p JOIN bookcase b ON p.subcomponent = b.component )
SELECT subcomponent, sum(quantity) AS quantity
FROM parts
WHERE subcomponent NOT IN ( SELECT component FROM bookcase )
GROUP BY subcomponent
ORDER BY subcomponent;
```

The results of this query are shown below.

subcomponent	quantity
backboard	1
foot	4
plank	5
screw	24

Alternatively, you can rewrite this query to perform an additional level of recursion, thus avoiding the need for the subquery in the main SELECT statement:

```
WITH RECURSIVE parts (component, subcomponent, quantity) AS
( SELECT component, subcomponent, quantity
  FROM bookcase WHERE component = 'bookcase'
    UNION ALL
  SELECT p.subcomponent, b.subcomponent,
    IF b.quantity IS NULL
    THEN p.quantity
    ELSE p.quantity * b.quantity
    ENDIF
  FROM parts p LEFT OUTER JOIN bookcase b
  WHERE p.subcomponent = b.component AND
        p.subcomponent IS NOT NULL
 )
SELECT component, sum(quantity) FROM parts
WHERE subcomponent IS NULL
GROUP BY component
ORDER BY component;
```

The results of this query are identical to those of the previous query.

Datatype declarations in recursive common table expressions

The datatypes of the columns in the temporary view are defined by those of the initial subquery. The datatypes of the columns from the recursive subquery must match. The database server automatically attempts to convert the values returned by the recursive subquery to match those of the initial query. If this is not possible, or if information may be lost in the conversion, an error is generated.

In general, explicit casts are often required when the initial subquery returns a literal value or NULL. Explicit casts may also be required when the initial subquery selects values from different columns than the recursive subquery.

Casts may be required if the columns of the initial subquery do not have the same domains as those of the recursive subquery. Casts must always be applied to NULL values in the initial subquery.

For example, the bookshelf parts explosion sample works correctly because the initial subquery returns rows from the bookcase table, and thus inherits the datatypes of the selected columns.

☞ For more information, see “Parts explosion problem” on page 317.

If this query is rewritten as follows, explicit casts are required.

```
WITH RECURSIVE parts (component, subcomponent, quantity) AS
( SELECT NULL, 'bookcase', 1          -- ERROR! Wrong domains!
    UNION ALL
  SELECT b.component, b.subcomponent,
         p.quantity * b.quantity
  FROM parts p JOIN bookcase b
    ON p.subcomponent = b.component )
SELECT * FROM parts
ORDER BY component, subcomponent
```

Without casts, errors result for the following reasons:

- The correct datatype for component names is VARCHAR, but the first column is NULL.
- The digit 1 is assumed to be a short integer, but the datatype of the quantity column is INT.

No cast is required for the second column because this column of the initial query is already a string.

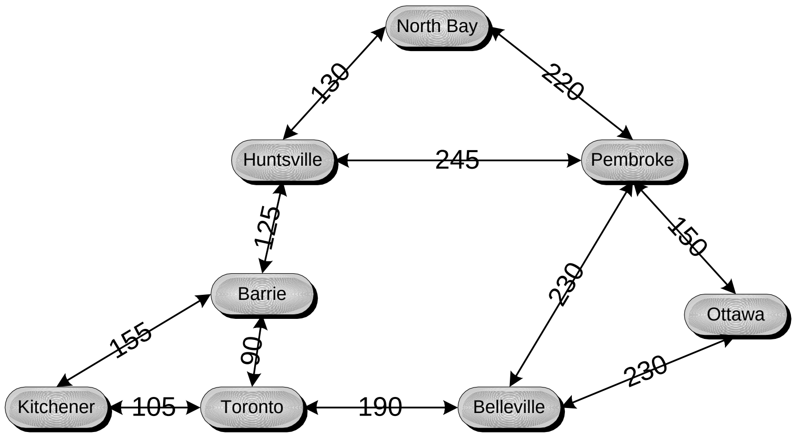
Casting the datatypes in the initial subquery allows the query to behave as intended:

```
WITH RECURSIVE parts (component, subcomponent, quantity) AS
( SELECT CAST(NULL AS VARCHAR),  -- CASTs must be used
         'bookcase',             -- to declare the
         CAST( 1   AS INT)       -- correct datatypes
      UNION ALL
  SELECT b.component, b.subcomponent,
         p.quantity * b.quantity
  FROM parts p JOIN bookcase b
    ON p.subcomponent = b.component )
SELECT * FROM parts
ORDER BY component, subcomponent
```

Least distance problem

You can use recursive common table expressions to find desirable paths on a directed graph. Each row in a database table represents a directed edge. Each row specifies an origin, a destination, and a cost of traveling from the origin to the destination. Depending on the problem, the cost may represent distance, travel time, or some other measure. Recursion permits you to explore possible routes through this graph. From the set of possible routes, you can then select the ones that interest you.

For example, consider the problem of finding desirable way to drive between the cities of Kitchener and Pembroke. There are quite a few possible routes, each of which takes you through a different set of intermediate cities. The goal is to find the shortest routes, and to compare them to reasonable alternatives.



First, define a table to represent the edges of this graph and insert one row for each edge. Since all the edges of this graph happen to be bi-directional, the edges that represent the reverse directions must be inserted also. This is done by selecting the initial set of rows, but interchanging the origin and destination. For example, one row must represent the trip from Kitchener to Toronto, and another row the trip from Toronto back to Kitchener.

```
CREATE TABLE travel (
    origin      AS VARCHAR(10),
    destination AS VARCHAR(10),
    distance    AS INT,
  PRIMARY KEY (origin, destination)
);
```

```
INSERT INTO travel
  SELECT 'Kitchener',  'Toronto',    105 UNION
  SELECT 'Kitchener',  'Barrie',     155 UNION
  SELECT 'North Bay',  'Pembroke',   220 UNION
  SELECT 'Pembroke',   'Ottawa',     150 UNION
  SELECT 'Barrie',     'Toronto',     90 UNION
  SELECT 'Toronto',    'Belleville', 190 UNION
  SELECT 'Belleville', 'Ottawa',     230 UNION
  SELECT 'Belleville', 'Pembroke',   230 UNION
  SELECT 'Barrie',     'Huntsville', 125 UNION
  SELECT 'Huntsville', 'North Bay',  130 UNION
  SELECT 'Huntsville', 'Pembroke',   245;
INSERT INTO travel   -- Insert the return trips
  SELECT destination, origin, distance
  FROM travel;
```

The next task is to write the recursive common table expression. Since the trip will start in Kitchener, the initial subquery begins by selecting all the possible paths out of Kitchener, along with the distance of each.

The recursive subquery extends the paths. For each path, it adds segments that continue along from the destinations of the previous segments, adding the length of the new segments so as to maintain a running total cost of each route. For efficiency, routes are terminated if they meet either of the following conditions:

- The path returns to the starting location.
- The path returns to the previous location.
- The path reaches the desired destination.

In the current example, no path should return to Kitchener and all paths should be terminated if they reach Pembroke.

It is particularly important to guarantee that recursive queries will terminate properly when using them to explore cyclic graphs. In this case, the above conditions are insufficient, as a route may include an arbitrarily large number of trips back and forth between two intermediate cities. The recursive query below guarantees termination by limiting the maximum number of segments in any given route to seven.

Since the point of the example query is to select a practical route, the main query selects only those routes that are less than 50 percent longer than the shortest route.

```
WITH RECURSIVE
    trip (route, destination, previous, distance, segments) AS
( SELECT CAST(origin || ', ' || destination AS VARCHAR(256)),
         destination, origin, distance, 1
  FROM travel
  WHERE origin = 'Kitchener'
    UNION ALL
  SELECT route || ', ' || v.destination,
         v.destination,            -- current endpoint
         v.origin,                 -- previous endpoint
         t.distance + v.distance,  -- total distance
         segments + 1              -- total number of segments
  FROM trip t JOIN travel v ON t.destination = v.origin
  WHERE v.destination <> 'Kitchener'  -- Don't return to start
    AND v.destination <> t.previous   -- Prevent backtracking
    AND v.origin      <> 'Pembroke'   -- Stop at the end
    AND segments                      -- TERMINATE RECURSION!
          < ( SELECT count(*)/2 FROM travel ) )
SELECT route, distance, segments FROM trip
WHERE destination = 'Pembroke' AND
      distance < 1.5 * ( SELECT min(distance)
                         FROM trip
                         WHERE destination = 'Pembroke' )
ORDER BY distance, segments, route;
```

When run with against the above data set, this statement yields the following results.

route	distance	segments
Kitchener, Barrie, Huntsville, Pembroke	525	3
Kitchener, Toronto, Belleville, Pembroke	525	3
Kitchener, Toronto, Barrie, Huntsville, Pembroke	565	4
Kitchener, Barrie, Huntsville, North Bay, Pembroke	630	4
Kitchener, Barrie, Toronto, Belleville, Pembroke	665	4
Kitchener, Toronto, Barrie, Huntsville, North Bay, Pembroke	670	5
Kitchener, Toronto, Belleville, Ottawa, Pembroke	675	4

Using multiple recursive common table expressions

A recursive query may include multiple recursive queries, as long as they are disjoint. It may also include a mix of recursive and non-recursive common table expressions. The RECURSIVE keyword must be present if at least one of the common table expressions is recursive.

For example, the following query—which returns the same result as the previous query—uses a second, non-recursive common table expression to select the length of the shortest route. The definition of the second common table expression is separated from the definition of the first by a comma.

```
WITH RECURSIVE
  trip (route, destination, previous, distance, segments) AS
    ( SELECT CAST(origin || ', ' || destination AS
         VARCHAR(256)),
             destination, origin, distance, 1
      FROM travel
      WHERE origin = 'Kitchener'
      UNION ALL
      SELECT route || ', ' || v.destination,
             v.destination,
             v.origin,
             t.distance + v.distance,
             segments + 1
      FROM trip t JOIN travel v ON t.destination = v.origin
      WHERE v.destination <> 'Kitchener'
        AND v.destination <> t.previous
        AND v.origin      <> 'Pembroke'
        AND segments
              < ( SELECT count(*)/2 FROM travel ) ),
  shortest ( distance ) AS                 -- Additional,
    ( SELECT min(distance)                 -- non-recursive
      FROM trip                            -- common table
      WHERE destination = 'Pembroke' )     -- expression
SELECT route, distance, segments FROM trip
WHERE destination = 'Pembroke' AND
      distance < 1.5 * ( SELECT distance FROM shortest )
ORDER BY distance, segments, route;
```

Like non-recursive common table expressions, recursive expressions, when used within stored procedures, may contain references to local variables or procedure parameters. For example, the best_routes procedure, defined below, identifies the shortest routes between the two named cities.

```
CREATE PROCEDURE best_routes (
   IN initial VARCHAR(10),
   IN final   VARCHAR(10)
)
BEGIN
  WITH RECURSIVE
      trip (route, destination, previous, distance, segments) AS
  ( SELECT CAST(origin || ', ' || destination AS VARCHAR(256)),
           destination, origin, distance, 1
    FROM travel
    WHERE origin = initial
      UNION ALL
    SELECT route || ', ' || v.destination,
           v.destination,            -- current endpoint
           v.origin,                 -- previous endpoint
           t.distance + v.distance,  -- total distance
           segments + 1              -- total number of segments
    FROM trip t JOIN travel v ON t.destination = v.origin
    WHERE v.destination <> initial     -- Don't return to start
      AND v.destination <> t.previous  -- Prevent backtracking
      AND v.origin      <> final       -- Stop at the end
      AND segments                     -- TERMINATE RECURSION!
            < ( SELECT count(*)/2 FROM travel ) )
  SELECT route, distance, segments FROM trip
  WHERE destination = final AND
        distance < 1.4 * ( SELECT min(distance)
                           FROM trip
                           WHERE destination = final )
  ORDER BY distance, segments, route;
END;

CALL best_routes ( 'Pembroke', 'Kitchener' );
```

CHAPTER 10

Using Subqueries

About this chapter

When you create a query, you use WHERE and HAVING clauses to restrict the rows that the query returns.

Sometimes, the rows you select depend on information stored in more than one table. A subquery in the WHERE or HAVING clause allows you to select rows from one table according to specifications obtained from another table. Additional ways to do this can be found in "Joins: Retrieving Data from Several Tables" on page 261.

Before your start

This subquery chapter assumes some knowledge of queries and the syntax of the select statement. Information about queries appears in "Queries: Selecting Data from a Table" on page 207.

Contents

Topic:	page
Introduction to subqueries	328
Using subqueries in the WHERE clause	329
Subqueries in the HAVING clause	330
Subquery comparison test	332
Quantified comparison tests with ANY and ALL	333
Testing set membership with IN conditions	336
Existence test	338
Outer references	340
Subqueries and joins	341
Nested subqueries	343
How subqueries work	345

Introduction to subqueries

A relational database stores information about different types of objects in different tables. For example, you should store information particular to products in one table, and information that pertains to sales orders in another. The product table contains the information about the various products. The sales order items table contains information about customers' orders.

In general, only the simplest questions can be answered using only one table. For example, if the company reorders products when there are fewer than 50 of them in stock, then it is possible to answer the question "Which products are nearly out of stock?" with this query:

```
SELECT id, name, description, quantity
FROM product
WHERE quantity < 50
```

However, if "nearly out of stock" depends on how many items of each type the typical customer orders, the number "50" will have to be replaced by a value obtained from the sales_order_items table.

Structure of the subquery

A subquery is structured like a regular query, and appears in the main query's SELECT, FROM, WHERE, or HAVING clause. Continuing with the previous example, you can use a subquery to select the average number of items that a customer orders, and then use that figure in the main query to find products that are nearly out of stock. The following query finds the names and descriptions of subquery the products which number less than twice the average number of items of each type that a customer orders.

```
SELECT name, description
FROM product WHERE quantity <  2 * (
   SELECT avg(quantity)
   FROM sales_order_items
   )
```

In the WHERE clause, subqueries help select the rows from the tables listed in the FROM clause that appear in the query results. In the HAVING clause, they help select the row groups, as specified by the main query's GROUP BY clause, that appear in the query results.

Using subqueries in the WHERE clause

Subqueries in the WHERE clause work as part of the row selection process. You use a subquery in the WHERE clause when the criteria you use to select rows depend on the results of another table.

Example

Find the products whose in-stock quantities are less than double the average ordered quantity.

```
SELECT name, description
FROM product WHERE quantity <  2 * (
   SELECT avg(quantity)
   FROM sales_order_items)
```

This is a two-step query: first, find the average number of items requested per order; and then find which products in stock number less than double that quantity.

The query in two steps

The quantity column of the sales_order_items table stores the *number* of items requested per item type, customer, and order. The subquery is

```
SELECT avg(quantity)
FROM sales_order_items
```

It returns the average quantity of items in the sales_order_items table, which is 25.851413.

The next query returns the names and descriptions of the items whose in-stock quantities are less than twice the previously-extracted value.

```
SELECT name, description
FROM product
WHERE quantity < 2*25.851413
```

Using a subquery combines the two steps into a single operation.

Purpose of a subquery in the WHERE clause

A subquery in the WHERE clause is part of a search condition. The chapter "Queries: Selecting Data from a Table" on page 207 describes simple search conditions you can use in the WHERE clause.

Subqueries in the HAVING clause

Although you usually use subqueries as search conditions in the WHERE clause, sometimes you can also use them in the HAVING clause of a query. When a subquery appears in the HAVING clause, like any expression in the HAVING clause, it is used as part of the row group selection.

Here is a request that lends itself naturally to a query with a subquery in the HAVING clause: “Which products’ average in-stock quantity is more than double the average number of each item ordered per customer?”

Example

```
SELECT name, avg(quantity)
FROM product
GROUP BY name
HAVING avg(quantity) > 2* (
   SELECT avg(quantity)
   FROM sales_order_items
   )
```

name	avg(product.quantity)
Tee Shirt	52.333333
Baseball Cap	62
Shorts	80

The query executes as follows:

- The subquery calculates the average quantity of items in the sales_order_items table.
- The main query then goes through the product table, calculating the average quantity product, grouping by product name.
- The HAVING clause then checks if each average quantity is more than double the quantity found by the subquery. If so, the main query returns that row group; otherwise, it doesn’t.
- The SELECT clause produces one summary row for each group, displaying the name of each product and its in-stock average quantity.

You can also use outer references in a HAVING clause, as shown in the following example, a slight variation on the one above.

Example

”Find the product ID numbers and line ID numbers of those products whose average ordered quantities is more than half the in-stock quantities of those products.”

```
SELECT prod_id, line_id
FROM sales_order_items
GROUP BY prod_id, line_id
HAVING 2* avg(quantity) > (
   SELECT quantity
   FROM product
   WHERE product.id = sales_order_items.prod_id)
```

prod_id	line_id
401	2
401	1
401	4
501	3
…	…

In this example, the subquery must produce the in-stock quantity of the product corresponding to the row group being tested by the HAVING clause. The subquery selects records for that particular product, using the outer reference sales_order_items.prod_id**.**

A subquery with a comparison returns a single value

This query uses the comparison ">", suggesting that the subquery must return exactly one value. In this case, it does. Since the id field of the product table is a primary key, there is only one record in the product table corresponding to any particular product id.

Subquery tests

The chapter "Queries: Selecting Data from a Table" on page 207 describes simple search conditions you can use in the HAVING clause. Since a subquery is just an expression that appears in the WHERE or HAVING clauses, the search conditions on subqueries may look familiar.

They include:

- **Subquery comparison test** Compares the value of an expression to a single value produced by the subquery for each record in the table(s) in the main query.
- **Quantified comparison test** Compares the value of an expression to each of the set of values produced by a subquery.
- **Subquery set membership test** Checks if the value of an expression matches one of the set of values produced by a subquery.
- **Existence test** Checks if the subquery produces any rows.

Subquery comparison test

The subquery comparison test (=, <>, <. <=, >, >=) is a modified version of the simple comparison test. The only difference between the two is that in the former, the expression following the operator is a subquery. This test is used to compare a value from a row in the main query to a *single* value produced by the subquery.

Example

This query contains an example of a subquery comparison test:

```
SELECT name, description, quantity
FROM product
WHERE quantity <  2 * (
   SELECT avg(quantity)
   FROM sales_order_items)
```

name	description	quantity
Tee Shirt	Tank Top	28
Baseball Cap	Wool cap	12
Visor	Cloth Visor	36
Visor	Plastic Visor	28
…	…	…

The following subquery retrieves a single value—the average quantity of items of each type per customer's order—from the sales_order_items table.

```
SELECT avg(quantity)
FROM sales_order_items
```

Then the main query compares the quantity of each in-stock item to that value.

A subquery in a comparison test returns one value

A subquery in a comparison test must return exactly one value. Consider this query, whose subquery extracts two columns from the sales_order_items table:

```
SELECT name, description, quantity
FROM product
WHERE quantity <  2 * (
   SELECT avg(quantity), max (quantity)
   FROM sales_order_items)
```

It returns the error `Subquery allowed only one select list item.`

Quantified comparison tests with ANY and ALL

The quantified comparison test has two categories, the ALL test and the ANY test:

The ANY test

The ANY test, used in conjunction with one of the SQL comparison operators (=, <>, <, <=, >, >=), compares a single value to the column of data values produced by the subquery. To perform the test, SQL uses the specified comparison operator to compare the test value to each data value in the column. If *any* of the comparisons yields a TRUE result, the ANY test returns TRUE.

A subquery used with ANY must return a single column.

Example

Find the order and customer IDs of those orders placed after the first product of the order #2005 was shipped.

```
SELECT id, cust_id
FROM sales_order
WHERE order_date > ANY (
   SELECT ship_date
   FROM sales_order_items
   WHERE id=2005)
```

id	**cust_id**
2006	105
2007	106
2008	107
2009	108
...	...

In executing this query, the main query tests the order dates for each order against the shipping dates of *every* product of the order #2005. If an order date is greater than the shipping date for *one* shipment of order #2005, then that id and customer id from the sales_order table are part of the result set. The ANY test is thus analogous to the OR operator: the above query can be read, "Was this sales order placed after the first product of the order #2005 was shipped, or after the second product of order #2005 was shipped, or..."

Understanding the ANY operator

The ANY operator can be a bit confusing. It is tempting to read the query as "Return those orders placed after any products of order #2005 were shipped." But this means the query will return the order IDs and customer

IDs for the orders placed after *all* products of order #2005 were shipped—which is not what the query does.

Instead, try reading the query like this: "Return the order and customer IDs for those orders placed after *at least one* product of order #2005 was shipped." Using the keyword SOME may provide a more intuitive way to phrase the query. The following query is equivalent to the previous query.

```
SELECT id, cust_id
FROM sales_order
WHERE order_date > SOME (
   SELECT ship_date
   FROM sales_order_items
   WHERE id=2005)
```

The keyword SOME is equivalent to the keyword ANY.

Notes about the ANY operator

There are two additional important characteristics of the ANY test:

- **Empty subquery result set** If the subquery produces an empty result set, the ANY test returns FALSE. This makes sense, since if there are no results, then it is not true that at least one result satisfies the comparison test.

- **NULL values in subquery result set** Assume that there is at least one NULL value in the subquery result set. If the comparison test is false for all non-NULL data values in the result set, the ANY search returns NULL. This is because in this situation, you cannot conclusively state whether there is a value for the subquery for which the comparison test holds. There may or may not be a value, depending on the "correct" values for the NULL data in the result set.

The ALL test

Like the ANY test, the ALL test is used in conjunction with one of the six SQL comparison operators (=, <>, <, <=, >, >=) to compare a single value to the data values produced by the subquery. To perform the test, SQL uses the specified comparison operator to compare the test value to each data value in the result set. If *all* of the comparisons yield TRUE results, the ALL test returns TRUE.

Example

Here is a request naturally handled with the ALL test: "Find the order and customer IDs of those orders placed after all products of order #2001 were shipped."

```
SELECT id, cust_id
FROM sales_order
WHERE order_date > ALL (
   SELECT ship_date
   FROM sales_order_items
   WHERE id=2001)
```

id	cust_id
2002	102
2003	103
2004	104
2005	101
…	…

In executing this query, the main query tests the order dates for each order against the shipping dates of *every* product of order #2001. If an order date is greater than the shipping date for *every* shipment of order #2001, then the id and customer id from the sales_order table are part of the result set. The ALL test is thus analogous to the AND operator: the above query can be read, "Was this sales order placed before the first product of order #2001 was shipped, and before the second product of order #2001 was shipped, and…"

Notes about the ALL operator

There are three additional important characteristics of the ALL test:

- **Empty subquery result set** If the subquery produces an empty result set, the ALL test returns TRUE. This makes sense, since if there are no results, then it is true that the comparison test holds for every value in the result set.
- **NULL values in subquery result set** If the comparison test is false for any values in the result set, the ALL search returns FALSE. It returns TRUE if all values are true. Otherwise, it returns UNKNOWN—for example, this can occur if there is a NULL value in the subquery result set but the search condition is TRUE for all non-NULL values.
- **Negating the ALL test** The following expressions are *not* equivalent.

  ```
  NOT a = ALL (subquery)
  a <> ALL (subquery)
  ```

  ☞ For more information about this test, see "Quantified comparison test" on page 347.

Testing set membership with IN conditions

You can use the subquery set membership test to compare a value from the main query to more than one value in the subquery.

The subquery set membership test compares a single data value for each row in the main query to the single column of data values produced by the subquery. If the data value from the main query matches *one* of the data values in the column, the subquery returns TRUE.

Example

Select the names of the employees who head the Shipping or Finance departments:

```
SELECT emp_fname, emp_lname
FROM employee
WHERE emp_id IN (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' or dept_name = 'Shipping'))
```

emp_fname	emp_lname
Jose	Martinez
Mary Anne	Shea

The subquery in this example

```
SELECT dept_head_id
FROM department
WHERE (dept_name='Finance' OR dept_name = 'Shipping')
```

extracts from the department table the id numbers that correspond to the heads of the Shipping and Finance departments. The main query then returns the names of the employees whose id numbers match one of the two found by the subquery.

Set membership test is equivalent to =ANY test

The subquery set membership test is equivalent to the =ANY test. The following query is equivalent to the query from the above example.

```
SELECT emp_fname, emp_lname
FROM employee
WHERE emp_id =ANY (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' or dept_name = 'Shipping'))
```

Negation of the set membership test

You can also use the subquery set membership test to extract those rows whose column values are not equal to any of those produced by a subquery. To negate a set membership test, insert the word NOT in front of the keyword IN.

Example

The subquery in this query returns the first and last names of the employees that are not heads of the Finance or Shipping departments.

```
SELECT emp_fname, emp_lname
FROM employee
WHERE emp_id NOT IN (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' OR dept_name = 'Shipping'))
```

Existence test

Subqueries used in the subquery comparison test and set membership test both return data values from the subquery table. Sometimes, however, you may be more concerned with whether the subquery returns *any* results, rather than *which* results. The existence test (EXISTS) checks whether a subquery produces any rows of query results. If the subquery produces one or more rows of results, the EXISTS test returns TRUE. Otherwise, it returns FALSE.

Example

Here is an example of a request expressed using a subquery: “Which customers placed orders after July 13, 2001?”

```
SELECT fname, lname
FROM customer
WHERE EXISTS (
   SELECT *
   FROM sales_order
   WHERE (order_date > '2001-07-13') AND
    (customer.id = sales_order.cust_id))
```

fname	**lname**
Almen	de Joie
Grover	Pendelton
Ling Ling	Andrews
Bubba	Murphy

Explanation of the existence test

Here, for each row in the customer table, the subquery checks if that customer ID corresponds to one that has placed an order after July 13, 2001. If it does, the query extracts the first and last names of that customer from the main table.

The EXISTS test does not use the results of the subquery; it just checks if the subquery produces any rows. So the existence test applied to the following two subqueries return the same results. These are subqueries and cannot be processed on their own, because they refer to the customer table which is part of the main query, but not part of the subquery.

☞ For more information, see “Correlated subqueries” on page 345.

```
SELECT *
FROM sales_order
WHERE (order_date > '2001-07-13') AND (customer.id = sales_
         order.cust_id)
SELECT ship_date
FROM sales_order
WHERE (order_date > '2001-07-13') AND (customer.id = sales_
         order.cust_id)
```

It does not matter which columns from the sales_order table appear in the SELECT statement, though by convention, the "SELECT *" notation is used.

Negating the existence test

You can reverse the logic of the EXISTS test using the NOT EXISTS form. In this case, the test returns TRUE if the subquery produces no rows, and FALSE otherwise.

Correlated subqueries

You may have noticed that the subquery contains a reference to the id column from the customer table. A reference to columns or expressions in the main table(s) is called an **outer reference** and the subquery is said to be **correlated**. Conceptually, SQL processes the above query by going through the customer table, and performing the subquery for each customer. If the order date in the sales_order table is after July 13, 2001, and the customer ID in the customer and sales_order tables match, then the first and last names from the customer table appear. Since the subquery references the main query, the subquery in this section, unlike those from previous sections, returns an error if you attempt to run it by itself.

Outer references

Within the body of a subquery, it is often necessary to refer to the value of a column in the active row of the main query. Consider the following query:

```
SELECT name, description
FROM product
WHERE quantity < 2 * (
   SELECT avg(quantity)
   FROM sales_order_items
   WHERE product.id = sales_order_items.prod_id)
```

This query extracts the names and descriptions of the products whose in-stock quantities are less than double the average ordered quantity of that product—specifically, the product being tested by the WHERE clause in the main query. The subquery does this by scanning the sales_order_items table. But the product.id column in the WHERE clause of the subquery refers to a column in the table named in the FROM clause of the *main* query—not the subquery. As SQL moves through each row of the product table, it uses the id value of the current row when it evaluates the WHERE clause of the subquery.

Description of an outer reference

The product.id column in this subquery is an example of an outer reference. A subquery that uses an outer reference is a correlated subquery. An outer reference is a column name that does not refer to any of the columns in any of the tables in the FROM clause of the subquery. Instead, the column name refers to a column of a table specified in the FROM clause of the main query. As the above example shows, the value of a column in an outer reference comes from the row currently being tested by the main query.

Subqueries and joins

The subquery optimizer automatically rewrites as joins many of the queries that make use of subqueries.

Example

Consider the request, “When did Mrs. Clarke and Suresh place their orders, and by which sales representatives?” It can be answered with the following query:

```
SELECT order_date, sales_rep
FROM sales_order
WHERE cust_id IN (
   SELECT id
   FROM customer
   WHERE lname = 'Clarke' OR fname = 'Suresh')
```

Order_date	sales_rep
2001-01-05	1596
2000-01-27	667
2000-11-11	467
2001-02-04	195
...	...

The subquery yields a list of customer IDs that correspond to the two customers whose names are listed in the WHERE clause, and the main query finds the order dates and sales representatives corresponding to those two people’s orders.

Replacing a subquery with a join

The same question can be answered using joins. Here is an alternative form of the query, using a two-table join:

```
SELECT order_date, sales_rep
FROM sales_order, customer
WHERE cust_id=customer.id AND
  (lname = 'Clarke' OR fname = 'Suresh')
```

This form of the query joins the sales_order table to the customer table to find the orders for each customer, and then returns only those records for Suresh and Clarke.

Some joins cannot be written as subqueries

Both of these queries find the correct order dates and sales representatives, and neither is more right than the other. Many people will find the subquery form more natural, because the request doesn’t ask for any information about customer IDs, and because it might seem odd to join the sales_order and customer tables together to answer the question.

If, however, the request changes to include some information from the customer table, the subquery form no longer works. For example, the request "When did Mrs. Clarke and Suresh place their orders, and by which representatives, and what are their full names?", it is necessary to include the customer table in the main WHERE clause:

```
SELECT fname, lname, order_date, sales_rep
FROM sales_order, customer
WHERE cust_id=customer.id AND (lname = 'Clarke' OR fname =
         'Suresh')
```

fname	lname	order_date	sales_rep
Belinda	Clarke	1/5/01	1596
Belinda	Clarke	1/27/00	667
Belinda	Clarke	11/11/00	467
Belinda	Clarke	2/4/01	195
…	…	…	…

Some subqueries cannot be written as joins

Similarly, there are cases where a subquery will work but a join will not. For example:

```
SELECT name, description, quantity
FROM product
WHERE quantity <  2 * (
   SELECT avg(quantity)
   FROM sales_order_items)
```

name	description	quantity
Tee Shirt	Tank Top	28
Baseball Cap	Wool cap	12
Visor	Cloth Visor	36
…	…	…

In this case, the inner query is a summary query and the outer query is not, so there is no way to combine the two queries by a simple join.

For more information on joins, see "Joins: Retrieving Data from Several Tables" on page 261.

Nested subqueries

As we have seen, subqueries always appear in the HAVING clause or the WHERE clause of a query. A subquery may itself contain a WHERE clause and/or a HAVING clause, and, consequently, a subquery may appear in another subquery. Subqueries inside other subqueries are called **nested subqueries**.

Examples

List the order IDs and line IDs of those orders shipped on the same day when any item in the fees department was ordered.

```
SELECT id, line_id
FROM sales_order_items
WHERE ship_date = ANY (
   SELECT order_date
   FROM sales_order
   WHERE fin_code_id IN (
      SELECT code
      FROM fin_code
      WHERE (description = 'Fees')))
```

id	line_id
2001	1
2001	2
2001	3
2002	1
…	…

Explanation of the nested subqueries

- In this example, the innermost subquery produces a column of financial codes whose descriptions are “Fees”:

```
SELECT code
FROM fin_code
WHERE (description = 'Fees')
```

- The next subquery finds the order dates of the items whose codes match one of the codes selected in the innermost subquery:

```
SELECT order_date
FROM sales_order
WHERE fin_code_id IN (subquery)
```

- Finally, the outermost query finds the order IDs and line IDs of the orders shipped on one of the dates found in the subquery.

```
SELECT id, line_id
FROM sales_order_items
WHERE ship_date = ANY (subquery)
```

Nested subqueries can also have more than three levels. Though there is no maximum number of levels, queries with three or more levels take considerably longer to run than do smaller queries.

How subqueries work

Understanding which queries are valid and which ones aren't can be complicated when a query contains a subquery. Similarly, figuring out what a multi-level query does can also be very involved, and it helps to understand how Adaptive Server Anywhere processes subqueries. For general information about processing queries, see "Summarizing, Grouping and Sorting Query Results" on page 231.

Correlated subqueries

In a simple query, the database server evaluates and processes the query's WHERE clause once for each row of the query. Sometimes, though, the subquery returns only one result, making it unnecessary for the database server to evaluate it more than once for the entire result set.

Uncorrelated subqueries

Consider this query:

```
SELECT name, description
FROM product
WHERE quantity <  2 * (
   SELECT avg(quantity)
   FROM sales_order_items)
```

In this example, the subquery calculates exactly one value: the average quantity from the sales_order_items table. In evaluating the query, the database server computes this value once, and compares each value in the quantity field of the product table to it to determine whether to select the corresponding row.

Correlated subqueries

When a subquery contains an outer reference, you cannot use this shortcut. For instance, the subquery in the query

```
SELECT name, description
FROM product
WHERE quantity < 2 * (
   SELECT avg(quantity)
   FROM sales_order_items
   WHERE product.id=sales_order_items.prod_id)
```

returns a value dependent upon the active row in the product table. Such a subquery is called a correlated subquery. In these cases, the subquery might return a different value for each row of the outer query, making it necessary for the database server to perform more than one evaluation.

Converting subqueries in the WHERE clause to joins

The Adaptive Server Anywhere query optimizer converts some multi-level queries to use joins. The conversion is carried out without any user action. This section describes which subqueries can be converted to joins so you can understand the performance of queries in your database.

Example

The question "When did Mrs. Clarke and Suresh place their orders, and by which sales representatives?" can be written as a two-level query:

```
SELECT order_date, sales_rep
FROM sales_order
WHERE cust_id IN (
   SELECT id
   FROM customer
   WHERE lname = 'Clarke' OR fname = 'Suresh')
```

An alternate, and equally correct way to write the query uses joins:

```
SELECT fname, lname, order_date, sales_rep
FROM sales_order, customer
WHERE cust_id=customer.id AND
  (lname = 'Clarke' OR fname = 'Suresh')
```

The criteria that must be satisfied in order for a multi-level query to be able to be rewritten with joins differ for the various types of operators. Recall that when a subquery appears in the query's WHERE clause, it is of the form

SELECT *select-list*
FROM *table*
WHERE
[**NOT**] *expression comparison-operator* **(** *subquery* **)**
| [**NOT**] *expression comparison-operator* { **ANY | SOME** } **(** *subquery* **)**
| [**NOT**] *expression comparison-operator* **ALL (** *subquery* **)**
| [**NOT**] *expression* **IN (** *subquery* **)**
| [**NOT**] **EXISTS (** *subquery* **)**
GROUP BY *group-by-expression*
HAVING *search-condition*

Whether a subquery can be converted to a join depends on a number of factors, such as the type of operator and the structures of the query and of the subquery.

Comparison operators

A subquery that follows a comparison operator (=, <>, <, <=, >, >=) must satisfy certain conditions if it is to be converted into a join. Subqueries that follow comparison operators are valid only if they return exactly one value for each row of the main query. In addition to this criterion, a subquery is converted to a join only if the subquery

- does not contain a GROUP BY clause

- does not contain the keyword DISTINCT
- is not a UNION query
- is not an aggregate query

Example

Suppose the request “When were Suresh’s products ordered, and by which sales representative?” were phrased as the subquery

```
SELECT order_date, sales_rep
FROM sales_order
WHERE cust_id = (
   SELECT id
   FROM customer
   WHERE fname = ’Suresh’)
```

This query satisfies the criteria, and therefore, it would be converted to a query using a join:

```
SELECT order_date, sales_rep
FROM sales_order, customer
WHERE cust_id=customer.id AND (lname = ’Clarke’ OR fname =
         ’Suresh’)
```

However, the request, “Find the products whose in-stock quantities are less than double the average ordered quantity” cannot be converted to a join, as the subquery contains the aggregate function avg:

```
SELECT name, description
FROM product
WHERE quantity <  2 * (
   SELECT avg(quantity)
   FROM sales_order_items)
```

Quantified comparison test

A subquery that follows one of the keywords ALL, ANY and SOME is converted into a join only if it satisfies certain criteria.

- The main query does not contain a GROUP BY clause, and is not an aggregate query, or the subquery returns exactly one value.
- The subquery does not contain a GROUP BY clause.
- The subquery does not contain the keyword DISTINCT.
- The subquery is not a UNION query.
- The subquery is not an aggregate query.
- The conjunct ‘expression comparison-operator ANY/SOME (subquery)’ must be negated.

- The conjunct ‘expression comparison-operator ALL (subquery)’ must not be negated.

The first four of these conditions are relatively straightforward.

Example

The request “When did Ms. Clarke and Suresh place their orders, and by which sales representatives?” can be handled in subquery form:

```
SELECT order_date, sales_rep
FROM sales_order
WHERE cust_id = ANY (
   SELECT id
   FROM customer
   WHERE lname = 'Clarke' OR fname = 'Suresh')
```

Alternately, it can be phrased in join form

```
SELECT fname, lname, order_date, sales_rep
FROM sales_order, customer
WHERE cust_id=customer.id AND (lname = 'Clarke' OR fname =
         'Suresh')
```

However, the request, “When did Ms. Clarke, Suresh, and any employee who is also a customer, place their orders?” would be phrased as a union query, and thus cannot be converted to a join:

```
SELECT order_date, sales_rep
FROM sales_order
WHERE cust_id = ANY (
   SELECT id
   FROM customer
   WHERE lname = 'Clarke' OR fname = 'Suresh'
   UNION
   SELECT emp_id
   FROM employee)
```

Similarly, the request “Find the order IDs and customer IDs of those orders that were not placed after all products of order #2001 were shipped,” is naturally expressed with a subquery:

```
SELECT id, cust_id
FROM sales_order
WHERE NOT order_date > ALL (
   SELECT ship_date
   FROM sales_order_items
   WHERE id=2001)
```

It would be converted to the join:

```
SELECT sales_order.id, cust_id
FROM sales_order, sales_order_items
WHERE (sales_order_items.id=2001) and (order_date <= ship_date)
```

However, the request "Find the order IDs and customer IDs of those orders not shipped after the first shipping dates of all the products" would be phrased as the aggregate query:

```
SELECT id, cust_id
FROM sales_order
WHERE NOT order_date > ALL (
   SELECT first (ship_date)
   FROM sales_order_items )
```

Therefore, it would not be converted to a join.

Negating subqueries with the ANY and ALL operators

The fifth criterion is a little more puzzling: queries of the form

SELECT *select-list*
FROM *table*
WHERE NOT *expression comparison-operator* **ALL(** *subquery* **)**
are converted to joins, *as are queries of the form*

SELECT *select-list*
FROM *table*
WHERE *expression comparison-operator* **ANY(** *subquery* **)**

but the queries

SELECT *select-list*
FROM *table*
WHERE *expression comparison-operator* **ALL(** *subquery* **)**

and

SELECT *select-list*
FROM *table*
WHERE NOT *expression comparison-operator* **ANY(** *subquery* **)**

are not.

Logical equivalence of ANY and ALL expressions

This is because the first two queries are in fact equivalent, as are the last two. Recall that the any operator is analogous to the OR operator, but with a variable number of arguments; and that the ALL operator is similarly analogous to the AND operator. Just as the expression

```
NOT ((X > A) AND (X > B))
```

is equivalent to the expression

```
(X <= A) OR (X <= B)
```

the expression

```
NOT order_date > ALL (
   SELECT first (ship_date)
   FROM sales_order_items )
```

is equivalent to the expression

```
order_date <= ANY (
   SELECT first (ship_date)
   FROM sales_order_items )
```

Negating the ANY and ALL expressions

In general, the expression

NOT *column-name operator* **ANY(** *subquery* **)**

is equivalent to the expression

column-name inverse-operator **ALL(** *subquery* **)**

and the expression

NOT *column-name operator* **ALL(** *subquery* **)**

is equivalent to the expression

column-name inverse-operator **ANY(** *subquery* **)**

where *inverse-operator* is obtained by negating *operator*, as shown in the table:

Table of operators and their inverses

The following table lists the inverse of each operator.

Operator	inverse-operator
=	<>
<	=>
>	=<
=<	>
=>	<
<>	=

Set membership test

A query containing a subquery that follows the keyword
IN is converted into a join only if:

- The main query does not contain a GROUP BY clause, and is not an aggregate query, or the subquery returns exactly one value.
- The subquery does not contain a GROUP BY clause.
- The subquery does not contain the keyword DISTINCT.

- The subquery is not a UNION query.
- The subquery is not an aggregate query.
- The conjunct 'expression IN (subquery)' must not be negated.

Example

So, the request "Find the names of the employees who are also department heads", expressed by the query:

```
SELECT emp_fname, emp_lname
FROM employee
WHERE emp_id IN (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' or dept_name = 'Shipping'))
```

would be converted to a joined query, as it satisfies the conditions. However, the request, "Find the names of the employees who are either department heads or customers" would not be converted to a join if it were expressed by the UNION query.

A UNION query following the IN operator can't be converted

```
SELECT emp_fname, emp_lname
FROM employee
WHERE emp_id IN (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' or dept_name = 'Shipping')
   UNION
   SELECT cust_id
   FROM sales_order)
```

Similarly, the request "Find the names of employees who are not department heads" is formulated as the negated subquery

```
SELECT emp_fname, emp_lname
FROM employee
  WHERE NOT emp_id IN (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' OR dept_name = 'Shipping'))
```

and would not be converted.

The conditions that must be fulfilled for a subquery that follows the IN keyword and the ANY keyword to be converted to a join are identical. This is not a coincidence, and the reason for this is that the expression

A query with an IN operator can be converted to one with an ANY operator

WHERE *column-name* **IN(** *subquery* **)**

is logically equivalent to the expression

WHERE *column-name* = **ANY(** *subquery* **)**

So the query

```
SELECT emp_fname, emp_lname
FROM employee
WHERE emp_id IN (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' or dept_name = 'Shipping'))
```

is equivalent to the query

```
SELECT emp_fname, emp_lname
FROM employee
WHERE emp_id = ANY (
   SELECT dept_head_id
   FROM department
   WHERE (dept_name='Finance' or dept_name = 'Shipping'))
```

Conceptually, Adaptive Server Anywhere converts a query with the IN operator to one with an ANY operator, and decides accordingly whether to convert the subquery to a join.

Existence test

A subquery that follows the keyword EXISTS is converted to a join only if it satisfies the following two conditions:

- The main query does not contain a GROUP BY clause, and is not an aggregate query, or the subquery returns exactly one value.
- The conjunct 'EXISTS (subquery)' is not negated.
- The subquery is correlated; that is, it contains an outer reference.

Example

Therefore, the request, "Which customers placed orders after July 13, 2001?", which can be formulated by this query whose non-negated subquery contains the outer reference **customer.id** = **sales_order.cust_id**, could be converted to a join.

```
SELECT fname, lname
FROM customer
WHERE EXISTS (
   SELECT *
   FROM sales_order
   WHERE (order_date > '2001-07-13')
 AND (customer.id = sales_order.cust_id))
```

The EXISTS keyword essentially tells the database server to check for empty result sets. When using inner joins, the database server automatically displays only the rows where there is data from all of the tables in the FROM clause. So, this query returns the same rows as does the one with the subquery:

```
SELECT fname, lname
FROM customer, sales_order
WHERE (sales_order.order_date > '2001-07-13')
AND (customer.id = sales_order.cust_id)
```

CHAPTER 11

Adding, Changing, and Deleting Data

About this chapter

This chapter describes how to modify the data in a database.

Most of the chapter is devoted to the INSERT, UPDATE, and DELETE statements, as well as statements for bulk loading and unloading.

Contents

Topic:	page
Data modification statements	356
Adding data using INSERT	357
Changing data using UPDATE	362
Changing data using INSERT	364
Deleting data using DELETE	365

Data modification statements

The statements you use to add, change, or delete data are called **data modification** statements. The most common such statements include:

- **Insert** adds new rows to a table
- **Update** changes existing rows in a table
- **Delete** removes specific rows from a table

Any single INSERT, UPDATE, or DELETE statement changes the data in only one table or view.

In addition to the common statements, the LOAD TABLE and TRUNCATE TABLE statements are especially useful for bulk loading and deleting of data.

Sometimes, the data modification statements are collectively known as the **data modification language** (DML) part of SQL.

Permissions for data modification

You can only execute data modification statements if you have the proper permissions on the database tables you want to modify. The database administrator and the owners of database objects use the GRANT and REVOKE statements to decide who has access to which data modification functions.

☞ Permissions can be granted to individual users, groups, or the public group. For more information on permissions, see "Managing User IDs and Permissions" [*ASA Database Administration Guide*, page 389].

Transactions and data modification

When you modify data, the transaction log stores a copy of the old and new state of each row affected by each data modification statement. This means that if you begin a transaction, realize you have made a mistake, and roll the transaction back, you also restore the database to its previous condition.

☞ For more information about transactions, see "Using Transactions and Isolation Levels" on page 99.

Adding data using INSERT

You add rows to the database using the INSERT statement. The INSERT statement has two forms: you can use the VALUES keyword or a SELECT statement:

INSERT using values

The VALUES keyword specifies values for some or all of the columns in a new row. A simplified version of the syntax for the INSERT statement using the VALUES keyword is:

INSERT [**INTO**] *table-name* [(*column-name*, . . .)]
VALUES (*expression* , . . .)

You can omit the list of column names if you provide a value for each column in the table, in the order in which they appear when you execute a query using SELECT *.

INSERT from SELECT

You can use SELECT within an INSERT statement to pull values from one or more tables. If the table you are inserting data into has a large number of columns, you can also use WITH AUTO NAME to simplify the syntax. Using WITH AUTO NAME, you only need to specify the column names in the SELECT statement, rather than in both the INSERT and the SELECT statements. The names in the SELECT statement must be column references or aliased expressions.

A simplified version of the syntax for the INSERT statement using a select statement is:

INSERT [**INTO**] *table-name*
WITH AUTO NAME *select-statement*

☞ For more information about the INSERT statement, see the “INSERT statement” [*ASA SQL Reference*, page 476].

Inserting values into all columns of a row

The following INSERT statement adds a new row to the department table, giving a value for every column in the row:

```
INSERT INTO department
VALUES ( 702, 'Eastern Sales', 902 )
```

Notes

♦ Type the values in the same order as the column names in the original CREATE TABLE statement, that is, first the ID number, then the name, then the department head ID.

♦ Surround the values by parentheses.

♦ Enclose all character data in single quotes.

- Use a separate insert statement for each row you add.

Inserting values into specific columns

You can add data to some columns in a row by specifying only those columns and their values. Define all other columns not included in the column list must to allow NULL or have defaults. If you skip a column that has a default value, the default appears in that column.

Adding data in only two columns, for example, dept_id and dept_name, requires a statement like this:

```
INSERT INTO department (dept_id, dept_name)
VALUES ( 703, 'Western Sales' )
```

The dept_head_id column has no default, but can allow NULL. A NULL is assigned to that column.

The order in which you list the column names must match the order in which you list the values. The following example produces the same results as the previous one:

```
INSERT INTO department (dept_name, dept_id )
VALUES ('Western Sales', 703)
```

Values for unspecified columns

When you specify values for only some of the columns in a row, one of four things can happen to the columns with no values specified:

- **NULL entered** NULL appears if the column allows NULL and no default value exists for the column.
- **A default value entered** The default value appears if a default exists for the column.
- **A unique, sequential value entered** A unique, sequential value appears if the column has the AUTOINCREMENT default or the IDENTITY property.
- **INSERT rejected, and an error message appears** An error message appears if the column does not allow NULL and no default exists.

By default, columns allow NULL unless you explicitly state NOT NULL in the column definition when creating tables. You can alter the default using the ALLOW_NULLS_BY_DEFAULT option.

Restricting column data using constraints

You can create constraints for a column or domain. Constraints govern the kind of data you can or cannot add.

☞ For more information on constraints, see "Using table and column constraints" on page 85.

Explicitly inserting NULL

You can explicitly insert NULL into a column by typing NULL. Do not enclose this in quotes, or it will be taken as a string.

For example, the following statement explicitly inserts NULL into the dept_head_id column:

```
INSERT INTO department
VALUES (703, 'Western Sales', NULL )
```

Using defaults to supply values

You can define a column so that, even though the column receives no value, a default value automatically appears whenever a row is inserted. You do this by supplying a default for the column.

☞ For more information about defaults, see "Using column defaults" on page 79.

Adding new rows with SELECT

To pull values into a table from one or more other tables, you can use a SELECT clause in the INSERT statement. The select clause can insert values into some or all of the columns in a row.

Inserting values for only some columns can come in handy when you want to take some values from an existing table. Then, you can use update to add the values for the other columns.

Before inserting values for some, but not all, columns in a table, make sure that either a default exists, or you specify NULL for the columns for which you are not inserting values. Otherwise, an error appears.

When you insert rows from one table into another, the two tables must have compatible structures—that is, the matching columns must be either the same data types or data types between which Adaptive Server automatically converts.

Example

If the columns are in the same order in their create table statements, you do not need to specify column names in either table. Suppose you have a table named newproduct that contains some rows of product information in the same format as in the product table. To add to product all the rows in newproduct:

```
INSERT product
SELECT *
FROM newproduct
```

You can use expressions in a SELECT statement inside an INSERT statement.

Inserting data into some columns

You can use the SELECT statement to add data to some, but not all, columns in a row just as you do with the VALUES clause. Simply specify the columns to which you want to add data in the INSERT clause.

Inserting Data from the Same Table

You can insert data into a table based on other data in the same table. Essentially, this means copying all or part of a row.

For example, you can insert new products, based on existing products, into the product table. The following statement adds new Extra Large Tee Shirts (of Tank Top, V-neck, and Crew Neck varieties) into the product table. The identification number is ten greater than the existing sized shirt:

```
INSERT INTO product
SELECT id+ 10, name, description,
    'Extra large', color, 50, unit_price
FROM product
WHERE name = 'Tee Shirt'
```

Inserting documents and images

If you want to store documents or images in LONG BINARY columns in your database, you can write an application that reads the contents of the file into a variable, and supplies that variable as a value for an INSERT statement.

☞ For more information about adding INSERT statements to applications, see "How to use prepared statements" [*ASA Programming Guide*, page 15], and "SET statement" [*ASA SQL Reference*, page 548].

☞ You can also use the xp_read_file system function to insert file contents into a table. This function is useful if you want to insert file contents from Interactive SQL, or some other environment that does not provide a full programming language.

☞ DBA authority is required to use this external function.

Example

In this example, you create a table, and insert an image into a column of the table. You can carry out these steps from Interactive SQL.

1. Create a table to hold some images.

```
CREATE TABLE pictures
( c1 INT DEFAULT AUTOINCREMENT PRIMARY KEY,
   filename VARCHAR(254),
   picture LONG BINARY )
```

2. Insert the contents of *portrait.gif* , in the current working directory of the database server, into the table.

```
INSERT INTO pictures (filename, picture)
VALUES (    'portrait.gif',
   xp_read_file( 'portrait.gif' ) )
```

☞ For more information, see “xp_read_file system procedure” [*ASA SQL Reference,* page 761].

Changing data using UPDATE

You can use the UPDATE statement, followed by the name of the table or view, to change single rows, groups of rows, or all rows in a table. As in all data modification statements, you can change the data in only one table or view at a time.

The UPDATE statement specifies the row or rows you want changed and the new data. The new data can be a constant or an expression that you specify or data pulled from other tables.

If an UPDATE statement violates an integrity constraint, the update does not take place and an error message appears. For example, if one of the values being added is the wrong data type, or if it violates a constraint defined for one of the columns or data types involved, the update does not take place.

UPDATE syntax

A simplified version of the UPDATE syntax is:

UPDATE *table-name*
SET *column_name = expression*
WHERE *search-condition*

If the company Newton Ent. (in the customer table of the sample database) is taken over by Einstein, Inc., you can update the name of the company using a statement such as the following:

```
UPDATE customer
SET company_name = 'Einstein, Inc.'
WHERE company_name = 'Newton Ent.'
```

You can use any expression in the WHERE clause. If you are not sure how the company name was spelled, you could try updating any company called Newton, with a statement such as the following:

```
UPDATE customer
SET company_name = 'Einstein, Inc.'
WHERE company_name LIKE 'Newton%'
```

The search condition need not refer to the column being updated. The company ID for Newton Entertainments is 109. As the ID value is the primary key for the table, you could be sure of updating the correct row using the following statement:

```
UPDATE customer
SET company_name = 'Einstein, Inc.'
WHERE id = 109
```

The SET clause

The SET clause specifies the columns to be updated, and their new values. The WHERE clause determines the row or rows to be updated. If you do not have a WHERE clause, the specified columns of all rows are updated with the values given in the SET clause.

You can provide any expression of the correct data type in the SET clause.

The WHERE clause

The WHERE clause specifies the rows to be updated. For example, the following statement replaces the One Size Fits All Tee Shirt with an Extra Large Tee Shirt

```
UPDATE product
SET size  = 'Extra Large'
WHERE name = 'Tee Shirt'
   AND size = 'One Size Fits All'
```

The FROM clause

You can use a FROM clause to pull data from one or more tables into the table you are updating.

Changing data using INSERT

You can use the ON EXISTING clause of the INSERT statement to update existing rows in a table (based on primary key lookup) with new values. This clause can only be used on tables that have a primary key. Attempting to use this clause on tables without primary keys or on proxy tables generates a syntax error.

Specifying the ON EXISTING clause causes the server to do a primary key lookup for each input row. If the corresponding row does not exist, it inserts the new row. For rows already existing in the table, you can choose to:

- generate an error for duplicate key values. This is the default behavior if the ON EXISTING clause is not specified.
- silently ignore the input row, without generating any errors.
- update the existing row with the values in the input row

☞ For more information, see the “INSERT statement” [*ASA SQL Reference*, page 476].

Deleting data using DELETE

Simple DELETE statements have the following form:

DELETE [**FROM**] *table-name*
WHERE *column-name* = *expression*

You can also use a more complex form, as follows

DELETE [**FROM**] *table-name*
FROM *table-list*
WHERE *search-condition*

The WHERE clause

Use the WHERE clause to specify which rows to remove. If no WHERE clause appears, the DELETE statement remove all rows in the table.

The FROM clause

The FROM clause in the second position of a DELETE statement is a special feature allowing you to select data from a table or tables and delete corresponding data from the first-named table. The rows you select in the FROM clause specify the conditions for the delete.

Example

This example uses the sample database. To execute the statements in the example, you should set the option WAIT_FOR_COMMIT to OFF. The following statement does this for the current connection only:

```
SET TEMPORARY OPTION WAIT_FOR_COMMIT = 'OFF'
```

This allows you to delete rows even if they contain primary keys referenced by a foreign key, but does not permit a COMMIT unless the corresponding foreign key is deleted also.

The following view displays products and the value of that product that has been sold:

```
CREATE VIEW ProductPopularity as
SELECT  product.id,
   SUM(product.unit_price * sales_order_items.quantity) as
         "Value Sold"
FROM  product JOIN sales_order_items
ON product.id = sales_order_items.prod_id
GROUP BY product.id
```

Using this view, you can delete those products which have sold less than $20,000 from the product table.

```
DELETE
FROM product
FROM product NATURAL JOIN ProductPopularity
WHERE "Value Sold" < 20000
```

You should roll back your changes when you have completed the example:

```
ROLLBACK
```

Deleting all rows from a table

You can use the TRUNCATE TABLE statement as a fast method of deleting all the rows in a table. It is faster than a DELETE statement with no conditions, because the delete logs each change, while the transaction log does not record truncate table operations individually.

The table definition for a table emptied with the TRUNCATE TABLE statement remains in the database, along with its indexes and other associated objects, unless you execute a DROP TABLE statement.

You cannot use TRUNCATE TABLE if another table has rows that reference it through a referential integrity constraint. Delete the rows from the foreign table, or truncate the foreign table and then truncate the primary table.

TRUNCATE TABLE syntax

The syntax of truncate table is:

TRUNCATE TABLE *table-name*

For example, to remove all the data in the sales_order table, type the following:

```
TRUNCATE TABLE sales_order
```

A TRUNCATE TABLE statement does not fire triggers defined on the table.

CHAPTER 12

Query Optimization and Execution

About this chapter

Once each query is parsed, the optimizer analyzes it and decides on an access plan that will compute the result using as few resources as possible. This chapter describes the steps the optimizer goes through to optimize a query. It documents the assumptions that underlie the design of the optimizer, and discusses selectivity estimation, cost estimation, and the other steps of optimization.

Although update, insert, and delete statements must also be optimized, the focus of this chapter is on select queries. The optimization of these other commands follows similar principles.

Contents

Topic:	page
The role of the optimizer	368
How the optimizer works	369
Query execution algorithms	379
Physical data organization and access	392
Indexes	395
Semantic query transformations	404
Subquery and function caching	418
Reading access plans	420

The role of the optimizer

The role of the optimizer is to devise an efficient way to execute SQL statements. The optimizer expresses its chosen method in the form of an **access plan**. The access plan describes which tables to scan, which index, if any, to use for each table, which join strategy to use, and what order to read the tables in. Often, a great number of plans exist that all accomplish the same goal. Other variables may further enlarge the number of possible access plans.

Cost based

The optimizer begins selecting for the choices available using efficient, and in some cases proprietary, algorithms. It bases its decisions on predictions of the resources each query requires. The optimizer takes into account both the cost of disk access operations and the estimated CPU cost of each operation.

Syntax independent

Most commands may be expressed in many different ways using the SQL language. These expressions are semantically equivalent in that they accomplish the same task, but may differ substantially in syntax. With few exceptions, the Adaptive Server Anywhere optimizer devises a suitable access plan based only on the semantics of each statement.

Syntactic differences, although they may appear to be substantial, usually have no effect. For example, differences in the order of predicates, tables, and attributes in the query syntax have no affect on the choice of access plan. Neither is the optimizer affected by whether or not a query contains a view.

A good plan, not necessarily the best plan

The goal of the optimizer is to find a good access plan. Ideally, the optimizer would identify the most efficient access plan possible, but this goal is often impractical. Given a complicated query, a great number of possibilities may exist.

However efficient the optimizer, analyzing each option takes time and resources. The optimizer compares the cost of further optimization with the cost of executing the best plan it has found so far. If a plan has been devised that has a relatively low cost, the optimizer stops and allows execution of that plan to proceed. Further optimization might consume more resources than would execution of an access plan already found.

In the case of expensive and complicated queries, the optimizer works longer. In the case of very expensive queries, it may run long enough to cause a discernible delay.

How the optimizer works

The Adaptive Server Anywhere optimizer must decide the order in which to access tables in a query, and whether or not to use an index for each table. The optimizer attempts to pick the best strategy.

The best strategy for executing each query is the one that gets the results in the shortest period of time, with the least cost. The optimizer determines the cost of each strategy by estimating the number of disk reads and writes required, and chooses the strategy with the lowest cost.

The optimizer uses a generic disk access cost model to differentiate the relative performance differences between random and sequential retrieval on the database file. It is possible to calibrate a database for a particular hardware configuration using an ALTER DATABASE statement. The particulars of a specific cost model can be determined with the sa_get_dtt() stored procedure.

By default, query processing is optimized towards returning the complete result set. You can change this, using the OPTIMIZATION_GOAL option, to minimize the cost of returning the first row quickly.

You can view the access plan for any query in Interactive SQL by opening the Plan tab in the Results pane. To change the degree of detail that is displayed, change the setting in the Plan tab of the Options dialog (available from the Tools menu).

☞ For more information about optimization goals, see “OPTIMIZATION_GOAL option [database]” [*ASA Database Administration Guide,* page 613].

☞ For more information about reading access plans, see “Reading access plans” on page 420.

Optimizer estimates

The optimizer chooses a strategy for processing a statement based on histograms that are stored in the database and heuristics (educated guesses).

Histograms, also called column statistics, store information about the distribution of values in a column. In Adaptive Server Anywhere, a histogram represents the data distribution for a column by dividing the domain of the column into a set of consecutive value ranges (also called buckets) and by remembering, for each value range (or bucket), the number of rows in the table for which the column value falls in the bucket.

Adaptive Server Anywhere pays particular attention to single column values that are represented in a large number of rows in the table. Significant single value selectivities are maintained in singleton histogram buckets (for example, buckets that encompass a single value in the column domain). ASA tries to maintain a minimum number of singleton buckets in each histogram, usually between 10 and 100 depending upon the size of the table. Additionally, all single values with selectivities greater than 1% are kept as singleton buckets. As a result, a histogram for a given column remembers the top N single value selectivities for the column where the value of N is dependent upon the size of the table and the number of single value selectivities that are greater than 1%.

Once the minimum number of value ranges have been met, low-selectivity frequencies are replaced by large-selectivity frequencies as they come along. The histogram will only have more than the minimum number of singleton value ranges after it has seen enough values with a selectivity of greater than 1%.

Given the histogram on a column, Adaptive Server Anywhere attempts to estimate the number of rows satisfying a given query predicate on the column by adding up the number of rows in all value ranges that overlap the values satisfying the specified predicate. For value ranges in the histograms that are partially contained in the query result set, Adaptive Server Anywhere uses interpolation within the value range.

Adaptive Server Anywhere uses an implementation of histograms that causes the histograms to be more refined as a byproduct of query execution. As queries are executed, Adaptive Server Anywhere compares the number of rows estimated by the histograms for a given predicate with the number of rows actually found to satisfy the predicate, and then adjusts the values in the histogram to reduce the margin of error for subsequent optimizations.

For each table in a potential execution plan, the optimizer estimates the number of rows that will form part of the results. The number of rows depends on the size of the table and the restrictions in the WHERE clause or the ON clause of the query.

In many cases, the optimizer uses more sophisticated heuristics. For example, the optimizer uses default estimates only in cases where better statistics are unavailable. As well, the optimizer makes use of indexes and keys to improve its guess of the number of rows. The following are a few single-column examples:

- ♦ Equating a column to a value: estimate one row when the column has a unique index or is the primary key.
- ♦ A comparison of an indexed column to a constant: probe the index to estimate the percentage of rows that satisfy the comparison.

- Equating a foreign key to a primary key (key join): use relative table sizes in determining an estimate. For example, if a 5000 row table has a foreign key to a 1000 row table, the optimizer guesses that there are five foreign key rows for each primary key row.

☞ For more information about column statistics, see “SYSCOLSTAT system table” [*ASA SQL Reference*, page 627].

☞ For information about obtaining the selectivities of predicates and the distribution of column values, see:

- “sa_get_histogram system procedure” [*ASA SQL Reference*, page 717]
- “The Histogram utility” [*ASA Database Administration Guide*, page 481]
- “ESTIMATE function [Miscellaneous]” [*ASA SQL Reference*, page 125]
- “ESTIMATE_SOURCE function [Miscellaneous]” [*ASA SQL Reference*, page 125]

Updating column statistics

Column statistics are stored permanently in the database in the system table SYSCOLSTAT. Statistics are automatically updated if a significant amount of data is changed using the INSERT, UPDATE or DELETE statements.

If you suspect that performance is suffering because your statistics inaccurately reflect the current column values, you may want to execute the statements DROP STATISTICS or CREATE STATISTICS. CREATE STATISTICS deletes old statistics and creates new ones, while DROP STATISTICS just deletes the existing statistics.

With more accurate statistics available to it, the optimizer can compute better estimates, thus improving the performance of subsequent queries. However, incorrect estimates are only a problem if they lead to poorly optimized queries.

When you execute LOAD TABLE, statistics are created for the table. However, when rows are inserted, deleted or updated in a table, the statistics are not updated.

For small tables, a histogram does not significantly improve the optimizer’s ability to choose an efficient plan. You can specify the minimum table size for which histograms are created. The default is 1000 rows. However, when a CREATE STATISTICS statement is executed, a histogram is created for every table, regardless of the number of rows.

☞ For more information, see “MIN_TABLE_SIZE_FOR_HISTOGRAM option [database]” [*ASA Database Administration Guide*, page 609].

☞ For more information about column statistics, see:

- “SYSCOLSTAT system table” [*ASA SQL Reference*, page 627]
- “DROP STATISTICS statement” [*ASA SQL Reference*, page 418]
- “CREATE STATISTICS statement” [*ASA SQL Reference*, page 346]

Automatic performance tuning

One of the most common constraints in a query is equality with a column value. The following example tests for equality of the sex column.

```
SELECT *
FROM employee
WHERE sex = 'f'
```

Queries often optimize differently at the second execution. For the above type of constraint, Adaptive Server Anywhere learns from experience, automatically allowing for columns that have an unusual distribution of values. The database stores this information permanently unless you explicitly delete it using the DROP STATISTICS command. Note that subsequent queries with predicates over that column may cause the server to recreate a histogram on the column.

Underlying assumptions

A number of assumptions underlie the design direction and philosophy of the Adaptive Server Anywhere query optimizer. You can improve the quality or performance of your own applications through an understanding of the optimizer’s decisions. These assumptions provide a context in which you may understand the information contained in the remaining sections.

Minimal administration work

Traditionally, high performance database servers have relied heavily on the presence of a knowledgeable, dedicated, database administrator. This person spent a great deal of time adjusting data storage and performance controls of all kinds to achieve good database performance. These controls often required continuing adjustment as the data in the database changed.

Adaptive Server Anywhere learns and adjusts as the database grows and changes. Each query betters its knowledge of the data distribution in the database. Adaptive Server Anywhere automatically stores and uses this information to optimize future queries.

Every query both contributes to this internal knowledge and benefits from it. Every user can benefit from knowledge that Adaptive Server Anywhere has gained through executing another user's query.

Statistics-gathering mechanisms are thus an integral part of the database server, and require no external mechanism. Should you find an occasion where it would help, you can provide the database server with estimates of data distributions to use during optimization. If you encode these into a trigger or procedure, for example, you then assume responsibility for maintaining these estimates and updating them whenever appropriate.

Optimize for first rows or for entire result set

The OPTIMIZATION_GOAL option allows you to specify whether query processing should be optimized towards returning the first row quickly, or minimizing the cost of returning the complete result set. The default is first row.

☞ For more information, see "OPTIMIZATION_GOAL option [database]" [*ASA Database Administration Guide*, page 613].

Statistics are present and correct

The optimizer is self-tuning, storing all the needed information internally. The system table SYSCOLSTAT is a persistent repository of data distributions and predicate selectivity estimates. At the completion of each query, Adaptive Server Anywhere uses statistics gathered during query execution to update SYSCOLSTAT. In consequence, all subsequent queries gain access to more accurate estimates.

The optimizer relies heavily on these statistics and, therefore, the quality of the access plans it generates depends heavily on them. If you recently inserted a lot of new rows, these statistics may no longer accurately describe the data. You may find that your subsequent queries execute unusually slowly.

If you have significantly altered your data, and you find that query execution is slow, you may want to execute DROP STATISTICS and/or CREATE STATISTICS.

An index can usually be found to satisfy a predicate

Often, Adaptive Server Anywhere can evaluate predicates with the aid of an index. Using an index, the optimizer speeds access to data and reduces the amount of information read. For example, when OPTIMIZATION_GOAL is set to first-row, the Adaptive Server Anywhere optimizer will try to use indexes to satisfy ORDER BY and GROUP BY clauses.

When the optimizer cannot find a suitable index, it resorts to a sequential table scan, which can be expensive. An index can improve performance dramatically when joining tables. Add indexes to tables or rewrite queries wherever doing so facilitates the efficient processing of common requests.

Virtual Memory is a scarce resource

The operating system and a number of applications frequently share the memory of a typical computer. Adaptive Server Anywhere treats memory as a scarce resource. Because it uses memory economically, Adaptive Server Anywhere can run on relatively small computers. This economy is important if you wish your database to operate on portable computers or on older machines.

Reserving extra memory, for example to hold the contents of a cursor, may be expensive. If the buffer cache is full, one or more pages may have to be written to disk to make room for new pages. Some pages may need to be re-read to complete a subsequent operation.

In recognition of this situation, Adaptive Server Anywhere associates a higher cost with execution plans that require additional buffer cache overhead. This cost discourages the optimizer from choosing plans that use work tables.

On the other hand, it is careful to use memory where it improves performance. For example, it caches the results of subqueries when they will be needed repeatedly during the processing of the query.

Rewriting subqueries as EXISTS predicates

The assumptions which underlie the design of Adaptive Server Anywhere require that it conserves memory and that by default it returns the first few results of a cursor as quickly as possible. In keeping with these objectives, Adaptive Server Anywhere rewrites all set-operation subqueries, such as IN, ANY, or SOME predicates, as EXISTS predicates. By doing so, Adaptive Server Anywhere avoids creating unnecessary work tables and may more easily identify a suitable index through which to access a table.

Non-correlated subqueries are subqueries that contain no explicit reference to the table or tables contained in the rest higher-level portions of the query.

The following is an ordinary query that contains a non-correlated subquery. It selects information about all the customers who did not place an order on January 1, 2001.

Non-correlated subquery

```
SELECT *
FROM customer c
WHERE c.id NOT IN
   (   SELECT o.cust_id
      FROM sales_order o
      WHERE o.order_date = '2001-01-01' )
```

One possible way to evaluate this query is to first read the sales_order table and create a work table of all the customers who placed orders on January 1, 2001, then read the customer table and extract one row for each customer listed in the work table.

However, Adaptive Server Anywhere avoids materializing results as work tables. It also gives preference to plans that return the first few rows of a result most quickly. Thus, the optimizer rewrites such queries using EXISTS predicates. In this form, the subquery becomes **correlated**: the subquery now contains an explicit reference to the id column of the customer table.

Correlated subquery

```
SELECT *
FROM customer c
WHERE NOT EXISTS
   (   SELECT *
      FROM sales_order o
      WHERE o.order_date = '2000-01-01'
         AND o.cust_id = c.id )
```

```
c<seq> :  o<key_so_customer>
```

This query is semantically equivalent to the one above, but when expressed in this new syntax, two advantages become apparent.

1. The optimizer can choose to use either the index on the cust_id attribute or the order_date attribute of the sales_order table. (However, in the sample database, only the id and cust_id columns are indexed.)

2. The optimizer has the option of choosing to evaluate the subquery without materializing intermediate results as work tables.

Adaptive Server Anywhere can cache the results of this correlated subquery during processing. This strategy lets Adaptive Server Anywhere reuse previously computed results. In the case of query above, caching does not help because customer identification numbers are unique in the customer table.

☞ Further information on subquery caching is located in "Subquery and function caching" on page 418.

Access plan caching

Normally, the optimizer selects an access plan for a query every time the query is executed. Optimizing at execution time allows the optimizer to choose a plan based on current system state, as well as the values of current selectivity estimates and estimates based on the values of host variables. For queries that are executed very frequently, the cost of query optimization can outweigh the benefits of optimizing at execution time. For queries and INSERT, UPDATE and DELETE statements performed inside stored procedures, stored functions, and triggers, the optimizer caches execution plans between executions of the query.

After a statement in a stored procedure, stored function, or trigger has been executed several times by one connection, the optimizer builds a reusable plan for the statement. A reusable plan does not use the values of host variables for selectivity estimation or rewrite optimizations. The reusable plan may have a higher cost because of this. If the cost of the reusable plan is close to the best observed cost for the statement, the optimizer will choose to add the reusable plan to a plan cache. Otherwise, the benefit of optimizing on each execution outweighs the savings from avoiding optimization, and the execution plan is not cached.

The plan cache is a per-connection cache of the data structures used to execute an access plan. Reusing the cached plan involves looking up the plan in the cache and resetting it to an initial state. This is typically substantially faster than optimizing the statement. Cached plans may be stored to disk if they are used infrequently, and they do not increase the cache usage. The optimizer periodically re-optimizes queries to verify that the cached plan is still relatively efficient.

You can use the database or connection property QueryCachePages to determine the number of pages used to cache execution plans. These pages occupy space in the temporary file, but are not necessarily resident in memory.

You can use QueryCachedPlans statistic to show how many query execution plans are currently cached. This property can be retrieved using CONNECTION_PROPERTY to show how many query execution plans are cached for a given connection, or DB_PROPERTY can be used to count the number of cached execution plans across all connections. This property can be used in combination with QueryCachePages, QueryOptimized, QueryBypassed, and QueryReused to help determine the best setting for the MAX_PLANS_CACHED option

The maximum number of plans to cache is specified with the option setting MAX_PLANS_CACHED. The default is 20. To disable plan caching, set this option to 0.

☞ For more information, see “MAX_PLANS_CACHED option

[database]” [*ASA Database Administration Guide*, page 606].

Steps in optimization

The steps the Adaptive Server Anywhere optimizer follows in generating a suitable access plan include the following.

1. The parser converts the SQL query into an internal representation. It may rewrite the query, converting it to a syntactically different, but semantically equivalent, form. For example, a subquery may be rewritten as a join. These conversions make the statement easier to analyze.

2. Optimization proper commences just before execution. If you are using cursors in your application, optimization commences when the cursor is opened. Unlike many other commercial database systems, Adaptive Server Anywhere optimizes each statement just before executing it.

3. The optimizer performs semantic optimization on the statement. It rewrites each SQL statement whenever doing so leads to better, more efficient access plans.

4. The optimizer performs join enumeration for each subquery.

5. The optimizer optimizes access order.

Because Adaptive Server Anywhere performs just-in-time optimization of each statement, the optimizer has access to the values of host variables and stored procedure variables. Hence, it makes better choices because it performs better selectivity analysis.

Adaptive Server Anywhere optimizes each query you execute, regardless of how many times you executed it before, with the exception of queries that are contained in stored procedures or user-defined functions. For queries contained in stored procedures or user-defined functions, the optimizer may cache the access plans so that they can be reused.

☞ For more information, see “Access plan caching” on page 375.

Because Adaptive Server Anywhere saves statistics each time it executes a query, the optimizer can learn from the experience of executing previous plans and can adjust its choices when appropriate.

Simple queries

If a query is recognized as a simple query, a heuristic rather than cost-based optimization is used—the optimizer decides whether to use and index scan or sequential table scan, and builds and executes the access plan immediately. Steps 4 and 5 are bypassed.

A simple query is a DYNAMIC SCROLL or NO SCROLL cursor that does not contain any kind of subquery, more than one table, a proxy table, user defined functions, NUMBER(*), UNION, aggregation, DISTINCT, GROUP BY, or more than one predicate on a single column. Simple queries can contain ORDER BY only as long as the WHERE clause contains conditions on each primary key column.

Query execution algorithms

The following is an explanation of the algorithms Adaptive Server Anywhere uses to compute queries.

Accessing tables

The basic ways to access single tables are the index scan and the sequential table scan.

Index scans

An index scan uses an index to determine which rows satisfy a search condition. It reads only those pages that satisfy the condition. Indexes can return rows in sorted order.

Index scans are displayed in the short and long plan as *correlation_name*<*index_name*>, where *correlation_name* is the correlation name specified in the FROM clause, or the table name if none was specified; and *index_name* is the name of the index.

Indexes provide an efficient mechanism for reading a few rows from a large table. However, index scans cause pages to be read from the database in random order, which is more expensive than sequential reads. Index scans may also reference the same table page multiple times if there are several rows on the page that satisfy the search condition. If only a few pages are matched by the index scan, it is likely that the pages will remain in cache, and multiple access does not lead to extra I/O. However, if many pages are matched by the search condition, they may not all fit in cache. This can lead to the index scan reading the same page from disk multiple times.

The optimizer will tend to prefer index scans over sequential table scans if the OPTIMIZATION_GOAL setting is first-row. This is because indexes tend to return the first few rows of a query faster than table scans.

Indexes can also be used to satisfy an ordering requirement, either explicitly defined in an ORDER BY clause, or implicitly needed for a GROUP BY or DISTINCT clause. Ordered group-by and ordered distinct methods can return initial rows faster than hash-based grouping and distinct, but they may be slower at returning the entire result set.

The optimizer uses an index scan to satisfy a search condition if the search condition is sargable, and if the optimizer's estimate of the selectivity of the search condition is sufficiently low for the index scan to be cheaper than a sequential table scan.

An index scan can also evaluate non-sargable search conditions after rows are fetched from the index. Evaluating conditions in the index scan is slightly more efficient than evaluating them in a filter after the index scan.

☞ For more information about when Adaptive Server Anywhere can make use of indexes, see "Predicate analysis" on page 405.

☞ For more information about optimization goals, see "OPTIMIZATION_GOAL option [database]" [*ASA Database Administration Guide*, page 613].

Sequential table scans

A sequential table scan reads all the rows in all the pages of a table in the order in which they are stored in the database.

Sequential table scans are displayed in the short and long plan as *correlation_name*<*seq*>, where *correlation_name* is the correlation name specified in the FROM clause, or the table name if none was specified.

This type of scan is used when it is likely that a majority of table pages have a row that match the query's search condition or a suitable index is not defined.

Although sequential table scans may read more pages than index scans, the disk I/O can be substantially cheaper because the pages are read in contiguous blocks from the disk (this performance improvement is best if the database file is not fragmented on the disk). Sequential I/O minimizes overhead due to disk head movement and rotational latency. For large tables, sequential table scans also read groups of several pages at a time. This further reduces the cost of sequential table scans relative to index scans.

Although sequential table scans may take less time than index scans that match many rows, they also cannot exploit the cache as effectively as index scans if the scan is executed many times. Since index scans are likely to access fewer table pages, it is more likely that the pages will be available in the cache, resulting in faster access. Because of this, it is much better to have an index scan for table accesses that are repeated, such as the right hand side of a nested loops join.

For isolation level 3, Adaptive Server Anywhere acquires a lock on each row that is accessed—even if it does not satisfy the search condition. For this level, sequential table scans acquire locks on all of the rows in the table, while index scans only acquire locks on the rows that match the search condition. This means that sequential table scans may substantially reduce the throughput in multi-user environments. For this reason, the optimizer prefers indexed access over sequential access at isolation level 3. Sequential scans can efficiently evaluate simple comparison predicates between table columns and constants during the scan. Other search conditions that refer only to the table being scanned are evaluated after these simple comparisons, and this approach is slightly more efficient that evaluating the conditions in a filter after the sequential scan.

IN list

The IN list algorithm is used in cases where an IN predicate can be satisfied using an index. For example, in the following query, the optimizer recognizes that it can access the employee table using its primary key index.

```
SELECT *
FROM employee
WHERE emp_id in (102, 105, 129)
```

In order to accomplish this, a join is built with a special IN list table on the left hand side. Rows are fetched from the IN list and used to probe the employee table. Multiple IN lists can be satisfied using the same index. If the optimizer chooses not to use an index to satisfy the IN predicate (perhaps because another index gives better performance), then the IN list appears as a predicate in a filter.

Recursive table

A recursive table is a common table expression constructed as a result of a WITH clause in a query. The WITH clause is used for recursive union queries. Common table expressions are temporary views that are known only within the scope of a single SELECT statement.

☞ For more information, see "Common Table Expressions" on page 305.

Join algorithms

Join algorithms are required when more than one table appears in the FROM clause. You cannot specify which join algorithm is used—the choice is made by the optimizer.

Nested loops join

The nested loops join computes the join of its left and right sides by completely reading the right hand side for each row of the left hand side. (The syntactic order of tables in the query does not matter, because the optimizer chooses the appropriate join order for each block in the request.)

The optimizer may choose nested loops join if the join condition does not contain an equality condition, or if it is optimizing for first-row time.

Since a nested loops join reads the right hand side many times, it is very sensitive to the cost of the right hand side. If the right hand side is an index scan or a small table, then the right hand side can likely be computed using cached pages from previous iterations. On the other hand, if the right hand side is a sequential table scan or an index scan that matches many rows, then the right hand side needs to be read from disk many times. Typically, a nested loops join is less efficient than other join methods. However, nested loops join can provide the first matching row quickly compared to join methods that must compute their entire result before returning.

Nested loops join is the only join algorithm that can provide sensitive semantics for queries containing joins. This means that sensitive cursors on joins can only be executed with a nested loops join.

A semijoin fetches only the first matching row from the right hand side. It is a more efficient version of the nested loops join, but can only be used when an EXISTS, or sometimes a DISTINCT, keyword is used.

Nested loops semijoin

Similar to the nested loop join described above, the nested loops semijoin algorithm joins each row of the left-hand side with the right-hand side using a nested loops algorithm. As with nested loops join, the right-hand side may be read many times, so for larger inputs an index scan is preferable. However, nested loops semijoin differs from nested loop join in two respects. First, semijoin only outputs values from the left-hand side; the right hand side is used only for restricting which rows of the left-hand side appear in the result. Second, the nested loops semijoin algorithm stops each search of the right-hand side as soon as the first match is encountered. Nested loops semijoin can be used as the join algorithm when join's inputs include table expressions from an existentially-quantified (IN, SOME, ANY, EXISTS) nested query that has been rewritten as a join.

Nested block join and sorted block

The nested block join (also called the block nested loops join) reads a block of rows from the left hand side, and sorts the rows by the join attributes (the columns used in the join conditions). The left hand child of a nested block join is called a sorted block node. For each block of rows with equal join attributes, the right hand side is scanned once. This algorithm improves on the nested loops join if there are several rows on the left hand side that join with each row of the right hand side.

A nested block join will be chosen by the optimizer if the left hand side has many rows with the same values for join attributes and the right hand side has an index that satisfies the search condition.

Every nested block join has a left child that is a sorted block node. The cost shown for this node is the cost of reading and sorting the rows from the left input.

The left hand input is read into memory in blocks. Changes to tables in the left hand input may not be visible in the results. Because of this, a nested block join cannot provide sensitive semantics.

Nested block joins locks rows on the left input before they are copied to memory.

Hash join

The hash join algorithm builds an in-memory hash table of the smaller of its two inputs, and then reads the larger input and probes the in-memory hash table to find matches, which are written to a work table. If the smaller input does not fit into memory, the hash join operator partitions both inputs into smaller work tables. These smaller work tables are processed recursively until the smaller input fits into memory.

The hash join algorithm has the best performance if the smaller input fits into memory, regardless of the size of the larger input. In general, the optimizer will choose hash join if one of the inputs is expected to be substantially smaller than the other.

If the hash join algorithm executes in an environment where there is not enough cache memory to hold all the rows that have a particular value of the join attributes, then it is not able to complete. In this case, the hash join method discards the interim results and an indexed-based nested loops join is used instead. All of the rows of the smaller table are read and used to probe the work table to find matches. This indexed-based strategy is significantly slower than other join methods, and the optimizer will avoid generating access plans using a hash join if it detects that a low memory situation may occur during query execution. When the nested loops strategy is needed due to low memory, a performance counter is incremented. You can read this monitor with the QueryLowMemoryStrategy database/connection property, or in the “Query: Low Memory Strategies” counter in Windows Performance Monitor.

Note: Windows Performance Monitor may not be available on Windows CE, 95, 98, or Me.

☞ For more information, see QueryLowMemoryStrategy in “Connection-level properties” [*ASA Database Administration Guide*, page 647].

The hash join algorithm computes all of the rows of its result before returning the first row.

The hash join algorithm uses a work table, which provides insensitive semantics unless a value-sensitive cursor has been requested.

Hash join locks rows in its inputs before they are copied to memory.

Hash semijoin

The hash semijoin variant of the hash join algorithm performs a semijoin between the left-hand side and the right-hand side. As with nested loop semijoin described above, the right-hand side is only used to determine which rows from the left-hand side appear in the result. With hash semijoin the right-hand side is read to form an in-memory hash table which is subsequently probed by each row from the left-hand side. As soon as any match is found, the left-hand row is output to the result and the match process starts again for the next left-hand row. At least one equality join condition must be present in order for hash semijoin to be considered by the query optimizer. As with nested loop semijoin, hash semijoin will be utilized in cases where the join's inputs include table expressions from an existentially-quantified (IN, SOME, ANY, EXISTS) nested query that has been rewritten as a join. Hash semijoin will tend to outperform nested loop semijoin when the join condition includes inequalities, or if a suitable index does not exist to make indexed retrieval of the right-hand side sufficiently inexpensive.

As with hash join, the hash semijoin algorithm may revert to a nested loops semijoin strategy if there is insufficient cache memory to enable the operation to complete. Should this occur, a performance counter is incremented. You can read this monitor with the QueryLowMemoryStrategy database/connection property, or in the Query: Low Memory Strategies counter in Windows Performance Monitor.

Note: Windows Performance Monitor may not be available on Windows CE, 95, 98, or Me.

☞ For more information, see QueryLowMemoryStrategy in "Connection-level properties" [*ASA Database Administration Guide*, page 647].

Hash antisemijoin

The hash anti-semijoin variant of the hash join algorithm performs an anti-semijoin between the left-hand side and the right-hand side. As with nested loop anti-semijoin described above, the right-hand side is only used to determine which rows from the left-hand side appear in the result. With hash anti-semijoin the right-hand side is read to form an in-memory hash table which is subsequently probed by each row from the left-hand side. Each left-hand row is output only if it fails to match any row from the right-hand side. As with nested loop anti-semijoin, hash anti-semijoin will be utilized in cases where the join's inputs include table expressions from a universally-quantified (NOT IN, ALL, NOT EXISTS) nested query that has been rewritten as an anti-join. Hash anti-semijoin will tend to outperform nested loop anti-semijoin when the join condition includes inequalities, or if a suitable index does not exist to make indexed retrieval of the right-hand side sufficiently inexpensive.

As with hash join, the hash anti-semijoin algorithm may revert to a nested loops anti-semijoin strategy if there is insufficient cache memory to enable the operation to complete. Should this occur, a performance counter is incremented. You can read this monitor with the QueryLowMemoryStrategy database/connection property, or in the Query: Low Memory Strategies counter in Windows Performance Monitor.

Note: Windows Performance Monitor may not be available on Windows CE, 95, 98, or Me.

☞ For more information, see QueryLowMemoryStrategy in "Connection-level properties" [*ASA Database Administration Guide*, page 647].

Merge join

The merge join reads two inputs which are both ordered by the join attributes. For each row of the left input, the algorithm reads all of the matching rows of the right input by accessing the rows in sorted order.

If the inputs are not already ordered by the join attributes (perhaps because of an earlier merge join or because an index was used to satisfy a search condition), then the optimizer adds a sort to produce the correct row order. This sort adds cost to the merge join.

One advantage of a merge join compared to a hash join is that the cost of sorting can be amortized over several joins, provided that the merge joins are over the same attributes. The optimizer will choose merge join over a hash join if the sizes of the inputs are likely to be similar, or if it can amortize the cost of the sort over several operations.

Recursive hash join

The recursive hash join is a variant of the hash join algorithm that is used in recursive union queries.

☞ For more information, see "Hash join" on page 383, and "Recursive common table expressions" on page 314.

Recursive left outer hash join

The recursive left outer hash join is a variant of the hash join algorithm used in certain recursive union queries.

☞ For more information, see "Hash join" on page 383, and "Recursive common table expressions" on page 314.

Duplicate elimination

A duplicate elimination operator produces an output that has no duplicate rows. Duplicate elimination nodes may be introduced by the optimizer, for example, when converting a nested query into a join.

☞ For more information, see "Hash distinct" on page 386, "Ordered distinct" on page 387, and "Indexed distinct" on page 387.

Hash distinct

The hash distinct algorithm reads its input, and builds an in-memory hash table. If an input row is found in the hash table, it is ignored; otherwise it is written to a work table. If the input does not completely fit into the in-memory hash table, it is partitioned into smaller work tables, and processed recursively.

The hash distinct algorithm works very well if the distinct rows fit into an in-memory table, irrespective of the total number of rows in the input.

The hash distinct uses a work table, and as such can provide insensitive or value sensitive semantics.

If the hash distinct algorithm executes in an environment where there is very little cache memory available, then it will not be able to complete. In this case, the hash distinct method discards its interim results, and the indexed distinct algorithm is used instead. The optimizer avoids generating access plans using the hash distinct algorithm if it detects that a low memory situation may occur during query execution.

The hash distinct returns a row as soon as it finds one that has not previously been returned. However, the results of a hash distinct must be fully materialized before returning from the query. If necessary, the optimizer adds a work table to the execution plan to ensure this.

Hash distinct locks the rows of its input.

Ordered distinct

If the input is ordered by all the columns, then an ordered distinct can be used. This algorithm reads each row and compares it to the previous row. If it is the same, it is ignored; otherwise, it is output. The ordered distinct is effective if rows are already ordered (perhaps because of an index or a merge join); if the input is not ordered, the optimizer inserts a sort. No work table is used by the ordered distinct itself, but one is used by any inserted sort.

Indexed distinct

The indexed distinct algorithm maintains a work table of the unique rows from the input. As rows are read from the input, an index on the work table is searched to find a previously seen duplicate of the input row. If one is found, the input row is ignored. Otherwise, the input row is inserted into the work table. The work table index is created on all the columns of the SELECT list; in order to improve index performance, a hash expression is included as the first expression. This hash expression is a computed value embodying the values of all the columns in the SELECT list.

The indexed distinct method returns distinct rows as they are encountered. This allows it to return the first few rows quickly compared to other duplicate elimination methods. The indexed distinct algorithm only stores two rows in memory at a time, and can work well in extremely low memory situations. However, if the number of distinct rows is large, the execution cost of the indexed distinct algorithm is typically worse than hash distinct. The work table used to store distinct rows may not fit in cache, leading to rereading work table pages many times in a random access pattern.

Since the indexed distinct method uses a work table, it cannot provide fully sensitive semantics; however, it also does not provide fully insensitive semantics, and another work table is required for insensitive cursors.

The indexed distinct method locks the rows of its input.

Grouping

Grouping algorithms compute a summary of their input. They are applicable only if the query contains a GROUP BY clause, or if the query contains aggregate functions (such as `SELECT COUNT(*) FROM T`).

☞ For more information, see “Hash group by” on page 388, “Ordered group by” on page 388, “Indexed group by” on page 388, and “Single group by” on page 388.

Hash group by

The hash group by algorithm creates an in-memory hash table of group rows. As rows are read from the input, the group rows are updated. If the hash table doesn't fit into memory, the input is partitioned into smaller work tables which are recursively partitioned until they fit into memory. If there is not enough memory for the partitions, the optimizer discards the interim results from the hash group by, and uses an indexed group by algorithm. The optimizer avoids generating access plans using the hash group by algorithm if it detects that a low memory situation may occur during query execution.

The hash group by algorithm works very well if the groups fit into memory, irrespective of the size of the input.

The hash group by algorithm computes all of the rows of its result before returning the first row, and can be used to satisfy a fully sensitive or values sensitive cursor. The results of the hash group by must be fully materialized before returning from the query. If necessary, the optimizer adds a work table to the execution plan to ensure this.

Ordered group by

The ordered group by reads an input that is ordered by the grouping columns. As each row is read, it is compared to the previous row. If the grouping columns match, then the current group is updated; otherwise, the current group is output and a new group is started.

Indexed group by

The indexed group by algorithm is similar to the indexed distinct algorithm. It builds a work table containing one row per group. As input rows are read, the associated group is looked up in the work table using an index. The aggregate functions are updated, and the group row is rewritten to the work table. If no group record is found, a new group record is initialized and inserted into the work table.

Indexed group by is chosen when the optimizer is reasonably certain that the size of the input is very small.

The indexed group by computes all the rows of its result before returning the first row, and fully materializes its input. It can be used to satisfy a FULLY INSENSITIVE requirement.

Single group by

When no GROUP BY is specified, a single row aggregate is produced.

Sorting and unions

Sorting algorithms are applicable when the query includes an order by clause, and union algorithms are applicable for union queries.

☞ For more information, see "Merge sort" on page 389 and "Union all" on page 389.

Merge sort

The sort operator reads its input into memory, sorts it in memory, and then outputs the sorted results. If the input does not completely fit into memory, then several sorted runs are created and then merged together. Sort does not return any rows until it has read all of the input rows. Sort locks its input rows.

If the merge sort algorithm executes in an environment where there is very little cache memory available, it may not be able to complete. In this case, the merge sort orders the remainder of the input using an indexed-based sort method. Input rows are read and inserted into a work table, and an index is built on the ordering columns of the work table. In this case, rows are read from the work table using a complex index scan. This indexed-based strategy is significantly slower than other join methods. The optimizer avoids generating access plans using a merge sort algorithm if it detects that a low memory situation may occur during query execution. When the index-based strategy is needed due to low memory, a performance counter is incremented; you can read this monitor with the QueryLowMemoryStrategy property, or in the "Query: Low Memory Strategies" counter in Windows Performance Monitor.

Sort performance is affected by the size of the sort key, the row size, and the total size of the input. For large rows, it may be cheaper to use a VALUES SENSITIVE cursor. In that case, columns in the SELECT list are not copied into the work tables used by the sort. While the sort does not write output rows to a work table, the results of the wort must be materialized before rows are returned to the application. If necessary, the optimizer adds a work table to ensure this.

Union all

The union all algorithm reads rows from each of its inputs and outputs them, regardless of duplicates. This algorithm is used to implement UNION and UNION ALL clauses. In the UNION case, a duplicate elimination algorithm is needed to remove any duplicates generated by the union all.

Recursive union

The recursive union algorithm is employed during the execution of recursive union queries.

☞ For more information, see “Recursive common table expressions” on page 314.

Sort Top N

The Sort Top N algorithm is used for queries that contain a TOP N clause and an ORDER BY clause. It is an efficient algorithm for sorting only those rows required in the result set.

☞ For more information, see “SELECT statement” [*ASA SQL Reference,* page 541].

Miscellaneous

The following are additional methods that may be used in an access plan.

Filter, pre-filter and hash-filter

Filters apply search conditions. The search conditions appear in the statement in the WHERE and HAVING clauses and in the ON conditions of JOINS in the FROM clause.

Pre-filter is the same as filter, except that it doesn’t depend on input. For example, in the case of `WHERE 1 = 2` a pre-filter applies.

A hash-filter can be used when an execution plan fetches all of the rows of one table before fetching any rows from another table that joins to it. The hash filter builds an array of bits, and turns one bit on for each row of the first table that matches search conditions on that table. When accessing the second table, rows that could not possibly join with the first table are rejected.

For example, consider the plan:

```
R<idx> *JH S<seq> JH* T<idx>
```

Here we are joining R to S and T. We will have read all of the rows of R before reading any row from T, and we can immediately reject rows of T that can not possibly join with R. This reduces the number of rows that must be stored in the second hash join.

☞ For more information, see “The WHERE clause: specifying rows” on page 219.

Lock

Lock indicates that there is a lock at a certain isolation level. For example, at isolation level 1, a lock is maintained for only one row at a time. If you are at isolation level 0, no lock is acquired, but the node will still be called Lock. In this case, the lock node verifies that the row still exists.

☞ For more information, see “How locking works” on page 131.

Row limit

Row limits are set by the TOP n or FIRST clause of the SELECT statement.

☞ For more information, see “SELECT statement” [*ASA SQL Reference*, page 541].

Bloom filter

The Bloom filter or hash map is a data structure that represents the distribution of values in a column or set of columns. It may be used in queries that satisfy the following conditions:

- An operation in the query reads its entire input before returning a row to later operations. For example, a join of two tables on a single column requires that all the relevant rows be read to establish whether they meet the criterion for the join.
- A later operation in the query refers to the rows in the result of the operation. For example, a second join on the same column would use only those rows that satisfy the first join.

Explode

The Explode algorithm is used during the execution of set operations such as EXCEPT and INTERSECT. It is a feature of such operations that the number of rows in the result set is explicitly related to the number of rows in the two sets being operated on. The Explode algorithm ensures that the number of rows in the result set is correct.

☞ For more information, see “Performing set operations on query results with UNION, INTERSECT, and EXCEPT” on page 251.

Physical data organization and access

Storage allocations for each table or entry have a large impact on the efficiency of queries. The following points are of particular importance because each influence how fast your queries execute.

Disk allocation for inserted rows

Adaptive Server Anywhere stores rows contiguously, if possible

Every new row that is smaller than the page size of the database file will always be stored on a single page. If no present page has enough free space for the new row, Adaptive Server Anywhere writes the row to a new page. For example, if the new row requires 600 bytes of space but only 500 bytes are available on a partially filled page, then Adaptive Server Anywhere places the row on a new page.

To make table pages more contiguous on the disk, Adaptive Server Anywhere allocates table pages in blocks of eight pages. For example, when it needs to allocate a page it allocates eight pages, inserts the page in the block, and then fills up with the block with the next seven pages. In addition, it uses a free page bitmap to find contiguous blocks of pages within the dbspace, and performs sequential scans by reading groups of 64K, using the bitmap to find relevant pages. This leads to more efficient sequential scans.

Adaptive Server Anywhere may store rows in any order

Adaptive Server Anywhere locates space on pages and inserts rows in the order it receives them in. It assigns each to a page, but the locations it chooses in the table may not correspond to the order they were inserted in. For example, the engine may have to start a new page to store a long row contiguously. Should the next row be shorter, it may fit in an empty location on a previous page.

The rows of all tables are unordered. If the order that you receive or process the rows is important, use an ORDER BY clause in your SELECT statement to apply an ordering to the result. Applications that rely on the order of rows in a table can fail without warning.

If you frequently require the rows of a table to be in a particular order, consider creating an index on those columns specified in the query's ORDER BY clause.

Space is not reserved for NULL columns

Whenever Adaptive Server Anywhere inserts a row, it reserves only the space necessary to store the row with the values it contains at the time of creation. It reserves no space to store values that are NULL. It reserves no extra space to accommodate fields, such as text strings, which may enlarge.

Once inserted, rows identifiers are immutable

Once assigned a home position on a page, a row never moves from that page. If an update changes any of the values in the row so it no longer fits in its assigned page, then the row splits and the extra information is inserted on another page.

This characteristic deserves special attention, especially since Adaptive Server Anywhere allows no extra space when you insert the row. For example, suppose you insert a large number of empty rows into a table, then fill in the values, one column at a time, using update statements. The result would be that almost every value in a single row will be stored on a separate page. To retrieve all the values from one row, the engine may need to read several disk pages. This simple operation would become extremely and unnecessarily slow.

You should consider filling new rows with data at the time of insertion. Once inserted, they then have sufficient room for the data you expect them to hold.

A database file never shrinks

As you insert and delete rows from the database, Adaptive Server Anywhere automatically reuses the space they occupy. Thus, Adaptive Server Anywhere may insert a row into space formerly occupied by another row.

Adaptive Server Anywhere keeps a record of the amount of empty space on each page. When you ask it to insert a new row, it first searches its record of space on existing pages. If it finds enough space on an existing page, it places the new row on that page, reorganizing the contents of the page if necessary. If not, it starts a new page.

Over time, however, if you delete a number of rows and don't insert new rows small enough to use the empty space, the information in the database may become sparse. You can reload the table, or use the REORGANIZE TABLE statement to defragment the table.

☞ For more information, see "REORGANIZE TABLE statement" [*ASA SQL Reference*, page 522].

Table and page sizes

The page size you choose for your database can affect the performance of your database. In general, smaller page sizes are likely to benefit operations that retrieve a relatively small number of rows from random locations. By contrast, larger pages tend to benefit queries that perform sequential table scans, particularly when the rows are stored on pages in the order the rows are retrieved via an index. In this situation, reading one page into memory to obtain the values of one row may have the side effect of loading the contents of the next few rows into memory. Often, the physical design of disks permits them to retrieve fewer large blocks more efficiently than many small ones.

Adaptive Server Anywhere creates a bitmap for sufficiently large tables within databases that have at least a 2K page size. Each table's bitmap reflects the position of each table page in the entire dbspace file. For databases of 2K, 4K, or 8K pages, the server utilizes the bitmap to read large blocks (64K) of table pages instead of single pages at a time, reducing the total number of I/O operations to disk and hence improving performance. Users cannot control the server's criteria for bitmap creation or usage.

Note that bitmaps, also called page maps, are only available for databases created in version 8.0 and higher. If a database is upgraded from an older version, the server will not create a bitmap for database tables, even if they meet its criteria. Bitmaps are not created for work tables or system tables.

Should you choose a larger page size, such as 4 kb, you may wish to increase the size of the cache. Fewer large pages can fit into the same space. For example, 1 Mb of memory can hold 1000 pages that are each 1 kb in size, but only 250 pages that are 4 kb in size. How many pages is enough depends entirely on your database and the nature of the queries your application performs. You can conduct performance tests with various cache sizes. If your cache cannot hold enough pages, performance suffers as Adaptive Server Anywhere begins swapping frequently-used pages to disk.

Page sizes also affect indexes. By default, index pages have a hash size of 10 bytes: they store approximately the first 10 bytes of data for each index entry. This allows for a fan-out of roughly 200 using 4K pages, meaning that each index page holds 200 rows, or 40 000 rows with a two-level index. Each new level of an index allows for a table 200 times larger. Page size can significantly affect fan-out, in turn affecting the depth of index required for a table. Large databases should have 4K pages.

Adaptive Server Anywhere attempts to fill pages as much as possible. Empty space accumulates only when new objects are too large to fit empty space on existing pages. Consequently, adjusting the page size may not significantly affect the overall size of your database.

Indexes

Indexes can greatly improve the performance of searches on the indexed column(s). However, indexes take up space within the database and slow down insert, update, and delete operations. This section will help you to determine when you should create an index and tell you how to achieve maximum performance from your index.

There are many situations in which creating an index improves the performance of a database. An index provides an ordering of the rows of a table on the basis of the values in some or all of the columns. An index allows Adaptive Server Anywhere to find rows quickly. It permits greater concurrency by limiting the number of database pages accessed. An index also affords Adaptive Server Anywhere a convenient means of enforcing a uniqueness constraint on the rows in a table.

The Index Consultant is a tool that assists you in the selection of an appropriate set of indexes for your database. For more information, see "Index Consultant overview" on page 63.

When to create an index

There is no simple formula to determine whether or not an index should be created for a particular column. You must consider the tradeoff of the benefits of indexed retrieval versus the maintenance overhead of that index. The following factors may help to determine whether you should create an index.

- **Keys and unique columns** Adaptive Server Anywhere automatically creates indexes on primary keys, foreign keys, and unique columns. You should not create additional indexes on these columns. The exception is composite keys, which can sometimes be enhanced with additional indexes.

  ☞ For more information, see "Composite indexes" on page 397.

- **Frequency of search** If a particular column is searched frequently, you can achieve performance benefits by creating an index on that column. Creating an index on a column that is rarely searched may not be worthwhile.

- **Size of table** Indexes on relatively large tables with many rows provide greater benefits than indexes on relatively small tables. For example, a table with only 20 rows is unlikely to benefit from an index, since a sequential scan would not take any longer than an index lookup.

- **Number of updates** An index is updated every time a row is inserted or deleted from the table and every time an indexed column is updated. An index on a column slows the performance of inserts, updates and deletes. A database that is frequently updated should have fewer indexes than one that is read-only.

- **Space considerations** Indexes take up space within the database. If database size is a primary concern, you should create indexes sparingly.
- **Data distribution** If an index lookup returns too many values, it is more costly than a sequential scan. Adaptive Server Anywhere does not make use of the index when it recognizes this condition. For example, Adaptive Server Anywhere would not make use of an index on a column with only two values, such as employee.sex in the sample database. For this reason, you should not create an index on a column that has only a few distinct values.

The Index Consultant is a tool that assists you in the selection of an appropriate set of indexes for your database. For more information, see "Index Consultant overview" on page 63.

Temporary tables

You can create indexes on both local and global temporary tables. You may want to consider indexing a temporary table if you expect it will be large and accessed several times in sorted order or in a join. Otherwise, any improvement in performance for queries is likely to be outweighed by the cost of creating and dropping the index.

☞ For more information, see "Working with indexes" on page 58.

Improving index performance

If your index is not performing as well as expected, you may want to consider the following actions.

- Reorganize composite indexes.
- Increase the page size.

These measures are aimed at increasing index selectivity and index fan-out, as explained below.

Index selectivity

Index selectivity refers to the ability of an index to locate a desired index entry without having to read additional data.

If selectivity is low, additional information must be retrieved from the table page that the index references. These retrievals are called **full compares**, and they have a negative effect on index performance.

The FullCompare property function keeps track of the number of full compares that have occurred. You can also monitor this statistic using the Sybase Central Performance monitor or the Windows Performance Monitor.

Note: Windows Performance Monitor may not be available on Windows CE, 95, 98, or Me.

In addition, the number of full compares is provided in the graphical plan with statistics. For more information, see "Common statistics used in the plan" on page 422.

☞ For more information on the FullCompare function, see "Database-level properties" [*ASA Database Administration Guide*, page 664].

Index structure and index fan-out

Indexes are organized in a number of levels, like a tree. The first page of an index, called the root page, branches into one or more pages at the next level, and each of those pages branch again, until the lowest level of the index is reached. These lowest level index pages are called leaf pages. To locate a specific row, an index with *n* levels requires *n* reads for index pages and one read for the data page containing the actual row. In general, fewer than *n* reads from disk are needed, since index pages that are used frequently tend to be stored in cache.

The **index fan-out** is the number of index entries stored on a page. An index with a higher fan-out may have fewer levels than an index with a lower fan-out. Therefore, higher index fan-out generally means better index performance.

You can see the number of levels in an index by using the sa_index_levels system procedure.

☞ For more information, see "sa_index_levels system procedure" [*ASA SQL Reference*, page 720].

Composite indexes

An index can contain one, two, or more columns. An index on two or more columns is called a **composite index**. For example, the following statement creates a two-column composite index:

```
CREATE INDEX name
ON employee (emp_lname, emp_fname)
```

A composite index is useful if the first column alone does not provide high selectivity. For example, a composite index on emp_lname and emp_fname is useful when many employees have the same last name. A composite index on emp_id and emp_lname would not be useful because each employee has a unique ID, so the column emp_lname does not provide any additional selectivity.

Additional columns in an index can allow you to narrow down your search, but having a two-column index is not the same as having two separate indexes. A composite index is structured like a telephone book, which first sorts people by their last names, and then all the people with the same last name by their first names. A telephone book is useful if you know the last name, even more useful if you know both the first name and the last name, but worthless if you only know the first name and not the last name.

The compressed B-tree index method substantially improves performance for composite indexes.

Column order

When you create composite indexes, you should think carefully about the order of the columns. Composite indexes are useful for doing searches on all of the columns in the index or on the first columns only; they are not useful for doing searches on any of the later columns alone.

If you are likely to do many searches on one column only, that column should be the first column in the composite index. If you are likely to do individual searches on both columns of a two-column index, you may want to consider creating a second index that contains the second column only.

Primary keys that have more than one column are always automatically indexed as composite indexes with their columns in the order that they appear in the table definition, not in the order that they are specified in the primary key definition. You should consider the searches that you will execute involving the primary key to determine which column should come first. Consider adding an extra index on any later column of the primary key that is frequently searched.

For example, suppose you create a composite index on two columns. One column contains employee's first names, the other their last names. You could create an index that contains their first name, then their last name. Alternatively, you could index the last name, then the first name. Although these two indexes organize the information in both columns, they have different functions.

```
CREATE INDEX fname_lname
   ON employee emp_fname, emp_lname;
CREATE INDEX lname_fname
   ON employee emp_lname, emp_fname;
```

Suppose you then want to search for the first name John. The only useful index is the one containing the first name in the first column of the index. The index organized by last name then first name is of no use because someone with the first name John could appear anywhere in the index.

If you think it likely that you will need to look up people by first name only or second name only, then you should consider creating both of these indexes.

Alternatively, you could make two indexes, each containing only one of the columns. Remember, however, that Adaptive Server Anywhere only uses one index to access any one table while processing a single query. Even if you know both names, it is likely that Adaptive Server Anywhere will need to read extra rows, looking for those with the correct second name.

When you create an index using the CREATE INDEX command, as in the example above, the columns appear in the order shown in your command.

Primary key indexes and column order

The order of the columns in a primary key index is enforced to be the same as the order in which the columns appear in the table's definition, regardless as to the ordering of the columns specified in the PRIMARY KEY constraint. Moreover, Adaptive Server Anywhere enforces an additional constraint that a table's primary key columns must be at the beginning of each row. Hence if a primary key is added to an existing table the server may rewrite the entire table to ensure that the key columns are at the beginning of each row.

In situations where more than one column appears in a primary key, you should consider the types of searches needed. If appropriate, switch the order of the columns in the table definition so the most frequently searched-for column appears first, or create separate indexes, as required, for the other columns.

Composite indexes and ORDER BY

By default, the columns of an index are sorted in ascending order, but they can optionally be sorted in descending order by specifying DESC in the CREATE INDEX statement.

Adaptive Server Anywhere can choose to use an index to optimize an ORDER BY query as long as the ORDER BY clause contains only columns included in that index. In addition, the columns in the index must be ordered in exactly the same way, or in exactly the opposite way, as the ORDER BY clause. For single-column indexes, the ordering is always such that it can be optimized, but composite indexes require slightly more thought. The table below shows the possibilities for a two-column index.

Index columns	Optimizable ORDER BY queries	Not optimizable ORDER BY queries
ASC, ASC	ASC, ASC or DESC, DESC	ASC, DESC or DESC, ASC
ASC, DESC	ASC, DESC or DESC, ASC	ASC, ASC or DESC, DESC
DESC, ASC	DESC, ASC or ASC, DESC	ASC, ASC or DESC, DESC
DESC, DESC	DESC, DESC or ASC, ASC	ASC, DESC or DESC, ASC

An index with more than two columns follows the same general rule as above. For example, suppose you have the following index:

```
CREATE INDEX idx_example
ON table1 (col1 ASC, col2 DESC, col3 ASC)
```

In this case, the following queries can be optimized:

```
SELECT col1, col2, col3 from table1
ORDER BY col1 ASC, col2 DESC, col3 ASC
```

and

```
SELECT col1, col2, col3 from example
ORDER BY col1 DESC, col2 ASC, col3 DESC
```

The index is not used to optimize a query with any other pattern of ASC and DESC in the ORDER BY clause. For example:

```
SELECT col1, col2, col3 from table1
ORDER BY col1 ASC, col2 ASC, col3 ASC
```

is not optimized.

Other uses for indexes

Adaptive Server Anywhere uses indexes to achieve other performance benefits. Having an index allows Adaptive Server Anywhere to enforce column uniqueness, to reduce the number of rows and pages that must be locked, and to better estimate the selectivity of a predicate.

- **Enforce column uniqueness** Without an index, Adaptive Server Anywhere has to scan the entire table every time that a value is inserted to ensure that it is unique. For this reason, Adaptive Server Anywhere automatically builds an index on every column with a uniqueness constraint.

- **Reduce locks** Indexes reduce the number of rows and pages that must be locked during inserts, updates, and deletes. This reduction is a result of the ordering that indexes impose on a table.

  ☞ For more information on indexes and locking, see "How locking works" on page 131.

- **Estimate selectivity** Because an index is ordered, the optimizer can estimate the percentage of values that satisfy a given query by scanning the upper levels of the index. This action is called a partial index scan.

Types of index

Adaptive Server Anywhere supports two types of index, and automatically chooses between them depending on the declared width of the indexed columns. For a total column width that is less than 10 bytes, Adaptive Server Anywhere uses a B-tree index that contains an order-preserving encoding, or hash value, that represents the indexed data. Hash B-tree indexes are also used when the index key length is longer than one-eighth of the page size for the database or 256 bytes (whichever is lower). For data values whose combined declared length is between these two bounds, Adaptive Server Anywhere uses a compressed B-tree index that stores each key in a compressed form.

Indexes can be stored as either clustered or unclustered. Clustered indexes may assist performance, but only one index on a table can be clustered.

Hash B-tree indexes

A hash B-tree index does not store the actual row value(s) from the table. Instead, a hash B-tree index stores an order-preserving encoding of the original data. The number of bytes in each index entry used to store this hash value is termed the hash size, and is automatically chosen by the server based on the declared width of all of the indexed columns. The server compares these hashed values as it searches through an index to find a particular row.

Hash values

Adaptive Server Anywhere must represent values in an index to decide how to order them. For example, if you index a column of names, then it must know that Amos comes before Smith.

For each value in your index, Adaptive Server Anywhere creates a corresponding hash value. It stores the hash value in the index, rather than the actual value. Adaptive Server Anywhere can perform operations with the hash value. For example, it can tell when two values are equal or which of two values is greater.

When you index a small storage type, such as an integer, the hash value that

Adaptive Server Anywhere creates takes the same amount of space as the original value. For example, the hash value for an integer is 4 bytes in size, the same amount of space as required to store an integer. Because the hash value is the same size, Adaptive Server Anywhere can use hash values with a one-to-one correspondence to the actual value. Adaptive Server Anywhere can always tell whether two values are equal, or which is greater by comparing their hash values. However, it can retrieve the actual value only by reading the entry from the corresponding table.

When you index a column containing larger data types, the hash value will often be shorter than the size of the type. For example, if you index a column of string values, the hash value used is at most 9 bytes in length. Consequently, Adaptive Server Anywhere cannot always compare two strings using only the hash values. If the hash values are equal, Adaptive Server Anywhere must retrieve and compare the actual two values from the table.

For example, suppose you index the titles of books, many of which are similar. If you wish to search for a particular title, the index may identify only a set of possible rows. In this case, Adaptive Server Anywhere must retrieve each of the candidate rows and examine the full title.

Composite indexes

An ordered sequence of columns is also called a composite index. However, each index key in these indexes is at most a 9 byte hash value. Hence, the hash value cannot necessarily identify the correct row uniquely. When two hash values are equal, Adaptive Server Anywhere must retrieve and compare the actual values.

Compressed B-tree indexes

Compressed B-tree indexes store a compressed form of each indexed value in the index's internal nodes. To do this, compressed B-tree indexes store the values using Patricia tries, an optimized form of a trie data structure that is augmented with a skip-count to compress its representation. As a result, compressed B-tree indexes offer substantial improvements over hash indexes when the overall data length is reasonably large. More significantly, the compaction algorithm efficiently handles index values that are identical (or nearly so), so common substrings within the indexed values have negligible impact on storage requirements and performance. Compressed B-tree indexes are chosen automatically if the sum of the declared width of the indexed columns is between 10 bytes and one-eighth of the database page size to a maximum of 256 bytes.

Recommended page sizes

The page size of the database can have a significant effect on the index fan-out. The index fan-out approximately doubles as the page size doubles.

Each index lookup requires one page read for each of the levels of the index plus one page read for the table page, and a single query can require several thousand index lookups. A large fan-out often means that fewer index levels are required, which can improve searches considerably. For this reason, consider using a large page size, such as 4K, to improve index performance. You may also want to consider using a larger page size when you wish to index long string columns using compressed B-tree indexes, but the size limit on smaller page sizes is preventing their creation.

Semantic query transformations

To operate efficiently, Adaptive Server Anywhere usually rewrites your query, possibly in several steps, into a new form. It ensures that the new version computes the same result, even though it expresses the query in a new way. In other words, Adaptive Server Anywhere rewrites your queries into semantically equivalent, but syntactically different, forms.

Adaptive Server Anywhere can perform a number of different rewrite operations. If you read the access plans, you will frequently find that they do not correspond to a literal interpretation of your original statement. For example, the optimizer tries as much as possible to rewrite subqueries with joins. The fact that the optimizer has the freedom to rewrite your SQL statements and some of the ways in which it does so, are of importance to you.

Example

Unlike the SQL language definition, some languages mandate strict behavior for AND and OR operations. Some guarantee that the left-hand condition will be evaluated first. If the truth of the entire condition can then be determined, the compiler guarantees that the right-hand condition will not be evaluated.

This arrangement lets you combine conditions that would otherwise require two nested IF statements into one. For example, in C you can test whether a pointer is NULL before you use it as follows. You can replace the nested conditions

```
if ( X != NULL ) {
   if ( X->var != 0 ) {
      ... statements ...
   }
}
```

with the more compact expression

```
if ( X != NULL && X->var != 0 ) {
      ... statements ...
}
```

Unlike C, SQL has no such rules concerning execution order. Adaptive Server Anywhere is free to rearrange the order of such conditions as it sees fit. The reordered form is semantically equivalent because the SQL language specification makes no distinction. In particular, query optimizers are completely free to reorder predicates in a WHERE, HAVING, and ON clause.

Predicate analysis

A **predicate** is a conditional expression that, combined with the logical operators AND and OR, makes up the set of conditions in a WHERE, HAVING, or ON clause. In SQL, a predicate that evaluates to UNKNOWN is interpreted as FALSE.

A predicate that can exploit an index to retrieve rows from a table is called **sargable**. This name comes from the phrase *search argument-able* . Predicates that involve comparisons of a column with constants, other columns, or expressions may be sargable.

The predicate in the following statement is sargable. Adaptive Server Anywhere can evaluate it efficiently using the primary index of the employee table.

```
SELECT *
FROM employee
WHERE employee.emp_id = 123
```

employee<employee>

In contrast, the following predicate is *not* sargable. Although the emp_id column is indexed in the primary index, using this index does not expedite the computation because the result contains all, or all except one, row.

```
SELECT *
FROM employee
where employee.emp_id <> 123
```

employee<seq>

Similarly, no index can assist in a search for all employees whose first name *ends* in the letter "k". Again, the only means of computing this result is to examine each of the rows individually.

Functions

In general, a predicate that has a function on the column name is not sargable. For example, an index would not be used on the following query:

```
SELECT * from sales_order
WHERE year(order_date)='2000'
```

You can sometimes rewrite a query to avoid using a function, thus making it sargable. For example, you can rephrase the above query:

```
SELECT * from sales_order
WHERE order_date > '1999-12-31'
AND order_date < '2001-01-01'
```

A query that uses a function becomes sargable if you store the function values in a computed column and build an index on this column. A **computed column** is a column whose values are obtained from other columns in the table. For example, if you have a column called order_date that holds the date of an order, you can create a computed column called order_year that holds the values for the year extracted from the order_date column.

```
ALTER TABLE sales_order
ADD order_year INTEGER
COMPUTE year(order_date)
```

You can then add an index on the column order_year in the ordinary way:

```
CREATE INDEX idx_year
ON sales_order (order_year)
```

If you then execute the following statement

```
SELECT * from sales_order
WHERE year(order_date) = '2000'
```

the server recognizes that there is an indexed column that holds that information and uses that index to answer the query.

The domain of the computed column must be equivalent to the domain of the COMPUTE expression in order for the column substitution to be made. In the above example, if `year(order_date)` had returned a string instead of an integer, the optimizer would not have substituted the computed column for the expression, and consequently the index idx_year could not have been used to retrieve the required rows.

☞ For more information about computed columns, see "Working with computed columns" on page 46.

Examples

In each of these examples, attributes *x* and *y* are each columns of a single table. Attribute *z* is contained in a separate table. Assume that an index exists for each of these attributes.

Sargable	**Non-sargable**
$x = 10$	$x <> 10$
x IS NULL	x IS NOT NULL
$x > 25$	$x = 4$ OR $y = 5$
$x = z$	$x = y$
x IN (4, 5, 6)	x NOT IN (4, 5, 6)
x LIKE ‘pat%’	x LIKE ‘%tern’
$x = 20 - 2$	$x + 2 = 20$

Sometimes it may not be obvious whether a predicate is sargable. In these cases, you may be able to rewrite the predicate so it is sargable. For each example, you could rewrite the predicate x LIKE ‘pat%’ using the fact that “u” is the next letter in the alphabet after “t”: $x >=$ ’pat’ and $x <$ ’pau’. In this form, an index on attribute x is helpful in locating values in the restricted range. Fortunately, Adaptive Server Anywhere makes this particular transformation for you automatically.

A sargable predicate used for indexed retrieval on a table is a **matching** predicate. A WHERE clause can have a number of matching predicates. Which is most suitable can depend on the join strategy. The optimizer re-evaluates its choice of matching predicates when considering alternate join strategies.

Types of semantic transformations

The optimizer can perform a number of transformations in search of more efficient and convenient representations of your query. Because the optimizer performs these transformations, the plan may look quite different from a literal interpretation of your original query. Common manipulations include:

- unnecessary DISTINCT elimination
- subquery unnesting
- predicate pushdown in UNION or GROUPed views
- join elimination
- optimization for minimum or maximum functions
- OR, in-list optimization
- LIKE optimizations

- conversion of outer joins to inner joins
- discovery of exploitable conditions through predicate inference
- elimination of unnecessary case translation

The following subsections discuss each of these operations.

Unnecessary DISTINCT elimination

Sometimes a DISTINCT condition is unnecessary. For example, the properties of one or more column in your result may contain a UNIQUE condition, either explicitly, or implicitly because it is in fact a primary key.

Examples

The distinct keyword in the following command is unnecessary because the product table contains the primary key p.id, which is part of the result set.

```
SELECT DISTINCT p.id, p.quantity
FROM product p
```

```
p<seq>
```

The database server actually executes the semantically equivalent query:

```
SELECT p.id, p.quantity
FROM product p
```

Similarly, the result of the following query contains the primary keys of both tables so each row in the result must be distinct.

```
SELECT DISTINCT *
FROM sales_order o JOIN customer c
   ON o.cust_id = c.id
WHERE c.state = 'NY'
```

```
c<seq> JNL o<ix_sales_cust>
```

Subquery unnesting

You may express statements as nested queries, given the convenient syntax provided in the SQL language. However, rewriting nested queries as joins often leads to more efficient execution and more effective optimization, since Adaptive Server Anywhere can take better advantage of highly selective conditions in a subquery's WHERE clause.

Examples

The subquery in the following example can match at most one row for each row in the outer block. Because it can match at most one row, Adaptive Server Anywhere recognizes that it can convert it to an inner join.

```
SELECT s.*
FROM sales_order_items s
WHERE EXISTS
    (   SELECT *
      FROM product p
      WHERE s.prod_id = p.id
         AND p.id = 300 AND p.quantity > 300)
```

Following conversion, this same statement is expressed internally using join syntax:

```
SELECT s.*
FROM product p JOIN sales_order_items s
   ON p.id = s.prod_id
WHERE p.id = 300 AND p.quantity > 20
```

```
p<seq> JNL s<ky_prod_id>
```

Similarly, the following query contains a conjunctive EXISTS predicate in the subquery. This subquery can match more than one row.

```
SELECT p.*
FROM product p
WHERE EXISTS
    (   SELECT *
      FROM sales_order_items s
      WHERE s.prod_id = p.id
         AND s.id = 2001)
```

Adaptive Server Anywhere converts this query to an inner join, with a DISTINCT in the SELECT list.

```
SELECT DISTINCT p.*
FROM product p JOIN sales_order_items s
   ON p.id = s.prod_id
WHERE s.id = 2001
```

```
DistI[ s<id_fk> JNL p<product> ]
```

Adaptive Server Anywhere can also eliminate subqueries in comparisons, when the subquery can match at most one row for each row in the outer block. Such is the case in the following query.

```
SELECT *
FROM product p
WHERE p.id =
    (   SELECT s.prod_id
      FROM sales_order_items s
      WHERE s.id = 2001
         AND s.line_id = 1 )
```

Adaptive Server Anywhere rewrites this query as follows.

```
SELECT p.*
FROM product p, sales_order_items s
WHERE p.id = s.prod_id
   AND s.id = 2001
   AND s.line_id = 1
```

p<seq> JNL s<sales_order_items>

The DUMMY table is treated as a special table when subquery unnesting rewrite optimizations are performed. Subquery flattening is always done on subqueries of the form `SELECT expression FROM DUMMY`, even if the subquery is not correlated.

Predicate pushdown into GROUPed or UNION views

It is quite common for queries to restrict the result of a view so that only a few of the records are returned. In cases where the view contains GROUP BY or UNION, it would be preferable for the server to only compute the result for the desired rows.

Example

Suppose we have the view product_summary defined as

```
CREATE VIEW product_summary( product_id, num_orders, total_qty)
         as
SELECT prod_id, count(*), sum( quantity )
FROM sales_order_items
GROUP BY prod_id
```

which returns, for each product ordered, a count of the number of orders that include it, and the sum of the quantities ordered over all of the orders. Now consider the following query over this view:

```
SELECT *
FROM product_summary
WHERE product_id = 300
```

which restricts the output to that for product id 300. The query and the query from the view could be combined into one semantically equivalent SELECT statement, namely:

```
SELECT prod_id, count(*), sum( quantity )
FROM sales_order_items
GROUP BY prod_id
HAVING prod_id = 300.
```

A naive execution plan for this query would involve computing the aggregates for each product, and then restricting the result to only the single row for product ID 300. However, the HAVING predicate on the product_id column can be pushed into the query's WHERE clause since it is a grouping column, yielding

```
SELECT prod_id, count(*), sum( quantity )
FROM sales_order_items
WHERE prod_id = 300
GROUP BY prod_id
```

which significantly reduces the computation required. If this predicate is sufficiently selective, the optimizer could now use an index on prod_id to quickly retrieve only those rows for product 300, rather than sequentially scanning the sales_order_items table.

The same optimization is also used for views involving UNION or UNION ALL.

Join elimination

The join elimination rewrite optimization reduces the join degree of the query by eliminating tables from the query when it is safe to do so. Typically, this optimization is used when the query contains a primary key-foreign key join, and only primary key columns from the primary table are referenced in the query.

Example

For example, the query

```
SELECT s.id, s.line_id, p.id
FROM sales_order_items s KEY JOIN product p
```

would be rewritten as

```
SELECT s.id, s.line_id, s.prod_id
FROM sales_order_items s
WHERE s.prod_id IS NOT NULL.
```

The second query is semantically equivalent to the first because any row from the sales_order_items table that has a NULL foreign key to product will not appear in the result.

The join elimination optimization can also apply to tables involved in outer joins, although the conditions for which the optimization is valid are much more complex. Under certain other conditions, tables involved in primary key-primary key joins may also be candidates for elimination.

Users should be aware that when this optimization is used, the result of a DESCRIBE can differ from the expected result due to the substitution of columns. In addition, an UPDATE or DELETE WHERE CURRENT request may fail if the update statement refers to one or more of the eliminated base tables. To circumvent this problem, either ensure that additional columns from the eliminated table are present in the query's SELECT list (to avoid the optimization in the first place), or update the necessary row(s) using a separate statement.

Optimization for minimum or maximum functions

The min/max rewrite optimization is designed to exploit an existing index to efficiently compute the result of a simple aggregation query involving the MAX() or MIN() aggregate functions. The goal of this optimization is to be able to compute the result with a single-row lookup using the index. To be a candidate for this optimization, the query:

- must not contain a GROUP BY clause
- must be over a single table
- cannot contain anything other than conjunctive equality conditions in the WHERE clause
- must contain only a single aggregate function (MAX or MIN) in the query's SELECT list

Example

To illustrate this optimization, assume that an index prod_qty on (prod_id ASC, quantity ASC) exists on the sales_order_items table. Then the query

```
SELECT MIN( quantity )
FROM sales_order_items
Where prod_id = 300
```

is rewritten internally as

```
SELECT MIN( quantity )
FROM ( SELECT FIRST quantity
       FROM sales_order_items
       WHERE prod_id = 300 and quantity IS NOT NULL
       ORDER BY prod_id ASC, quantity ASC ) as s(quantity)
```

The NULL_VALUE_ELIMINATED warning may not be generated for aggregate queries when this optimization is applied.

The access plan (short form) for the rewritten query is:

```
GrByS[ RL[ sales_order_items<prod_qty> ] ]
```

IN-list optimization

The Adaptive Server Anywhere optimizer supports a special optimization for exploiting IN predicates on indexed columns. This optimization also applies equally to multiple predicates on the same indexed column that are ORed together, since the two are semantically equivalent. To enable the optimization, the IN-list must contain only constants.

When the optimizer encounters a qualifying IN-list predicate, and the IN-list predicate is sufficiently selective to consider indexed retrieval, the optimizer converts the IN-list predicate into a nested-loop join. The following example illustrates how the optimization works.

Suppose we have the query

```
SELECT *
FROM sales_order
WHERE sales_rep = 142 or sales_rep = 1596
```

that lists all of the orders for these two sales reps. This query is semantically equivalent to

```
SELECT *
FROM sales_order
WHERE sales_rep IN (142, 1596)
```

The optimizer estimates the combined selectivity of the IN-list predicate to be high enough to warrant indexed retrieval. Consequently the optimizer treats the IN-list as a virtual table, and joins this virtual table to the sales_order table on the sales_rep attribute. While the net effect of the optimization is to include an additional “join” in the access plan, the join degree of the query is not increased, so optimization time should not be affected.

There are two main advantages of this optimization. First, the IN-list predicate can be treated as a sargable predicate and exploited for indexed retrieval. Second, the optimizer can sort the IN-list to match the sort sequence of the index, leading to more efficient retrieval.

The short form of the access plan for the above query is

```
IN JNL sales_order<ky_so_employee_id>
```

LIKE optimizations

LIKE predicates involving patterns that are either literal constants or host variables are very common. Depending on the pattern, the optimizer may rewrite the LIKE predicate entirely, or augment it with additional conditions that could be exploited to perform indexed retrieval on the corresponding table.

Examples

In each of the following examples, assume that the pattern in the LIKE predicate is a literal constant or host variable, and X is a column in a base table.

- `X LIKE '%'` is rewritten as `X IS NOT NULL`
- `X LIKE 'abc'` is rewritten as `X = 'abc'`
- `X LIKE 'abc%'` is augmented with the predicates `X < 'abcZ'` and `X`

```
> = 'abc_'
```

where Z and _ represent the corresponding high values and low values for the collating sequence of this database. If the database is configured to store blank-padded strings, the second comparison operator is >, not >=, to ensure correct semantics.

Conversion of outer joins to inner joins

For the most part, the optimizer generates a left-deep processing tree for its access plans. The only exception to this rule is the existence of a right-deep nested outer join expression. The query execution engine's algorithms for computing LEFT or RIGHT OUTER JOINs require that preserved tables must precede null-supplying tables in any join strategy. Consequently the optimizer looks for opportunities to convert LEFT or RIGHT outer joins to inner joins whenever possible, since inner joins are commutable and give the optimizer greater degrees of freedom when performing join enumeration.

A LEFT or RIGHT OUTER JOIN can be converted to an inner join when a null-intolerant predicate on the null-supplying table is present in the query's WHERE clause. Since this predicate is null-intolerant, any all-NULL row that would be produced by the outer join will be eliminated from the result, hence making the query semantically equivalent to an inner join.

Example

For example, consider the query

```
SELECT *
FROM product p KEY LEFT OUTER JOIN sales_order_items s
WHERE s.quantity > 15
```

which is intended to list all products and their orders for larger quantities; the LEFT OUTER JOIN is intended to ensure that all products are listed, even if they have no orders. The problem with this query is that the predicate in the WHERE clause will eliminate from the result any product with no orders, because the predicate `s.quantity > 15` will be interpreted as FALSE if `s.quantity` is NULL. Hence the query is semantically equivalent to

```
SELECT *
FROM product p KEY JOIN sales_order_items s
WHERE s.quantity > 15
```

and it is this rewritten form of the query that the server will optimize.

In this example, the query is almost certainly written incorrectly; it should probably read

```
SELECT *
FROM product p
    KEY LEFT OUTER JOIN sales_order_items s
          ON s.quantity > 15
```

so that the test of quantity is part of the outer join condition.

While it is rare for this optimization to apply to straightforward outer join queries, it can often apply when a query refers to one or more views that are written using outer joins. The query's WHERE clause may include conditions that restrict the output of the view such that all null-supplying rows from one or more table expressions would be eliminated, hence making this optimization applicable.

Discovery of exploitable conditions

An efficient access strategy for virtually any query relies on the presence of sargable conditions in the WHERE/ON/HAVING clauses. Indexed retrieval is possible only by exploiting sargable conditions as matching predicates. In addition, hash, merge, and block-nested loop joins can only be used when an equijoin condition is present. For these reasons, Adaptive Server Anywhere does detailed analysis of the search conditions in the original query text in order to discover simplified or implied conditions that can be exploited by the optimizer.

As a preprocessing step, several simplifications are made to predicates in the original statement once view expansion and merging have taken place. For example:

- `X = X` is rewritten as `X IS NOT NULL` if X is nullable; otherwise the predicate is eliminated.
- `ISNULL(X,X)` is rewritten as simply `X`.
- `X+0` is rewritten as `X` if X is a numeric column.
- `AND 1=1` is eliminated.
- `OR 1=0` is eliminated.
- IN-list predicates that consist of a single element are converted to simple equality conditions.

After this preprocessing step, Adaptive Server Anywhere attempts to normalize the original search condition into conjunctive normal form (CNF). For an expression to be in CNF, each term in the expression must be ANDed together. Each term is either made up of a single atomic condition, or a set of conditions ORed together.

Converting an arbitrary condition into CNF may yield an expression of similar complexity but with a much larger set of conditions. Adaptive Server Anywhere recognizes this situation, and refrains from naively converting the condition into CNF. Instead, Adaptive Server Anywhere analyzes the original expression for exploitable predicates that are implied by the original search condition, and ANDs these inferred conditions to the query. Complete normalization is also avoided if this would require duplication of an expensive predicate (for example, a quantified subquery predicate). However, the algorithm will merge IN-list predicates together whenever feasible.

Once the search condition has either been completely normalized or the exploitable conditions have been found, the optimizer performs transitivity analysis to discover transitive equality conditions, primarily transitive join conditions and conditions with a constant. In doing so the optimizer will increase its degrees of freedom when performing join enumeration during its cost-based optimization phase, since these transitive conditions may permit additional alternative join orders.

Example

Suppose the original query is

```
SELECT e.emp_lname, s.id, s.order_date
FROM sales_order s, employee e
WHERE (e.emp_id = s.sales_rep and
          (s.sales_rep = 142 or s.sales_rep = 1596)
      )
         OR
      ( e.emp_id = s.sales_rep and s.cust_id = 667)
```

This query has no conjunctive equijoin condition; hence without detailed predicate analysis the optimizer would fail to discover an efficient access plan. Fortunately, Adaptive Server Anywhere is able to convert the entire expression to CNF, yielding the equivalent query

```
SELECT e.emp_lname, s.id, s.order_date
FROM sales_order as s, employee as e
WHERE e.emp_id = s.sales_rep AND
   (s.sales_rep = 142 or s.sales_rep = 1596 or s.cust_id = 667)'
```

which can now be efficiently optimized as an inner join query.

Elimination of unnecessary case translation

By default, Adaptive Server Anywhere databases support case-insensitive string comparisons. Occasionally the optimizer may encounter queries where the user is explicitly forcing text conversion through the use of the UPPER() or LOWER() built-in functions when such conversion is unnecessary. Adaptive Server Anywhere will automatically eliminate this unnecessary conversion when the database's collating sequence permits it. Eliminating the case translation may then permit the comparison predicate to be used for indexed retrieval of the corresponding table.

Example

On a case insensitive database, the query

```
SELECT *
FROM customer
WHERE UPPER(lname) = 'SMITH'
```

is rewritten internally as

```
SELECT *
FROM customer
WHERE lname = 'SMITH'
```

and the optimizer can now consider using an index on customer.lname.

Subquery and function caching

When Adaptive Server Anywhere processes a subquery, it caches the result. This caching is done on a request-by-request basis; cached results are never shared by concurrent requests or connections. Should Adaptive Server Anywhere need to re-evaluate the subquery for the same set of correlation values, it can simply retrieve the result from the cache. In this way, Adaptive Server Anywhere avoids many repetitious and redundant computations. When the request is completed (the query's cursor is closed), Adaptive Server Anywhere releases the cached values.

As the processing of a query progresses, Adaptive Server Anywhere monitors the frequency with which cached subquery values are reused. If the values of the correlated variable rarely repeat, then Adaptive Server Anywhere needs to compute most values only once. In this situation, Adaptive Server Anywhere recognizes that it is more efficient to recompute occasional duplicate values, than to cache numerous entries that occur only once. Hence the server suspends the caching of this subquery for the remainder of the statement and proceeds to re-evaluate the subquery for each and every row in the outer query block.

Adaptive Server Anywhere also does not cache if the size of the dependent column is more than 255 bytes. In such cases, you may wish to rewrite your query or add another column to your table to make such operations more efficient.

Function caching

Some built-in and user-defined functions are cached in the same way that subquery results are cached. This can result in a substantial improvement for expensive functions that are called during query processing with the same parameters. However, it may mean that a function is called less times than would otherwise be expected.

For a functions to be cached, it must satisfy two conditions:

- ♦ It must always return the same result for a given set of parameters.
- ♦ It must have no side effects on the underlying data.

Functions that satisfy these conditions are called **deterministic** or **idempotent** functions.

Built-in functions are treated as deterministic with a few exceptions. The RAND, NEW_ID, and GET_IDENTITY functions are treated as non-deterministic, and their results are not cached.

User-defined functions are treated as deterministic unless they are specified as NOT DETERMINISTIC when created.

☞ For more information about user-defined functions, see “CREATE FUNCTION statement” [*ASA SQL Reference,* page 315].

Reading access plans

The optimizer can tell you the query optimization strategy (plan) it has chosen in response to any statement.

The optimizer's job is to understand the semantics of your query and to construct a plan that computes its result. This plan may not correspond exactly to the syntax you used. The optimizer is free to rewrite your query in any semantically equivalent form.

☞ For more information about the rules Adaptive Server Anywhere obeys when rewriting your query, see "Rewriting subqueries as EXISTS predicates" on page 374 and "Semantic query transformations" on page 404.

☞ For information about the methods that the optimizer uses to implement your query, see "Query execution algorithms" on page 379.

You can view the plan in Interactive SQL or using SQL functions. You can choose to retrieve the access plan in several different formats:

- Short text
- Long text
- Graphical
- Graphical with statistics
- UltraLite (short, long, or graphical)

As well, you can obtain plans for SQL queries with a particular cursor type.

☞ For more information about how to access the plan, see "Accessing the plan" on page 434. For information about how to read plans, see "Text plans" on page 427 and "Graphical plans" on page 429.

Following is an explanation of the statistics and other items that are displayed in access plans.

Abbreviations used in the plan

Following are the abbreviations that are used in short plan, and in the short name form of the graphical plans:

Name	Short Plan / Short name
Hash except all	EAH
Hash except	EH
Hash group by	GrByH
Hash rollup group by	GrByHR

Name	Short Plan / Short name
Ordered group by	GrByO
Ordered rollup group by	GrByOR
Single row group by	GrByS
Indexed group by	GrByI
Hash distinct	DistH
Indexed distinct	DistI
Ordered distinct	DistO
Sort Top N	StrN
Hash filter	HF
Hash intersect all	IAH
Hash intersect	IH
Exists join	JE
Nested loops semijoin	JNLS
Hash exists	JHE
Hash not exists	JHNE
Hash join	JH
Sorted block	SrtBl
Left outer hash join	JHO
Full outer hash join	JHFO
Recursive hash join	JHR
Left outer recursive hash join	JHRO
Nested block join	JNB
Left outer nested block join	JNBO
Not exists join	JNE
Nested loops join	JNL
Left outer nested loops join	JNLO
Full outer nested loops join	JNLFO
Merge join	JM

Name	Short Plan / Short name
Left outer merge join	JMO
Full outer merge join	JMFO
Merge except	EM
Merge except all	EAM
Merge intersect	IM
Merge intersect all	IAM
Row limit	RL
Row replicate	RR
Recursive table	RT. In short plan is rt<seq>
Recursive union	RU
Union all	UA
Table scan	In short plan is *tablename*<seq>. In graphical plans is just the table name.
Index scan	In short plan is *tablename*<*indexname*>. In graphical plans is just the table name.
In list	IN

☞ For an explanation of the algorithms, see "Query execution algorithms" on page 379.

Common statistics used in the plan

The following statistics are actual, measured amounts.

Statistic	Explanation
Invocations	Number of times a row was requested from the sub tree.
RowsReturned	Number of rows returned for the current node.
RunTime	Time required for execution of the sub-tree, including time for children.
CacheHits	Number of successful reads of the cache.
CacheRead	Number of database pages that have been looked up in the cache.

Statistic	Explanation
CacheReadTable	Number of table pages that have been read from the cache.
CacheReadIndLeaf	Number of index leaf pages that have been read from the cache.
CacheReadIndInt	Number of index internal node pages that have been read from the cache.
DiskRead	Number of pages that have been read from disk.
DiskReadTable	Number of table pages that have been read from disk.
DiskReadIndLeaf	Number of index leaf pages that have been read from disk.
DiskReadIndInt	Number of index internal node pages that have been read from disk.
DiskWrite	Number of pages that have been written to disk (work table pages or modified table pages).
IndAdd	Number of entries that have been added to indexes.
IndLookup	Number of entries that have been looked up in indexes.
FullCompare	Number of comparisons that have been performed beyond the hash value in an index.

Common estimates used in the plan

Statistic	Explanation
EstRowCount	Estimated number of rows that the node will return each time it is invoked.
AvgRowCount	Average number of rows returned on each invocation. This is not an estimate, but is calculated as RowsReturned / Invocations. If this value is significantly different from EstRowCount, the selectivity estimates may be poor.
EstRunTime	Estimated time required for execution (sum of EstDiskReadTime, EstDiskWriteTime, and EstCpuTime).
AvgRunTime	Average time required for execution (measured).
EstDiskReads	Estimated number of read operations from the disk.

Statistic	Explanation
AvgDiskReads	Average number of read operations from the disk (measured).
EstDiskWrites	Estimated number of write operations to the disk.
AvgDiskWrites	Average number of write operations to the disk (measured).
EstDiskReadTime	Estimated time required for reading rows from the disk.
EstDiskWriteTime	Estimated time required for writing rows to the disk.
EstCpuTime	Estimated processor time required for execution.

Items in the plan related to SELECT, INSERT, UPDATE, and DELETE

Item	Explanation
Optimization Goal	Determines whether query processing is optimized towards returning the first row quickly, or minimizing the cost of returning the complete result set. See "OPTIMIZATION_GOAL option [database]" [*ASA Database Administration Guide,* page 613].
ANSI update constraints	Controls the range of updates that are permitted (options are OFF, CURSORS, and STRICT). See "ANSI_UPDATE_CONSTRAINTS option [compatibility]" [*ASA Database Administration Guide,* page 576]
Optimization level	Reserved for future use.
Select list	List of expressions selected by the query.

Items in the plan related to locks

Item	Explanation
Locked tables	List of all locked tables and their isolation levels.

Items in the plan related to scans

Item	Explanation
Table name	Actual name of the table.
Correlation name	Alias for the table.
Estimated rows	Estimated number of rows in the table.
Estimated pages	Estimated number of pages in the table.
Estimated row size	Estimated row size for the table.
Page maps	YES when a page map is used to read multiple pages.

Items in the plan related to index scans

Item	Explanation
Index name	Name of the index.
Key type	Can be one of PRIMARY KEY, FOREIGN KEY, CONSTRAINT (unique constraint), or UNIQUE (unique index). The key type is not displayed if the index is a non-unique secondary index.
Depth	Height of the index. For more information, see "Table and page sizes" on page 393.
Estimated leaf pages	Estimated number of leaf pages.
Cardinality	The cardinality of the index if it is different from the estimated number of rows. This applies only to Adaptive Server Anywhere databases version 6.0 and earlier.
Selectivity	The estimated number of rows that match the range bounds.
Direction	FORWARD or BACKWARD.
Range bounds	Range bounds are shown as a list (col_name=value) or col_name IN [low, high].

Items in the plan related to joins, filter, and pre-filter

Item	Explanation
Predicate	The search condition that is evaluated in this node, along with selectivity estimates and measurement. For more information, see "Selectivity in the plan" on page 433

Items in the plan related to hash filter

Item	Explanation
Build values	Estimated number of distinct values in the input.
Probe values	Estimated number of distinct values in the input when checking the predicate.
Bits	Number of bits selected to build the hash map.
Pages	Number of pages required to store the hash map.

Items in the plan related to Union

Item	Explanation
Union List	The columns involved in a UNION operation.

Items in the plan related to GROUP BY

Item	Explanation
Aggregates	All the aggregate functions.
Group-by list	All the columns in the group by clause.

Items in the plan related to DISTINCT

Item	Explanation
Distinct list	All the columns in the distinct clause.

Items in the plan related to IN LIST

Item	Explanation
In List	All the expressions in the specified set.
Expression SQL	Expressions to compare to the list.

Items in the plan related to SORT

Item	Explanation
Order-by	List of all expressions to sort by.

Items in the plan related to row limits

Item	Explanation
Row limit count	Maximum number of rows returned as specified by FIRST or TOP n.

Text plans

There are two types of text plan: short and long. To choose a plan type in Interactive SQL, open the Options dialog from the Tools menu, and click the Plan tab. To use SQL functions to access the plan, see "Accessing the Plan with SQL functions" on page 435.

Colons separate join strategies

The following command contains two **query blocks**: the outer select statement from the sales_order and sales_order_items tables, and the subquery that selects from the product table.

```
SELECT *
FROM sales_order AS o
   KEY JOIN sales_order_items AS i
WHERE EXISTS
   (   SELECT *
      FROM product p
      WHERE p.id = 300 )
```

```
i<seq> JNL o<sales_order> :  p<seq>
```

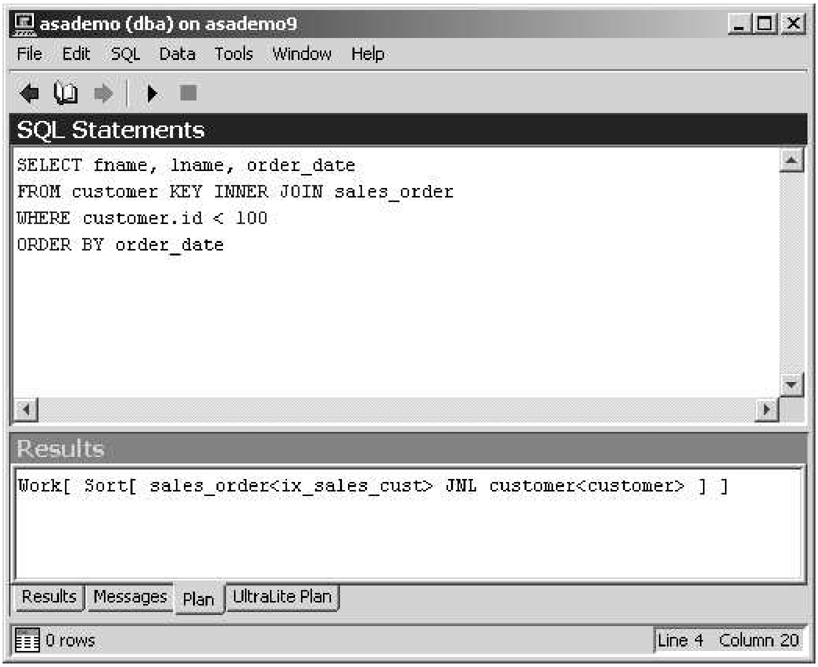
Colons separate join strategies. Plans always list the join strategy for the main block first. Join strategies for other query blocks follow. The order of join strategies for these other query blocks may not correspond to the order in your statement nor to the order in which they execute.

Short text plan

The short plan is useful when you want to compare plans quickly. It provides the least amount of information of all the access plan formats, but it provides it on a single line.

In the following example, the plan starts with the word SORT because the

ORDER BY clause causes the entire result set to be sorted. The customer table is accessed by its primary key index, also called customer. An index scan is used to satisfy the search condition because the column customer.id is a primary key. The abbreviation JNL indicates that the optimizer is using a nested loops join to process the query. Finally, the sales_order table is accessed using the foreign key index ky_so_customer to find matching rows in the customer table.

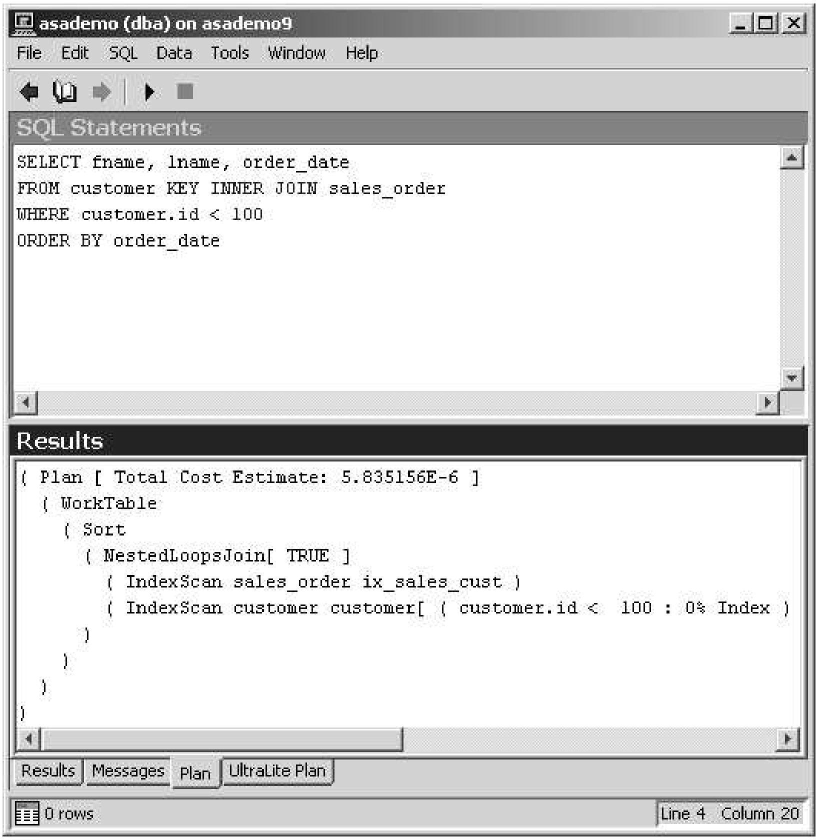


☞ For more information about code words used in the plan, see “Abbreviations used in the plan” on page 420.

Long text plan

The long plan provides a little more information than the short plan, and provides information in a way that is easy to print and view without scrolling down.

In the long plan output for the same query, the first line is `Plan [ I/O Estimate: 1 ]`. The words Plan or Sub-plan indicate the start of a query block (in this case, there is only one). The I/O estimates how many I/O are required for the query (in this case, one). Again, the plan indicates that the results are sorted, and that a nested loops join is the join algorithm to be used. On the same line as the algorithm, there is either the word TRUE or the search condition and selectivity estimate for the algorithm (in this case, there is none). The WHERE condition is represented on the line starting with FILTER, followed by the search condition, selectivity estimate for the search condition, and source of the selectivity estimate.



☞ For more information about code words used in the plan, see "Abbreviations used in the plan" on page 420.

Graphical plans

There are two types of graphical plan: the graphical plan, and the graphical plan with statistics. To choose a plan type in Interactive SQL, open the Options dialog from the Tools menu, and click the Plan tab. To access the plan with SQL functions, see "Accessing the Plan with SQL functions" on page 435.

Once the graphical plan is displayed, you can configure the way it is displayed by right-clicking the left pane and choosing Customize.

You can print the graphical plan for later reference. To print the plan, right-click a node and choose Print.

To obtain context-sensitive help for each node in the graphical plan, select the node, right-click it and choose Help. For example, right-click Nested Loops Join and choose Help for information about the resources used by that part of the execution. There is also pop-up information that is available by hovering your cursor over each element in the graphical plan.

Graphical plan

The graphical plan provides a great deal more information than the short or long plans. You can choose to see either the graphical plan, or the graphical plan with statistics. Both allow you to quickly view which parts of the plan have been estimated as the most expensive. The graphical plan with statistics, though more expensive to view, also provides the actual query execution statistics as monitored by the server when the query is executed, and permits direct comparison between the estimates used by the query optimizer in constructing the access plan with the actual statistics monitored during execution. Note, however, that the optimizer is often unable to precisely estimate a query's cost, so expect there to be differences. The graphical plan is the default format for access plans.

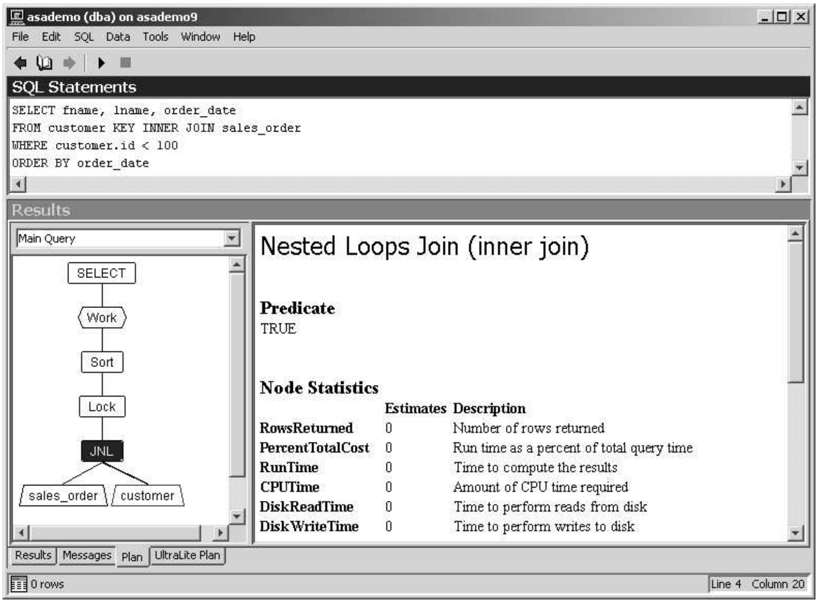
The graphical plan is designed to provide some key information visually:

- Each operation displayed in the graphical plan is displayed in a container. The container indicates whether the operation materializes data, whether it is an index scan, whether it is a table scan, or whether it is some other operation.
- The number of rows that an operation passes to the next operation in the plan is indicated by the thickness of the line joining the operations. This provides a visual indicator of the operations carried out on most data in the query.
- The container for an operation that is particularly slow is given a red border.

Each of these display features is customizable.

Following is the same query that was used to describe the short and long text plans, presented with the graphical plan. The diagram is in the form of a tree, indicating that each node requests rows from the nodes beneath it. The Lock node indicates that the result set is materialized, or that a row is returned to an application. In this case, the sort requires that results are materialized. At level 0, rows aren't really locked: Adaptive Server Anywhere just ensures that the row has not been deleted since it was read from the base tables. At level 1, a row is locked only until the next row is accessed. At levels 2 and 3, read locks are applied and held until COMMIT.

You can obtain detailed information about the nodes in the plan by clicking the node in the graphical diagram. In this example, the nested loops join node is selected. The information in the right pane pertains only to that node.



☞ For more information about abbreviations used in the plan, see "Abbreviations used in the plan" on page 420.

Graphical plan with statistics

The graphical plan with statistics shows you all the estimates that are provided with the graphical plan, but also shows actual runtime costs of executing the statement. To do this, the statement must actually be executed. This means that there may be a delay in accessing the plan for expensive queries. It also means that any parts of your query such as deletes or updates are actually executed, although you can perform a rollback to undo these changes.

Use the graphical plan with statistics when you are having performance problems, and the estimated row count or run time differs from your expectations. The graphical plan with statistics provides estimates and actual statistics for you to compare. A large difference between actual and estimate is a warning sign that the optimizer might not have sufficient information to prepare correct estimates.

The database options and other global settings that affect query execution are displayed for the root operator only.

Following are some of the key statistics you can check in the graphical plan with statistics, and some possible remedies:

- **Row count actuals and estimates** Row count measures the rows in the result set. If the estimated row count is significantly different from the actual row count, the selectivity is probably incorrect.

- **Selectivity actuals and estimates** Accurate selectivity estimates are critical for the proper operation of the query optimizer. For example, if the optimizer mistakenly estimates a predicate to be highly selective (with, say, a selectivity of 5%), but the actual selectivity is much lower (for example, 50%), then performance may suffer. In general, estimates will not be precise. However, a significantly large error does indicate a possible problem. If the predicate is over a base column for which there does not exist a histogram, executing a CREATE STATISTICS statement to create a histogram may correct the problem. If selectivity error remains a problem then, as a last resort, you may wish to consider specifying a user estimate of selectivity along with the predicate in the query text.

  ☞ For more information about selectivity, see "Selectivity in the plan" on page 433.

  ☞ For more information about creating statistics, see "CREATE STATISTICS statement" [*ASA SQL Reference*, page 346].

  ☞ For more information about user estimates, see "Explicit selectivity estimates" [*ASA SQL Reference*, page 30].

- **Runtime actuals and estimates** Runtime measures the time to execute the query. If the runtime is incorrect for a table scan or index scan, you may improve performance by executing the REORGANIZE TABLE statement.

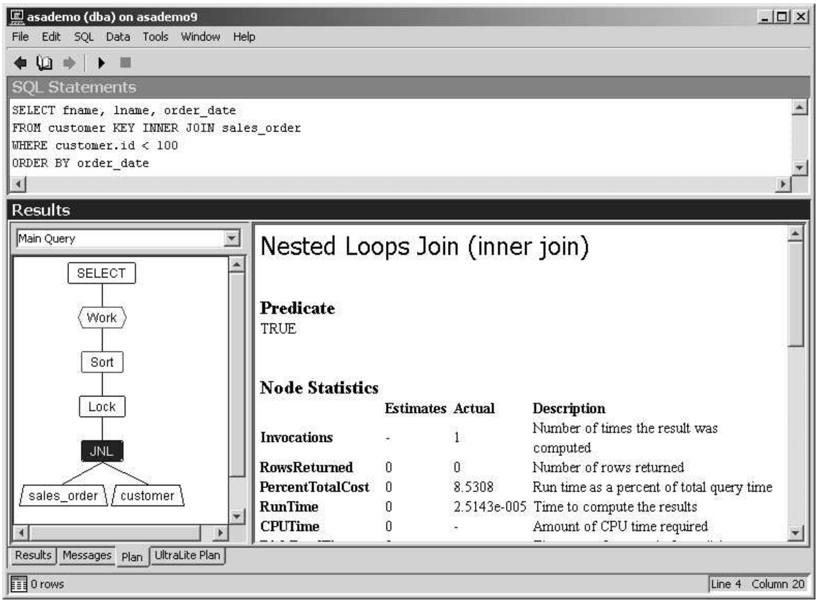
  ☞ For more information, see "REORGANIZE TABLE statement" [*ASA SQL Reference*, page 522].

- **Estimate source** When the source of the estimate is Guess, the optimizer has no information to use, which may indicate a problem. If the estimate source is Index and the selectivity estimate is incorrect, your problem may be that the index is skewed: you may benefit from defragmenting the index with the REORGANIZE TABLE statement.

  ☞ For a complete list of the possible sources of selectivity estimates, see "ESTIMATE_SOURCE function [Miscellaneous]" [*ASA SQL Reference*, page 125].

- **Cache reads and hits** If the number of cache reads and cache hits are exactly the same, then your entire database is in cache—an excellent thing. When reads are greater than hits, it means that the server is attempting to go to cache but failing, and that it must read from disk. In some cases, such as hash joins, this is expected. In other cases, such as nested loops joins, a poor cache-hit ratio may indicate a performance problem, and you may benefit from increasing your cache size.

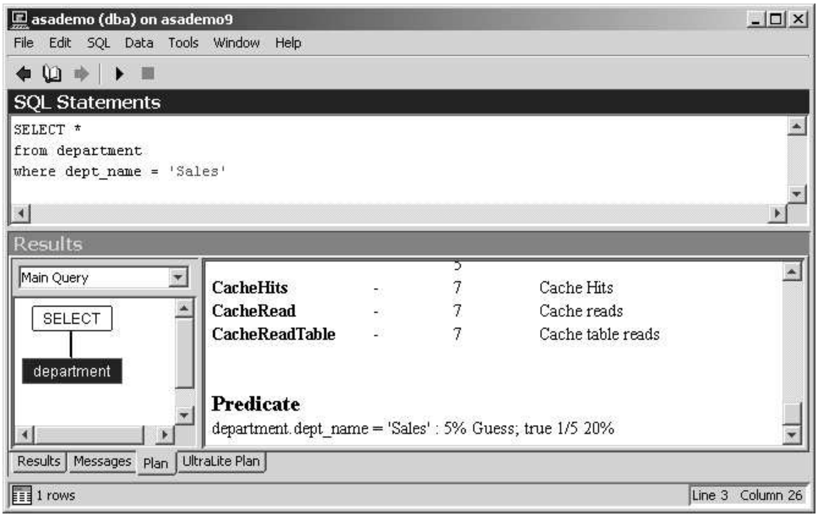
Following is an example of the graphical plan with statistics. Again, the nested loops join node is selected. The statistics in the right pane indicate the resources used by that part of the query.



☞ For more information about code words used in the plan, see "Abbreviations used in the plan" on page 420.

Selectivity in the plan

Following is an example of the Predicate showing selectivity of a search condition. In this example, the Filter node is selected, and the statistics pane shows the Predicate as the search condition and selectivity statistics.



This predicate is

```
department.dept_name = 'Sales' : 20% COLUMN
```

This can be read as follows:

- `department.dept_name = 'Sales'` is the search condition.
- 20% is the optimizer's estimate of the selectivity. This is the same output as is provided by the ESTIMATE function. For more information, see "ESTIMATE function [Miscellaneous]" [*ASA SQL Reference*, page 125].
- The source of the estimate is COLUMN. This is the same output as is provided by the ESTIMATE_SOURCE function. For a complete list of the possible sources of selectivity estimates, see "ESTIMATE_SOURCE function [Miscellaneous]" [*ASA SQL Reference*, page 125].

> *Note:* If you select the graphical plan, but not the graphical plan with statistics, the final two statistics are not displayed.

Accessing the plan

You can see the access plan in Interactive SQL, or using SQL functions. The plan is also displayed from the Index Consultant

Accessing the plan in Interactive SQL

The following types of plan are available in Interactive SQL:

- **Short plan**

- **Long plan**
- **Graphical plan**
- **Graphical plan with statistics**

To choose the type of plan you want to see, click Tools ➤ Options and select the Plan tab.

To see the plan, execute a query and then open the Plan tab. The Plan tab is located at the bottom of the Interactive SQL window.

UltraLite plan

You can also view the UltraLite plan for your query. The UltraLite plan does not include statistics.

To view the UltraLite plan in Interactive SQL, open the Options dialog from the Tools menu and select Show UltraLite Plan. This option is selected by default. You control the UltraLite plan type by selecting one of the types above (graphical, short plan, or long plan). If you choose graphical plan with statistics, you get the graphical plan.

The UltraLite Plan tab appears at the bottom of the Interactive SQL window. For some queries, the UltraLite execution plan may differ from the plan selected for Adaptive Server Anywhere.

☞ For more information, see "GRAPHICAL_ULPLAN function [Miscellaneous]" [*ASA SQL Reference*, page 137].

Accessing the Plan with SQL functions

You can access the plan using SQL functions, and retrieve the output in XML format.

- To access the short plan, see the "EXPLANATION function [Miscellaneous]" [*ASA SQL Reference*, page 132].
- To access the long plan, see the "PLAN function [Miscellaneous]" [*ASA SQL Reference*, page 170].
- To access the graphical plan, see the "GRAPHICAL_PLAN function [Miscellaneous]" [*ASA SQL Reference*, page 135].
- To access the UltraLite plan, see the "GRAPHICAL_ULPLAN function [Miscellaneous]" [*ASA SQL Reference*, page 137], "SHORT_ULPLAN function [Miscellaneous]" [*ASA SQL Reference*, page 181], or "LONG_ULPLAN function [Miscellaneous]" [*ASA SQL Reference*, page 152].

PART III

SQL DIALECTS AND COMPATIBILITY

This part describes Transact-SQL compatibility and those features of Adaptive Server Anywhere that are not commonly found in other SQL implementations.

CHAPTER 13

Transact-SQL Compatibility

About this chapter

Transact-SQL is the dialect of SQL supported by Sybase Adaptive Server Enterprise.

This chapter is a guide for creating applications that are compatible with both Adaptive Server Anywhere and Adaptive Server Enterprise. It describes Adaptive Server Anywhere support for Transact-SQL language elements and statements, and for Adaptive Server Enterprise system tables, views, and procedures.

Contents

Topic:	page
An overview of Transact-SQL support	440
Adaptive Server architectures	443
Configuring databases for Transact-SQL compatibility	449
Writing compatible SQL statements	458
Transact-SQL procedure language overview	463
Automatic translation of stored procedures	466
Returning result sets from Transact-SQL procedures	467
Variables in Transact-SQL procedures	468
Error handling in Transact-SQL procedures	469

An overview of Transact-SQL support

Adaptive Server Anywhere supports a large subset of **Transact-SQL**, which is the dialect of SQL supported by Sybase Adaptive Server Enterprise. This chapter describes compatibility of SQL between Adaptive Server Anywhere and Adaptive Server Enterprise.

Goals

The goals of Transact-SQL support in Adaptive Server Anywhere are as follows:

- **Application portability** Many applications, stored procedures, and batch files can be written for use with both Adaptive Server Enterprise and Adaptive Server Anywhere databases.
- **Data portability** Adaptive Server Anywhere and Adaptive Server Enterprise databases can exchange and replicate data between each other with minimum effort.

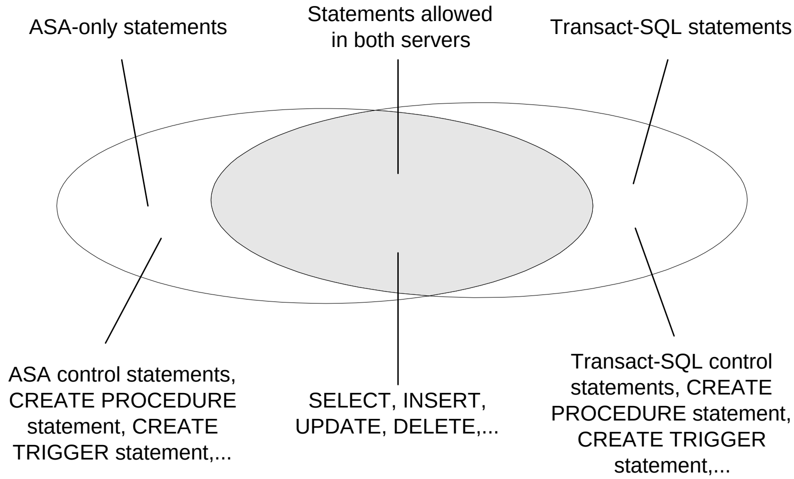
The aim is to write applications to work with both Adaptive Server Enterprise and Adaptive Server Anywhere. Existing Adaptive Server Enterprise applications generally require some changes to run on an Adaptive Server Anywhere database.

How Transact-SQL is supported

Transact-SQL support in Adaptive Server Anywhere takes the following form:

- Many SQL statements are compatible between Adaptive Server Anywhere and Adaptive Server Enterprise.
- For some statements, particularly in the procedure language used in procedures, triggers, and batches, a separate Transact-SQL statement is supported together with the syntax supported in previous versions of Adaptive Server Anywhere. For these statements, Adaptive Server Anywhere supports two **dialects** of SQL. In this chapter, we name those dialects Transact-SQL and Watcom-SQL.
- A procedure, trigger, or batch is executed in either the Transact-SQL or Watcom-SQL dialect. You must use control statements from one dialect only throughout the batch or procedure. For example, each dialect has different flow control statements.

The following diagram illustrates how the two dialects overlap.



Similarities and differences

Adaptive Server Anywhere supports a very high percentage of Transact-SQL language elements, functions, and statements for working with existing data. For example, Adaptive Server Anywhere supports all of the numeric functions, all but one of the string functions, all aggregate functions, and all date and time functions. As another example, Adaptive Server Anywhere supports Transact-SQL outer joins (using =* and *= operators) and extended DELETE and UPDATE statements using joins.

Further, Adaptive Server Anywhere supports a very high percentage of the Transact-SQL stored procedure language (CREATE PROCEDURE and CREATE TRIGGER syntax, control statements, and so on) and many, but not all, aspects of Transact-SQL data definition language statements.

There are design differences in the architectural and configuration facilities supported by each product. Device management, user management, and maintenance tasks such as backups tend to be system-specific. Even here, Adaptive Server Anywhere provides Transact-SQL system tables as views, where the tables that are not meaningful in Adaptive Server Anywhere have no rows. Also, Adaptive Server Anywhere provides a set of system procedures for some of the more common administrative tasks.

This chapter looks first at some system-level issues where differences are most noticeable, before discussing data manipulation and data definition language aspects of the dialects where compatibility is high.

Transact-SQL only

Some SQL statements supported by Adaptive Server Anywhere are part of one dialect, but not the other. You cannot mix the two dialects within a procedure, trigger, or batch. For example, Adaptive Server Anywhere supports the following statements, but as part of the Transact-SQL dialect only:

- ♦ Transact-SQL control statements IF and WHILE
- ♦ Transact-SQL EXECUTE statement
- ♦ Transact-SQL CREATE PROCEDURE and CREATE TRIGGER statements
- ♦ Transact-SQL BEGIN TRANSACTION statement
- ♦ SQL statements *not* separated by semicolons are part of a Transact-SQL procedure or batch

Adaptive Server Anywhere only

Adaptive Server Enterprise does not support the following statements:

- ♦ control statements CASE, LOOP, and FOR
- ♦ Adaptive Server Anywhere versions of IF and WHILE
- ♦ CALL statement
- ♦ Adaptive Server Anywhere versions of the CREATE PROCEDURE, CREATE FUNCTION, and CREATE TRIGGER statements
- ♦ SQL statements separated by semicolons

Notes

The two dialects cannot be mixed within a procedure, trigger, or batch. This means that:

- ♦ You can include Transact-SQL-only statements together with statements that are part of both dialects in a batch, procedure, or trigger.
- ♦ You can include statements not supported by Adaptive Server Enterprise together with statements that are supported by both servers in a batch, procedure, or trigger.
- ♦ You cannot include Transact-SQL-only statements together with Adaptive Server Anywhere-only statements in a batch, procedure, or trigger.

Adaptive Server architectures

Adaptive Server Enterprise and Adaptive Server Anywhere are complementary products, with architectures designed to suit their distinct purposes. Adaptive Server Anywhere works well as a workgroup or departmental server requiring little administration, and as a personal database. Adaptive Server Enterprise works well as an enterprise-level server for the largest databases.

This section describes architectural differences between Adaptive Server Enterprise and Adaptive Server Anywhere. It also describes the Adaptive Server Enterprise-like tools that Adaptive Server Anywhere includes for compatible database management.

Servers and databases

The relationship between servers and databases is different in Adaptive Server Enterprise and Adaptive Server Anywhere.

In Adaptive Server Enterprise, each database exists inside a server, and each server can contain several databases. Users can have login rights to the server, and can connect to the server. They can then use each database on that server for which they have permissions. System-wide system tables, held in a master database, contain information common to all databases on the server.

No master database in Adaptive Server Anywhere

In Adaptive Server Anywhere, there is no level corresponding to the Adaptive Server Enterprise master database. Instead, each database is an independent entity, containing all of its system tables. Users can have connection rights to a database, not to the server. When a user connects, they connect to an individual database. There is no system-wide set of system tables maintained at a master database level. Each Adaptive Server Anywhere database server can dynamically load and unload multiple databases, and users can maintain independent connections on each.

Adaptive Server Anywhere provides tools in its Transact-SQL support and in its Open Server support to allow some tasks to be carried out in a manner similar to Adaptive Server Enterprise. For example, Adaptive Server Anywhere provides an implementation of the Adaptive Server Enterprise **sp_addlogin** system procedure that carries out the nearest equivalent action: adding a user to a database.

☞ For information about Open Server support, see “Adaptive Server Anywhere as an Open Server” [*ASA Database Administration Guide*, page 109].

File manipulation statements

Adaptive Server Anywhere does not support the Transact-SQL statements DUMP DATABASE and LOAD DATABASE. Adaptive Server Anywhere has its own CREATE DATABASE and DROP DATABASE statements with different syntax.

Device management

Adaptive Server Anywhere and Adaptive Server Enterprise use different models for managing devices and disk space, reflecting the different uses for the two products. While Adaptive Server Enterprise sets out a comprehensive resource management scheme using a variety of Transact-SQL statements, Adaptive Server Anywhere manages its own resources automatically, and its databases are regular operating system files.

Adaptive Server Anywhere does not support Transact-SQL DISK statements, such as DISK INIT, DISK MIRROR, DISK REFIT, DISK REINIT, DISK REMIRROR, and DISK UNMIRROR.

☞ For information on disk management, see “Working with Database Files” [*ASA Database Administration Guide*, page 253]

Defaults and rules

Adaptive Server Anywhere does not support the Transact-SQL CREATE DEFAULT statement or CREATE RULE statement. The CREATE DOMAIN statement allows you to incorporate a default and a rule (called a CHECK condition) into the definition of a domain, and so provides similar functionality to the Transact-SQL CREATE DEFAULT and CREATE RULE statements.

In Adaptive Server Enterprise, the CREATE DEFAULT statement creates a named **default**. This default can be used as a default value for columns by binding the default to a particular column or as a default value for all columns of a domain by binding the default to the data type using the **sp_bindefault** system procedure.

The CREATE RULE statement creates a named **rule** which can be used to define the domain for columns by binding the rule to a particular column or as a rule for all columns of a domain by binding the rule to the data type. A rule is bound to a data type or column using the **sp_bindrule** system procedure.

In Adaptive Server Anywhere, a domain can have a default value and a CHECK condition associated with it, which are applied to all columns defined on that data type. You create the domain using the CREATE DOMAIN statement.

You can define default values and rules, or CHECK conditions, for individual columns using the CREATE TABLE statement or the ALTER

TABLE statement.

☞ For a description of the Adaptive Server Anywhere syntax for these statements, see "SQL Statements" [*ASA SQL Reference,* page 213].

System tables

In addition to its own system tables, Adaptive Server Anywhere provides a set of system views that mimic relevant parts of the Adaptive Server Enterprise system tables. You'll find a list and individual descriptions in "Views for Transact-SQL compatibility" [*ASA SQL Reference,* page 701], which describes the system catalogs of the two products. This section provides a brief overview of the differences.

The Adaptive Server Anywhere system tables rest entirely within each database, while the Adaptive Server Enterprise system tables rest partly inside each database and partly in the master database. The Adaptive Server Anywhere architecture does not include a master database.

In Adaptive Server Enterprise, the database owner (user ID **dbo**) owns the system tables. In Adaptive Server Anywhere, the system owner (user ID **SYS**) owns the system tables. A **dbo** user ID owns the Adaptive Server Enterprise-compatible system views provided by Adaptive Server Anywhere.

Administrative roles

Adaptive Server Enterprise has a more elaborate set of administrative roles than Adaptive Server Anywhere. In Adaptive Server Enterprise there is a set of distinct roles, although more than one login account on an Adaptive Server Enterprise can be granted any role, and one account can possess more than one role.

Adaptive Server Enterprise roles

In Adaptive Server Enterprise distinct roles include:

- **System Administrator** Responsible for general administrative tasks unrelated to specific applications; can access any database object.
- **System Security Officer** Responsible for security-sensitive tasks in Adaptive Server Enterprise, but has no special permissions on database objects.
- **Database Owner** Has full permissions on objects inside the database he or she owns, can add users to a database and grant other users the permission to create objects and execute commands within the database.
- **Data definition statements** Permissions can be granted to users for specific data definition statements, such as CREATE TABLE or CREATE

VIEW, enabling the user to create database objects.

- **Object owner** Each database object has an owner who may grant permissions to other users to access the object. The owner of an object automatically has all permissions on the object.

In Adaptive Server Anywhere, the following database-wide permissions have administrative roles:

- The Database Administrator (DBA authority) has, like the Adaptive Server Enterprise database owner, full permissions on all objects inside the database (other than objects owned by SYS) and can grant other users the permission to create objects and execute commands within the database. The default database administrator is user ID **DBA**.
- The RESOURCE permission allows a user to create any kind of object within a database. This is instead of the Adaptive Server Enterprise scheme of granting permissions on individual CREATE statements.
- Adaptive Server Anywhere has object owners in the same way that Adaptive Server Enterprise does. The owner of an object automatically has all permissions on the object, including the right to grant permissions.

For seamless access to data held in both Adaptive Server Enterprise and Adaptive Server Anywhere, you should create user IDs with appropriate permissions in the database (RESOURCE in Adaptive Server Anywhere, or permission on individual CREATE statements in Adaptive Server Enterprise) and create objects from that user ID. If you use the same user ID in each environment, object names and qualifiers can be identical in the two databases, ensuring compatible access.

Users and groups

There are some differences between the Adaptive Server Enterprise and Adaptive Server Anywhere models of users and groups.

In Adaptive Server Enterprise, users connect to a server, and each user requires a login ID and password to the server as well as a user ID for each database they want to access on that server. Each user of a database can only be a member of one group.

In Adaptive Server Anywhere, users connect directly to a database and do not require a separate login ID to the database server. Instead, each user receives a user ID and password on a database so they can use that database. Users can be members of many groups, and group hierarchies are allowed.

Both servers support user groups, so you can grant permissions to many users at one time. However, there are differences in the specifics of groups in the two servers. For example, Adaptive Server Enterprise allows each user to be a member of only one group, while Adaptive Server Anywhere has no such restriction. You should compare the documentation on users and groups in the two products for specific information.

Both Adaptive Server Enterprise and Adaptive Server Anywhere have a public group, for defining default permissions. Every user automatically becomes a member of the public group.

Adaptive Server Anywhere supports the following Adaptive Server Enterprise system procedures for managing users and groups.

☞ For the arguments to each procedure, see "Adaptive Server Enterprise system and catalog procedures" [*ASA SQL Reference*, page 763].

System procedure	Description
sp_addlogin	In Adaptive Server Enterprise, this adds a user to the server. In Adaptive Server Anywhere, this adds a user to a database.
sp_adduser	In Adaptive Server Enterprise and Adaptive Server Anywhere, this adds a user to a database. While this is a distinct task from **sp_addlogin** in Adaptive Server Enterprise, in Adaptive Server Anywhere, they are the same.
sp_addgroup	Adds a group to a database.
sp_changegroup	Adds a user to a group, or moves a user from one group to another.
sp_droplogin	In Adaptive Server Enterprise, removes a user from the server. In Adaptive Server Anywhere, removes a user from the database.
sp_dropuser	Removes a user from the database.
sp_dropgroup	Removes a group from the database.

In Adaptive Server Enterprise, login IDs are server-wide. In Adaptive Server Anywhere, users belong to individual databases.

Database object permissions

The Adaptive Server Enterprise and Adaptive Server Anywhere GRANT and REVOKE statements for granting permissions on individual database objects are very similar. Both allow SELECT, INSERT, DELETE, UPDATE, and REFERENCES permissions on database tables and views, and UPDATE permissions on selected columns of database tables. Both allow EXECUTE permissions to be granted on stored procedures.

For example, the following statement is valid in both Adaptive Server Enterprise and Adaptive Server Anywhere:

```
GRANT INSERT, DELETE
ON TITLES
TO MARY, SALES
```

This statement grants permission to use the INSERT and DELETE statements on the **TITLES** table to user **MARY** and to the **SALES** group.

Both Adaptive Server Anywhere and Adaptive Server Enterprise support the WITH GRANT OPTION clause, allowing the recipient of permissions to grant them in turn, although Adaptive Server Anywhere does not permit WITH GRANT OPTION to be used on a GRANT EXECUTE statement.

Database-wide permissions

Adaptive Server Enterprise and Adaptive Server Anywhere use different models for database-wide user permissions. These are discussed in "Users and groups" on page 446. Adaptive Server Anywhere employs DBA permissions to allow a user full authority within a database. The System Administrator in Adaptive Server Enterprise enjoys this permission for all databases on a server. However, DBA authority on an Adaptive Server Anywhere database is different from the permissions of an Adaptive Server Enterprise Database Owner, who must use the Adaptive Server Enterprise **SETUSER** statement to gain permissions on objects owned by other users.

Adaptive Server Anywhere employs RESOURCE permissions to allow a user the right to create objects in a database. A closely corresponding Adaptive Server Enterprise permission is GRANT ALL, used by a Database Owner.

Configuring databases for Transact-SQL compatibility

You can eliminate some differences in behavior between Adaptive Server Anywhere and Adaptive Server Enterprise by selecting appropriate options when creating a database or, if you are working on an existing database, when rebuilding the database. You can control other differences by connection level options using the SET TEMPORARY OPTION statement in Adaptive Server Anywhere or the SET statement in Adaptive Server Enterprise.

Creating a Transact-SQL-compatible database

This section describes choices you must make when creating or rebuilding a database.

Quick start

Here are the steps you need to take to create a Transact-SQL-compatible database. The remainder of the section describes which options you need to set.

❖ To create a Transact-SQL compatible database (Sybase Central)

1. Start Sybase Central.
2. Choose Tools ➤ Adaptive Server Anywhere 9 ➤ Create Database.
3. Follow the instructions in the wizard.
4. When you see a button called Emulate Adaptive Server Enterprise, click it, and then click Next.
5. Follow the remaining instructions in the wizard.

❖ To create a Transact-SQL compatible database (Command line)

1. Enter the following command at a system prompt:

```
dbinit -b -c -k db-name.db
```

☞ For more information about these options, see “Initialization utility options” [*ASA Database Administration Guide,* page 487].

❖ To create a Transact-SQL compatible database (SQL)

1. Connect to any Adaptive Server Anywhere database.
2. Enter the following statement, for example, in Interactive SQL:

```
CREATE DATABASE 'db-name.db'
ASE COMPATIBLE
```

   In this statement, ASE COMPATIBLE means compatible with Adaptive Server Enterprise.

Make the database case sensitive

By default, string comparisons in Adaptive Server Enterprise databases are case sensitive, while those in Adaptive Server Anywhere are case insensitive.

When building an Adaptive Server Enterprise-compatible database using Adaptive Server Anywhere, choose the case sensitive option.

- ♦ If you are using Sybase Central, this option is in the Create Database wizard.
- ♦ If you are using the *dbinit* command-line utility, specify the `-c` command-line switch.

Ignore trailing blanks in comparisons

When building an Adaptive Server Enterprise-compatible database using Adaptive Server Anywhere, choose the option to ignore trailing blanks in comparisons.

- ♦ If you are using Sybase Central, this option is in the Create Database wizard.
- ♦ If you are using the *dbinit* command line utility, specify the `-b` command-line switch.

When you choose this option, Adaptive Server Enterprise and Adaptive Server Anywhere considers the following two strings equal:

```
'ignore the trailing blanks   '
'ignore the trailing blanks'
```

If you do not choose this option, Adaptive Server Anywhere considers the two strings above different.

A side effect of this choosing this option is that strings are padded with blanks when fetched by a client application.

Remove historical system views

Older versions of Adaptive Server Anywhere employed two system views whose names conflict with the Adaptive Server Enterprise system views provided for compatibility. These views include SYSCOLUMNS and SYSINDEXES. If you are using Open Client or JDBC interfaces, create your database excluding these views. You can do this with the *dbinit* `-k` command-line switch.

If you do not use this option when creating your database, the following two statements return different results:

```
SELECT * FROM SYSCOLUMNS ;
```

```
SELECT * FROM dbo.syscolumns ;
```

❖ To drop the Adaptive Server Anywhere system views from an existing database

1. Connect to the database as a user with DBA authority.

2. Execute the following statements:

   ```
   DROP VIEW SYS.SYSCOLUMNS ;
   DROP VIEW SYS.SYSINDEXES
   ```

> ***Caution***
> *Ensure that you do not drop the dbo.syscolumns or dbo.sysindexes system view.*

Setting options for Transact-SQL compatibility

You set Adaptive Server Anywhere database options using the SET OPTION statement. Several database option settings are relevant to Transact-SQL behavior.

Set the allow_nulls_by_default option

By default, Adaptive Server Enterprise disallows NULLs on new columns unless you explicitly tell the column to allow NULLs. Adaptive Server Anywhere permits NULL in new columns by default, which is compatible with the SQL/92 ISO standard.

To make Adaptive Server Enterprise behave in a SQL/92-compatible manner, use the **sp_dboption** system procedure to set the **allow_nulls_by_default** option to true.

To make Adaptive Server Anywhere behave in a Transact-SQL-compatible manner, set the **allow_nulls_by_default** option to OFF. You can do this using the SET OPTION statement as follows:

```
SET OPTION PUBLIC.allow_nulls_by_default = 'OFF'
```

Set the quoted_identifier option

By default, Adaptive Server Enterprise treats identifiers and strings differently than Adaptive Server Anywhere, which matches the SQL/92 ISO standard.

The **quoted_identifier** option is available in both Adaptive Server Enterprise and Adaptive Server Anywhere. Ensure the option is set to the same value in both databases, for identifiers and strings to be treated in a compatible manner.

For SQL/92 behavior, set the **quoted_identifier** option to ON in both Adaptive Server Enterprise and Adaptive Server Anywhere.

For Transact-SQL behavior, set the **quoted_identifier** option to OFF in both Adaptive Server Enterprise and Adaptive Server Anywhere. If you choose this, you can no longer use identifiers that are the same as keywords, enclosed in double quotes.

For more information on the **quoted_identifier** option, see "QUOTED_IDENTIFIER option [compatibility]" [*ASA Database Administration Guide,* page 620].

Set the automatic_timestamp option to ON

Transact-SQL defines a **timestamp** column with special properties. With the **automatic_timestamp** option set to ON, the Adaptive Server Anywhere treatment of **timestamp** columns is similar to Adaptive Server Enterprise behavior.

With the **automatic_timestamp** option set to ON in Adaptive Server Anywhere (the default setting is OFF), any new columns with the TIMESTAMP data type that do not have an explicit default value defined receive a default value of **timestamp**.

☞ For information on **timestamp** columns, see "The special Transact-SQL timestamp column and data type" on page 454.

Set the string_rtruncation option

Both Adaptive Server Enterprise and Adaptive Server Anywhere support the string_rtruncation option, which affects error message reporting when an INSERT or UPDATE string is truncated. Ensure that each database has the option set to the same value.

☞ For more information on the STRING_RTRUNCATION option, see "STRING_RTRUNCATION option [compatibility]" [*ASA Database Administration Guide,* page 626].

☞ For more information on database options for Transact-SQL compatibility, see "Compatibility options" [*ASA Database Administration Guide,* page 566].

Case sensitivity

Case sensitivity in databases refers to:

- **Data** The case sensitivity of the data is reflected in indexes, in the results of queries, and so on.

- **Identifiers** Identifiers include table names, column names, user IDs, and so on.
- **Passwords** Case sensitivity of passwords is treated differently to other identifiers.

Case sensitivity of data

You decide the case sensitivity of Adaptive Server Anywhere data in comparisons when you create the database. By default, Adaptive Server Anywhere databases are case-insensitive in comparisons, although data is always held in the case in which you enter it.

Adaptive Server Enterprise's sensitivity to case depends on the sort order installed on the Adaptive Server Enterprise system. Case sensitivity can be changed for single-byte character sets by reconfiguring the Adaptive Server Enterprise sort order.

Case sensitivity of identifiers

Adaptive Server Anywhere does not support case sensitive identifiers. In Adaptive Server Enterprise, the case sensitivity of identifiers follows the case sensitivity of the data. User IDs are treated like any other identified, and are always case insensitive. The default user ID for databases is upper case **DBA**.

In Adaptive Server Enterprise, domain names are case sensitive. In Adaptive Server Anywhere, they are case insensitive, with the exception of Java data types.

User IDs and passwords

In Adaptive Server Anywhere, passwords follow the case sensitivity of the data. Extended characters used in passwords are case sensitive, regardless of the database's case sensitivity. The default password for databases is upper case **SQL**.

In Adaptive Server Enterprise, the case sensitivity of user IDs and passwords follows the case sensitivity of the server.

Ensuring compatible object names

Each database object must have a unique name within a certain **name space**. Outside this name space, duplicate names are allowed. Some database objects occupy different name spaces in Adaptive Server Enterprise and Adaptive Server Anywhere.

In Adaptive Server Anywhere, indexes and triggers are owned by the owner of the table on which they are created. Index and trigger names must be unique for a given owner. For example, while the tables t1 owned by user user1 and t2 owned by user user2 may have indexes of the same name, no two tables owned by a single user may have an index of the same name.

Adaptive Server Enterprise has a less restrictive name space for index names than Adaptive Server Anywhere. Index names must be unique on a given table, but any two tables may have an index of the same name. For compatible SQL, stay within the Adaptive Server Anywhere restriction of unique index names for a given table owner.

Adaptive Server Enterprise has a more restrictive name space on trigger names than Adaptive Server Anywhere. Trigger names must be unique in the database. For compatible SQL, you should stay within the Adaptive Server Enterprise restriction and make your trigger names unique in the database.

The special Transact-SQL timestamp column and data type

Adaptive Server Anywhere supports the Transact-SQL special timestamp column. The timestamp column, together with the tsequal system function, checks whether a row has been updated.

> **Two meanings of timestamp**
> Adaptive Server Anywhere has a TIMESTAMP data type, which holds accurate date and time information. It is distinct from the special Transact-SQL TIMESTAMP column and data type.

Creating a Transact-SQL timestamp column in Adaptive Server Anywhere

To create a Transact-SQL timestamp column, create a column that has the (Adaptive Server Anywhere) data type TIMESTAMP and a default setting of timestamp. The column can have any name, although the name timestamp is common.

For example, the following CREATE TABLE statement includes a Transact-SQL timestamp column:

```
CREATE TABLE table_name (
   column_1 INTEGER ,
   column_2 TIMESTAMP DEFAULT TIMESTAMP
)
```

The following ALTER TABLE statement adds a Transact-SQL timestamp column to the sales_order table:

```
ALTER TABLE sales_order
ADD timestamp TIMESTAMP DEFAULT TIMESTAMP
```

In Adaptive Server Enterprise a column with the name timestamp and no data type specified automatically receives a TIMESTAMP data type. In Adaptive Server Anywhere you must explicitly assign the data type yourself.

If you have the AUTOMATIC_TIMESTAMP database option set to ON, you do not need to set the default value: any new column created with TIMESTAMP data type and with no explicit default receives a default value of timestamp. The following statement sets AUTOMATIC_TIMESTAMP to ON:

```
SET OPTION PUBLIC.AUTOMATIC_TIMESTAMP='ON'
```

The data type of a timestamp column

Adaptive Server Enterprise treats a timestamp column as a domain that is VARBINARY(8), allowing NULL, while Adaptive Server Anywhere treats a timestamp column as the TIMESTAMP data type, which consists of the date and time, with fractions of a second held to six decimal places.

When fetching from the table for later updates, the variable into which the timestamp value is fetched should correspond to the column description.

Timestamping an existing table

If you add a special timestamp column to an existing table, all existing rows have a NULL value in the timestamp column. To enter a timestamp value (the current timestamp) for existing rows, update all rows in the table such that the data does not change. For example, the following statement updates all rows in the sales_order table, without changing the values in any of the rows:

```
UPDATE sales_order
SET region = region
```

In Interactive SQL, you may need to set the TIMESTAMP_FORMAT option to see the differences in values for the rows. The following statement sets the TIMESTAMP_FORMAT option to display all six digits in the fractions of a second:

```
SET OPTION TIMESTAMP_FORMAT='YYYY-MM-DD HH:NN:ss.SSSSSS'
```

If all six digits are not shown, some timestamp column values may appear to be equal: they are not.

Using tsequal for updates

With the tsequal system function you can tell whether a timestamp column has been updated or not.

For example, an application may SELECT a timestamp column into a variable. When an UPDATE of one of the selected rows is submitted, it can use the tsequal function to check whether the row has been modified. The tsequal function compares the timestamp value in the table with the timestamp value obtained in the SELECT. Identical timestamps means there are no changes. If the timestamps differ, the row has been changed since the SELECT was carried out.

A typical UPDATE statement using the tsequal function looks like this:

```
UPDATE publishers
SET city = 'Springfield'
WHERE pub_id = '0736'
AND TSEQUAL(timestamp, '1995/10/25 11:08:34.173226')
```

The first argument to the tsequal function is the name of the special timestamp column; the second argument is the timestamp retrieved in the SELECT statement. In Embedded SQL, the second argument is likely to be a host variable containing a TIMESTAMP value from a recent FETCH on the column.

The special IDENTITY column

To create an IDENTITY column, use the following CREATE TABLE syntax:

```
CREATE TABLE table-name (
   ...
   column-name numeric(n,0) IDENTITY NOT NULL,
   ...
)
```

where *n* is large enough to hold the value of the maximum number of rows that may be inserted into the table.

The IDENTITY column stores sequential numbers, such as invoice numbers or employee numbers, which are automatically generated. The value of the IDENTITY column uniquely identifies each row in a table.

In Adaptive Server Enterprise, each table in a database can have one IDENTITY column. The data type must be numeric with scale zero, and the IDENTITY column should not allow nulls.

In Adaptive Server Anywhere, the IDENTITY column is a column default setting. You can explicitly insert values that are not part of the sequence into the column with an INSERT statement. Adaptive Server Enterprise does not allow INSERTs into identity columns unless the identity_insert option is *on* . In Adaptive Server Anywhere, you need to set the NOT NULL property yourself and ensure that only one column is an IDENTITY column. Adaptive Server Anywhere allows any numeric data type to be an IDENTITY column.

In Adaptive Server Anywhere the identity column and the AUTOINCREMENT default setting for a column are identical.

Retrieving IDENTITY column values with @@identity

The first time you insert a row into the table, an IDENTITY column has a value of 1 assigned to it. On each subsequent insert, the value of the column increases by one. The value most recently inserted into an identity column is available in the @@identity global variable.

The value of @@identity changes each time a statement attempts to insert a row into a table.

- ♦ If the statement affects a table without an IDENTITY column, @@identity is set to 0.
- ♦ If the statement inserts multiple rows, @@identity reflects the last value inserted into the IDENTITY column.

This change is permanent. @@identity does not revert to its previous value if the statement fails or if the transaction that contains it is rolled back.

☞ For more information on the behavior of @@identity, see “@@identity global variable” [*ASA SQL Reference*, page 45].

Writing compatible SQL statements

This section describes general guidelines for writing SQL for use on more than one database-management system, and discusses compatibility issues between Adaptive Server Enterprise and Adaptive Server Anywhere at the SQL statement level.

General guidelines for writing portable SQL

When writing SQL for use on more than one database-management system, make your SQL statements as explicit as possible. Even if more than one server supports a given SQL statement, it may be a mistake to assume that default behavior is the same on each system. General guidelines applicable to writing compatible SQL include:

- Spell out all of the available options, rather than using default behavior.
- Use parentheses to make the order of execution within statements explicit, rather than assuming identical default order of precedence for operators.
- Use the Transact-SQL convention of an @ sign preceding variable names for Adaptive Server Enterprise portability.
- Declare variables and cursors in procedures, triggers, and batches immediately following a BEGIN statement. Adaptive Server Anywhere requires this, although Adaptive Server Enterprise allows declarations to be made anywhere in a procedure, trigger, or batch.
- Avoid using reserved words from either Adaptive Server Enterprise or Adaptive Server Anywhere as identifiers in your databases.
- Assume large namespaces. For example, ensure that each index has a unique name.

Creating compatible tables

Adaptive Server Anywhere supports domains which allow constraint and default definitions to be encapsulated in the data type definition. It also supports explicit defaults and CHECK conditions in the CREATE TABLE statement. It does not, however, support named constraints or named defaults.

NULL

Adaptive Server Anywhere and Adaptive Server Enterprise differ in some respects in their treatment of NULL. In Adaptive Server Enterprise, NULL is sometimes treated as if it were a value.

For example, a unique index in Adaptive Server Enterprise cannot contain rows that hold null and are otherwise identical. In Adaptive Server Anywhere, a unique index can contain such rows.

By default, columns in Adaptive Server Enterprise default to NOT NULL, whereas in Adaptive Server Anywhere the default setting is NULL. You can control this setting using the **allow_nulls_by_default** option. Specify explicitly NULL or NOT NULL to make your data definition statements transferable.

☞ For information on this option, see "Setting options for Transact-SQL compatibility" on page 451.

Temporary tables

You can create a temporary table by placing a pound sign (#) in front of a CREATE TABLE statement. These temporary tables are Adaptive Server Anywhere declared temporary tables, and are available only in the current connection. For information about declared temporary tables in Adaptive Server Anywhere, see "DECLARE LOCAL TEMPORARY TABLE statement" [*ASA SQL Reference*, page 397].

Physical placement of a table is carried out differently in Adaptive Server Enterprise and in Adaptive Server Anywhere. Adaptive Server Anywhere supports the **ON** *segment-name* clause, but *segment-name* refers to an Adaptive Server Anywhere dbspace.

☞ For information about the CREATE TABLE statement, see "CREATE TABLE statement" [*ASA SQL Reference*, page 361].

Writing compatible queries

There are two criteria for writing a query that runs on both Adaptive Server Anywhere and Adaptive Server Enterprise databases:

- The data types, expressions, and search conditions in the query must be compatible.
- The syntax of the SELECT statement itself must be compatible.

This section explains compatible SELECT statement syntax, and assumes compatible data types, expressions, and search conditions. The examples assume the QUOTED_IDENTIFIER setting is OFF: the default Adaptive Server Enterprise setting, but not the default Adaptive Server Anywhere setting.

Adaptive Server Anywhere supports the following subset of the Transact-SQL SELECT statement.

Syntax

SELECT [**ALL** | **DISTINCT**] *select-list*
. . . [**INTO** *#temporary-table-name*]
. . . [**FROM** *table-spec* [**HOLDLOCK** | **NOHOLDLOCK**],
. . . *table-spec* [**HOLDLOCK** | **NOHOLDLOCK**], . . .]
. . . [**WHERE** *search-condition*]
. . . [**GROUP BY** *column-name*, . . .]
. . . [**HAVING** *search-condition*]
[**ORDER BY** { *expression* | *integer* }
[**ASC** | **DESC**], . . .]

Parameters

select-list:
*table-name.**
| *****
| *expression*
| *alias-name = expression*
| *expression as identifier*
| *expression as T_string*

table-spec:
[*owner* .]*table-name*
. . . [[**AS**] *correlation-name*]
. . . [**(INDEX** *index_name* [**PREFETCH** *size*][**LRU** | **MRU**] **)**]

alias-name:*identifier* :
| **'***string***'** | **"***string***"**

☞ For a full description of the SELECT statement, see “SELECT statement” [*ASA SQL Reference,* page 541].

Adaptive Server Anywhere does not support the following keywords and clauses of the Transact-SQL SELECT statement syntax:

- SHARED keyword
- COMPUTE clause
- FOR BROWSE clause
- GROUP BY ALL clause

Notes

- The INTO table_name clause, which creates a new table based on the SELECT statement result set, is supported only for declared temporary tables where the table name starts with a #. Declared temporary tables exist for a single connection only.
- Adaptive Server Anywhere does not support the Transact-SQL extension to the GROUP BY clause allowing references to columns and expressions that are not used for creating groups. In Adaptive Server Enterprise, this extension produces summary reports.

- The FOR READ ONLY clause and the FOR UPDATE clause are parsed, but have no effect.
- The performance parameters part of the table specification is parsed, but has no effect.
- The HOLDLOCK keyword is supported by Adaptive Server Anywhere. It makes a shared lock on a specified table or view more restrictive by holding it until the completion of a transaction (instead of releasing the shared lock as soon as the required data page is no longer needed, whether or not the transaction has been completed). For the purposes of the table for which the HOLDLOCK is specified, the query is carried out at isolation level 3.
- The HOLDLOCK option applies only to the table or view for which it is specified, and only for the duration of the transaction defined by the statement in which it is used. Setting the isolation level to 3 applies a holdlock for each select within a transaction. You cannot specify both a HOLDLOCK and NOHOLDLOCK option in a query.
- The NOHOLDLOCK keyword is recognized by Adaptive Server Anywhere, but has no effect.
- Transact-SQL uses the SELECT statement to assign values to local variables:

  ```
  SELECT @localvar = 42
  ```

  The corresponding statement in Adaptive Server Anywhere is the SET statement:

  ```
  SET localvar = 42
  ```

  The variable name can optionally be set using the SET statement and the Transact-SQL convention of an @ sign preceding the name:

  ```
  SET @localvar = 42
  ```

- Adaptive Server Enterprise does not support the following clauses of the SELECT statement syntax:
  - INTO host-variable-list
  - INTO variable-list.
  - Parenthesized queries.
- Adaptive Server Enterprise uses join operators in the WHERE clause , rather than the FROM clause and the ON condition for joins.

Compatibility of joins

In Transact-SQL, joins appear in the WHERE clause, using the following syntax:

start of select, *update*, *insert*, *delete*, *or subquery*
  FROM { *table-list* | *view-list* } **WHERE** [**NOT**]
  [*table-name*.| *view name*.]*column-name*
    join-operator
  [*table-name*.| *view-name*.]*column_name*
  [{ **AND** | **OR** } [**NOT**]
  [*table-name*.| *view-name*.]*column_name*
    join-operator
  [*table-name*.| *view-name*.]*column-name*]. . .
end of select, *update*, *insert*, *delete*, *or subquery*

The *join-operator* in the WHERE clause may be any of the comparison operators, or may be either of the following **outer-join operators**:

- ♦ ***=** Left outer join operator
- ♦ **=*** Right outer join operator.

Adaptive Server Anywhere supports the Transact-SQL outer-join operators as an alternative to the native SQL/92 syntax. You cannot mix dialects within a query. This rule applies also to views used by a query—an outer-join query on a view must follow the dialect used by the view-defining query.

Adaptive Server Anywhere also provides a SQL/92 syntax for joins other than outer joins, in which the joins are placed in the FROM clause rather than the WHERE clause.

☞ For information about joins in Adaptive Server Anywhere and in the ANSI/ISO SQL standards, see "Joins: Retrieving Data from Several Tables" on page 261, and "FROM clause" [*ASA SQL Reference*, page 445].

☞ For more information on Transact-SQL compatibility of joins, see "Transact-SQL outer joins (*= or =*)" on page 278.

Transact-SQL procedure language overview

The **stored procedure language** is the part of SQL used in stored procedures, triggers, and batches.

Adaptive Server Anywhere supports a large part of the Transact-SQL stored procedure language in addition to the Watcom-SQL dialect based on SQL/92.

Transact-SQL stored procedure overview

Based on the ISO/ANSI draft standard , the Adaptive Server Anywhere stored procedure language differs from the Transact-SQL dialect in many ways. Many of the concepts and features are similar, but the syntax is different. Adaptive Server Anywhere support for Transact-SQL takes advantage of the similar concepts by providing automatic translation between dialects. However, a procedure must be written exclusively in one of the two dialects, not in a mixture of the two.

Adaptive Server Anywhere support for Transact-SQL stored procedures

There are a variety of aspects to Adaptive Server Anywhere support for Transact-SQL stored procedures, including:

- Passing parameters
- Returning result sets
- Returning status information
- Providing default values for parameters
- Control statements
- Error handling
- User-defined functions

Transact-SQL trigger overview

Trigger compatibility requires compatibility of trigger features and syntax. This section provides an overview of the feature compatibility of Transact-SQL and Adaptive Server Anywhere triggers.

Adaptive Server Enterprise executes triggers after the triggering statement has completed: they are **statement level**, **after** triggers. Adaptive Server Anywhere supports both **row level** triggers (which execute before or after each row has been modified) and statement level triggers (which execute after the entire statement).

Row-level triggers are not part of the Transact-SQL compatibility features, and are discussed in "Using Procedures, Triggers, and Batches" on page 609.

Description of unsupported or different Transact-SQL triggers

Features of Transact-SQL triggers that are either unsupported or different in Adaptive Server Anywhere include:

- **Triggers firing other triggers** Suppose a trigger carries out an action that would, if carried out directly by a user, fire another trigger. Adaptive Server Anywhere and Adaptive Server Enterprise respond slightly differently to this situation. By default in Adaptive Server Enterprise, triggers fire other triggers up to a configurable nesting level, which has the default value of 16. You can control the nesting level with the Adaptive Server Enterprise **nested triggers** option. In Adaptive Server Anywhere, triggers fire other triggers without limit unless there is insufficient memory.

- **Triggers firing themselves** Suppose a trigger carries out an action that would, if carried out directly by a user, fire the same trigger. Adaptive Server Anywhere and Adaptive Server Enterprise respond slightly differently to this situation. In Adaptive Server Anywhere, non-Transact-SQL triggers fire themselves recursively, while Transact-SQL dialect triggers do not fire themselves recursively.

  By default in Adaptive Server Enterprise, a trigger does not call itself recursively, but you can turn on the **self_recursion** option to allow triggers to call themselves recursively.

- **ROLLBACK statement in triggers** Adaptive Server Enterprise permits the ROLLBACK TRANSACTION statement within triggers, to roll back the entire transaction of which the trigger is a part. Adaptive Server Anywhere does not permit ROLLBACK (or ROLLBACK TRANSACTION) statements in triggers because a triggering action and its trigger together form an atomic statement.

  Adaptive Server Anywhere does provide the Adaptive Server Enterprise-compatible ROLLBACK TRIGGER statement to undo actions within triggers. See "ROLLBACK TRIGGER statement" [*ASA SQL Reference*, page 539].

Transact-SQL batch overview

In Transact-SQL, a **batch** is a set of SQL statements submitted together and executed as a group, one after the other. Batches can be stored in command files. The Interactive SQL utility in Adaptive Server Anywhere and the *isql* utility in Adaptive Server Enterprise provide similar capabilities for executing batches interactively.

The control statements used in procedures can also be used in batches. Adaptive Server Anywhere supports the use of control statements in batches and the Transact-SQL-like use of non-delimited groups of statements terminated with a GO statement to signify the end of a batch.

For batches stored in command files, Adaptive Server Anywhere supports the use of parameters in command files. Adaptive Server Enterprise does not support parameters.

☞ For information on parameters, see “PARAMETERS statement [Interactive SQL]” [*ASA SQL Reference*, page 506].

Automatic translation of stored procedures

In addition to supporting Transact-SQL alternative syntax, Adaptive Server Anywhere provides aids for translating statements between the Watcom-SQL and Transact-SQL dialects. Functions returning information about SQL statements and enabling automatic translation of SQL statements include:

- **SQLDialect(statement)** Returns **Watcom-SQL** or **Transact-SQL**.
- **WatcomSQL(statement)** Returns the Watcom-SQL syntax for the statement.
- **TransactSQL(statement)** Returns the Transact-SQL syntax for the statement.

These are functions, and so can be accessed using a select statement from Interactive SQL. For example:

```
select SqlDialect('select * from employee')
```

returns the value Watcom-SQL.

Using Sybase Central to translate stored procedures

Sybase Central has facilities for creating, viewing, and altering procedures and triggers.

❖ To translate a stored procedure using Sybase Central

1. Connect to a database using Sybase Central, either as owner of the procedure you wish to change, or as a DBA user.
2. Open the Procedures & Functions folder.
3. Right-click the procedure you want to translate and from the popup menu choose one of the Translate to commands, depending on the dialect you want to use.

   The procedure appears in the right pane in the selected dialect. If the selected dialect is not the one in which the procedure is stored, the server translates it to that dialect. Any untranslated lines appear as comments.
4. Rewrite any untranslated lines as needed.
5. When finished, choose File ➤ Save Procedure to save the translated version to the database. You can also export the text to a file for editing outside of Sybase Central.

Returning result sets from Transact-SQL procedures

Adaptive Server Anywhere uses a RESULT clause to specify returned result sets. In Transact-SQL procedures, the column names or alias names of the first query are returned to the calling environment.

Example of Transact-SQL procedure

The following Transact-SQL procedure illustrates how Transact-SQL stored procedures returns result sets:

```
CREATE PROCEDURE showdept (@deptname varchar(30))
AS
   SELECT employee.emp_lname, employee.emp_fname
   FROM department, employee
   WHERE department.dept_name = @deptname
   AND department.dept_id = employee.dept_id
```

Example of Watcom-SQL procedure

The following is the corresponding Adaptive Server Anywhere procedure:

```
CREATE PROCEDURE showdept(in deptname varchar(30))
RESULT ( lastname char(20), firstname char(20))
BEGIN
   SELECT employee.emp_lname, employee.emp_fname
   FROM department, employee
   WHERE department.dept_name = deptname
   AND department.dept_id = employee.dept_id
END
```

☞ For more information about procedures and results, see “Returning results from procedures” on page 640

Variables in Transact-SQL procedures

Adaptive Server Anywhere uses the SET statement to assign values to variables in a procedure. In Transact-SQL, values are assigned using either the SELECT statement with an empty table-list, or the SET statement. The following simple procedure illustrates how the Transact-SQL syntax works:

```
CREATE PROCEDURE multiply
               @mult1 int,
               @mult2 int,
               @result int output
AS
SELECT @result = @mult1 * @mult2
```

This procedure can be called as follows:

```
CREATE VARIABLE @product int
go
EXECUTE multiply 5, 6, @product OUTPUT
go
```

The variable **@product** has a value of 30 after the procedure executes.

☞ For more information on using the SELECT statement to assign variables, see "Writing compatible queries" on page 459. For more information on using the SET statement to assign variables, see "SET statement" [*ASA SQL Reference*, page 548].

Error handling in Transact-SQL procedures

Default procedure error handling is different in the Watcom-SQL and Transact-SQL dialects. By default, Watcom-SQL dialect procedures exit when they encounter an error, returning SQLSTATE and SQLCODE values to the calling environment.

Explicit error handling can be built into Watcom-SQL stored procedures using the EXCEPTION statement, or you can instruct the procedure to continue execution at the next statement when it encounters an error, using the ON EXCEPTION RESUME statement.

When a Transact-SQL dialect procedure encounters an error, execution continues at the following statement. The global variable **@@error** holds the error status of the most recently executed statement. You can check this variable following a statement to force return from a procedure. For example, the following statement causes an exit if an error occurs.

```
IF @@error != 0 RETURN
```

When the procedure completes execution, a return value indicates the success or failure of the procedure. This return status is an integer, and can be accessed as follows:

```
DECLARE @status INT
EXECUTE @status = proc_sample
IF @status = 0
   PRINT 'procedure succeeded'
ELSE
   PRINT 'procedure failed'
```

The following table describes the built-in procedure return values and their meanings:

Value	Meaning
0	Procedure executed without error
–1	Missing object
–2	Data type error
–3	Process was chosen as deadlock victim
–4	Permission error
–5	Syntax error
–6	Miscellaneous user error
–7	Resource error, such as out of space

Value	Meaning
–8	Non-fatal internal problem
–9	System limit was reached
–10	Fatal internal inconsistency
–11	Fatal internal inconsistency
–12	Table or index is corrupt
–13	Database is corrupt
–14	Hardware error

The RETURN statement can be used to return other integers, with their own user-defined meanings.

Using the RAISERROR statement in procedures

The RAISERROR statement is a Transact-SQL statement for generating user-defined errors. It has a similar function to the SIGNAL statement.

☞ For a description of the RAISERROR statement, see "RAISERROR statement [T-SQL]" [*ASA SQL Reference*, page 515].

By itself, the RAISERROR statement does not cause an exit from the procedure, but it can be combined with a RETURN statement or a test of the **@@error** global variable to control execution following a user-defined error.

If you set the ON_TSQL_ERROR database option to CONTINUE, the RAISERROR statement no longer signals an execution-ending error. Instead, the procedure completes and stores the RAISERROR status code and message, and returns the most recent RAISERROR. If the procedure causing the RAISERROR was called from another procedure, the RAISERROR returns after the outermost calling procedure terminates.

You lose intermediate RAISERROR statuses and codes after the procedure terminates. If, at return time, an error occurs along with the RAISERROR, then the error information is returned and you lose the RAISERROR information. The application can query intermediate RAISERROR statuses by examining **@@error** global variable at different execution points.

Transact-SQL-like error handling in the Watcom-SQL dialect

You can make a Watcom-SQL dialect procedure handle errors in a Transact-SQL-like manner by supplying the ON EXCEPTION RESUME clause to the CREATE PROCEDURE statement:

```
CREATE PROCEDURE sample_proc()
ON EXCEPTION RESUME
BEGIN
   ...
END
```

The presence of an ON EXCEPTION RESUME clause prevents explicit exception handling code from being executed, so avoid using these two clauses together.

CHAPTER 14

Differences from Other SQL Dialects

About this chapter

Adaptive Server Anywhere complies completely with the SQL-92-based United States Federal Information Processing Standard Publication (FIPS PUB) 127.

Adaptive Server Anywhere is entry-level compliant with the ISO/ANSI SQL-92 standard, and with minor exceptions is compliant with SQL-99 core specifications.

Complete, detailed information about compliance is provided in the reference documentation for each feature of Adaptive Server Anywhere.

This chapter describes those features of Adaptive Server Anywhere that are not commonly found in other SQL implementations.

Contents

Topic:	page
Adaptive Server Anywhere SQL features	474

Adaptive Server Anywhere SQL features

The following features of the SQL supported by Adaptive Server Anywhere are not found in many other SQL implementations.

Type conversions

Full type conversion is implemented. Any data type can be compared with or used in any expression with any other data type.

Dates

Adaptive Server Anywhere has date, time and timestamp types that includes a year, month and day, hour, minutes, seconds and fraction of a second. For insertions or updates to date fields, or comparisons with date fields, a free format date is supported.

In addition, the following operations are allowed on dates:

- **date + integer** Add the specified number of days to a date.
- **date - integer** Subtract the specified number of days from a date.
- **date - date** Compute the number of days between two dates.
- **date + time** Make a timestamp out of a date and time.

Also, many functions are provided for manipulating dates and times. See "SQL Functions" [*ASA SQL Reference*, page 83] for a description of these.

Integrity

Adaptive Server Anywhere supports both entity and referential integrity. This has been implemented via the following two extensions to the CREATE TABLE and ALTER TABLE commands.

```
PRIMARY KEY ( column-name, ... )
[NOT NULL] FOREIGN KEY [role-name]
            [(column-name, ...)]
         REFERENCES table-name [(column-name, ...)]
            [ CHECK ON COMMIT ]
```

The PRIMARY KEY clause declares the primary key for the relation. Adaptive Server Anywhere will then enforce the uniqueness of the primary key, and ensure that no column in the primary key contains the NULL value.

The FOREIGN KEY clause defines a relationship between this table and another table. This relationship is represented by a column (or columns) in this table which must contain values in the primary key of another table. The system will then ensure referential integrity for these columns - whenever these columns are modified or a row is inserted into this table, these columns will be checked to ensure that either one or more is NULL or the values match the corresponding columns for some row in the primary key of the other table. For more information, see "CREATE TABLE statement" [*ASA SQL Reference*, page 361].

Joins

Adaptive Server Anywhere allows **automatic joins** between tables. In addition to the NATURAL and OUTER join operators supported in other implementations, Adaptive Server Anywhere allows KEY joins between tables based on foreign key relationships. This reduces the complexity of the WHERE clause when performing joins.

Updates

Adaptive Server Anywhere allows more than one table to be referenced by the UPDATE command. Views defined on more than one table can also be updated. Many SQL implementations will not allow updates on joined tables.

Altering tables

The ALTER TABLE command has been extended. In addition to changes for entity and referential integrity, the following types of alterations are allowed:

```
ADD column data-type
MODIFY column data-type
DELETE column
RENAME new-table-name
RENAME old-column TO new-column
```

The MODIFY can be used to change the maximum length of a character column as well as converting from one data type to another. For more information, see "ALTER TABLE statement" [*ASA SQL Reference*, page 250].

Subqueries where expressions are allowed

Adaptive Server Anywhere allows subqueries to appear wherever expressions are allowed. Many SQL implementations only allow subqueries on the right side of a comparison operator. For example, the following command is valid in Adaptive Server Anywhere but not valid in most other SQL implementations.

```
SELECT      emp_lname,
         birth_date,
         (   SELECT dept_name
            FROM department
            WHERE emp_id = employee.emp_ID
            AND dept_id = 200 )
FROM employee
```

Additional functions

Adaptive Server Anywhere supports several functions not in the ANSI SQL definition. See "SQL Functions" [*ASA SQL Reference*, page 83] for a full list of available functions.

Cursors

When using Embedded SQL, cursor positions can be moved arbitrarily on the FETCH statement. Cursors can be moved forward or backward relative to the current position or a given number of records from the beginning or end of the cursor.

Part IV

XML in the Database

This part describes how to use XML in the database.

CHAPTER 15

Using XML in the Database

About this chapter

This chapter provides a summary of the XML support in Adaptive Server Anywhere, including importing, exporting, storing, and querying XML data.

Contents

Topic:	page
What is XML?	480
Storing XML documents in relational databases	481
Exporting relational data as XML	482
Importing XML documents as relational data	483
Obtaining query results as XML	490
Using SQL/XML to obtain query results as XML	510

What is XML?

Extensible Markup Language (XML) represents structured data in text format. XML was designed specifically for use on the Web.

XML is a simple markup language, like HTML, but is also flexible, like SGML. XML is hierarchical, and its main purpose is to describe the structure of data for both humans and computer software to author and read.

Rather than providing a static set of elements which describe various forms of data, XML lets you define elements. As a result, many types of structured data can be described with XML. XML documents can optionally use a document type definition (DTD) or XML schema to define the structure, elements, and attributes that are used in an XML file.

☞ For more detailed information about XML, see *http://www.w3.org/XML/*.

XML and Adaptive Server Anywhere

There are several ways you can use XML with Adaptive Server Anywhere:

- Storing XML documents in the database
- Exporting relational data as XML
- Importing XML into the database
- Querying relational data as XML

Storing XML documents in relational databases

Adaptive Server Anywhere supports two data types that can be used to store XML documents in your database: the XML data type and the LONG VARCHAR data type. Both of these data types store the XML document as a string in the database.

Benefits of using the XML data type

You can cast between the XML data type and any other data type that can be cast to or from a string. Note that there is no checking that the string is well-formed when it is cast to XML.

When you generate elements from relational data, any characters that are invalid in XML are quoted unless the data is of type XML. For example, suppose you wish to generate a <product> element with the following content:

```
<hat>
```

so that the element content contains less than and greater than signs. If you write a query that specifies that element content is of type XML, as follows:

```
SELECT XMLFOREST( CAST( '<hat>' AS XML ) AS product )
```

then the greater than and less than signs are not quoted and you get the following result:

```
<x><y/></x>
```

However, if the query does not specify that element content is of type XML, for example:

```
SELECT XMLFOREST( '<hat>' AS product )
```

then the less than and greater than signs are quoted as follows:

```
<x>&lt;y/&gt;</x>
```

Note that attribute content is always quoted, regardless of the data type.

☞ For more information about how element content is quoted, see “Invalid column names” on page 493.

☞ For more information about the XML data type, see “XML data type [Character]” [*ASA SQL Reference*, page 55].

Exporting relational data as XML

Adaptive Server Anywhere provides two ways to export your relational data as XML: the Interactive SQL OUTPUT statement and the ADO.NET DataSet object. Both the OUTPUT statement and the ADO.NET DataSet object are used to save your relational data as XML.

The FOR XML clause and SQL/XML functions allow you to generate the results as XML from the relational data in your database. You can then export the generated XML to a file using the UNLOAD statement or the xp_write_file system procedure.

Exporting relational data as XML from Interactive SQL

The Interactive SQL OUTPUT statement supports an XML format that outputs query results to a generated XML file.

This generated XML file is encoded in UTF-8 and contains an embedded DTD. In the XML file, binary values are encoded in character data (CDATA) blocks with the binary data rendered as 2-hex-digit strings.

The INPUT statement does not accept XML as a file format.

☞ For more information about exporting XML with the OUTPUT statement, see “OUTPUT statement [Interactive SQL]” [*ASA SQL Reference,* page 501].

Exporting relational data as XML using the DataSet object

The ADO.NET DataSet object allows you to save the contents of the DataSet in an XML document. Once you have filled the DataSet (for example, with the results of a query on your database) you can save either the schema or both the schema and data from the DataSet in an XML file. The WriteXml method saves both the schema and data in an XML file, while the WriteXmlSchema method saves only the schema in an XML file. You can fill a DataSet object using the Adaptive Server Anywhere ADO.NET data provider.

☞ For information about exporting relational data as XML using a DataSet, see “Inserting, updating, and deleting rows using the AsaCommand object” [*ASA Programming Guide,* page 352].

Importing XML documents as relational data

Adaptive Server Anywhere supports two different ways to import XML into your database:

- using the OPENXML function to generate a result set from an XML document
- using the ADO.NET DataSet object to read the data and/or schema from an XML document into a DataSet

Importing XML using OPENXML

OPENXML is used in the FROM clause of a query to generate a result set from an XML document. OPENXML uses a subset of the XPath query language to select nodes from an XML document.

Using XPath expressions

When you use OPENXML, the XML document is parsed and the result is modeled as a tree. The tree is made up of nodes. XPath expressions are used to select nodes in the tree. The following list describes some commonly-used XPath expressions:

- ***/*** indicates the root node of the XML document
- **. (single period)** indicates the current node of the XML document
- ***//*** indicates all descendants of the current node, including the current node
- **..** indicates the parent node of the current node
- ***./@attributename*** indicates the attribute of the current node having the name *attributename*
- ***./childname*** indicates the children of the current node that are elements having the name *childname*

Consider the following XML document:

```
<inventory>
 <product id="301" size="Medium">Tee Shirt
  <quantity>54</quantity>
 </product>
 <product id="302" size="One size fits all">Tee Shirt
  <quantity>75</quantity>
 </product>
 <product id="400" size="One size fits all">Baseball Cap
  <quantity>112</quantity>
 </product>
</inventory>
```

The <inventory> element is the root node. You can refer to it using the following XPath expression:

```
/inventory
```

Suppose that the current node is a <quantity> element. You can refer to this node using the following XPath expression:

```
.
```

To find all the <product> elements that are children of the <inventory> element, use the following XPath expression:

```
/inventory/product
```

If the current node is a <product> element and you want to refer to the size attribute, use the following XPath expression:

```
./@size
```

☞ For a complete list of XPath syntax supported by OPENXML, see "OPENXML function [String]" [*ASA SQL Reference*, page 165].

☞ For information about the XPath query language, see *http://www.w3.org/TR/xpath.*

Generating a result set using OPENXML

Each match for the first *xpath-query* argument to OPENXML generates one row in the result set. The WITH clause specifies the schema of the result set and how the value is found for each column in the result set. For example, consider the following query:

```
SELECT * FROM OPENXML( '<inventory>
                         <product>Tee Shirt
                          <quantity>54</quantity>
                          <color>Orange</color>
                         </product>
                         <product>Baseball Cap
                          <quantity>112</quantity>
                          <color>Black</color>
                         </product>
                        </inventory>',
                       '/inventory/product' )
WITH ( quantity CHAR(3) 'quantity',
       color CHAR(20) 'color')
```

The first *xpath-query* argument is **/inventory/product**, and there are two <product> elements in the XML, so two rows are generated by this query.

The WITH clause specifies that there are two columns: quantity and color. The values for these columns are taken from the <quantity> and <color> elements. The query above generates the following result:

quantity	color
54	Orange
112	Black

☞ For more information, see “OPENXML function [String]” [*ASA SQL Reference*, page 165].

Using OPENXML to generate an edge table

OPENXML can be used to generate an edge table, a table that contains a row for every element in the XML document. You may wish to generate an edge table so that you can query the data in the result set using SQL.

The following SQL statement creates a variable, x, that contains an XML document. The XML generated by the query has a root element called <root>, which is generated using the XMLELEMENT function, and elements are generated for each column in the employee, sales_order, and customer tables using FOR XML AUTO with the ELEMENTS modifier specified.

☞ For information about the XMLELEMENT function, see “XMLELEMENT function [String]” [*ASA SQL Reference*, page 207].

☞ For information about FOR XML AUTO, see “Using FOR XML AUTO” on page 496.

```
CREATE VARIABLE x XML;
SET x=(SELECT XMLELEMENT( NAME root,
         (SELECT * FROM employee
         KEY JOIN sales_order
         KEY JOIN customer
         FOR XML AUTO, ELEMENTS)));
```

The generated XML looks as follows:

```
<root>
 <employee>
  <emp_id>299</emp_id>
  <manager_id>902</manager_id>
  <emp_fname>Rollin</emp_fname>
  <emp_lname>Overbey</emp_lname>
  <dept_id>200</dept_id>
  <street>191 Companion Ct.</street>
  <city>Kanata</city>
  <state>CA</state>
  <zip_code>94608</zip_code>
  <phone>5105557255</phone>
  <status>A</status>
  <ss_number>025487133</ss_number>
  <salary>39300.000</salary>
  <start_date>1987-02-19</start_date>
```

```
    <birth_date>1964-03-15</birth_date>
    <bene_health_ins>Y</bene_health_ins>
    <bene_life_ins>Y</bene_life_ins>
    <bene_day_care>N</bene_day_care>
    <sex>M</sex>
    <sales_order>
     <id>2001</id>
     <cust_id>101</cust_id>
     <order_date>2000-03-16</order_date>
     <fin_code_id>r1</fin_code_id>
     <region>Eastern</region>
     <sales_rep>299</sales_rep>
     <customer>
      <id>101</id>
      <fname>Michaels</fname>
      <lname>Devlin</lname>
      <address>114 Pioneer Avenue</address>
      <city>Kingston</city>
      <state>NJ</state>
      <zip>07070</zip>
      <phone>2015558966</phone>
      <company_name>The Power Group</company_name>
     </customer>
    </sales_order>
  </employee>
  ...
```

The following query uses the descendant-or-self (**//***) XPath expression to match every element in the above XML document, and for each element the id metaproperty is used to obtain an id for the node, and the parent (**../**) XPath expression is used with the id metaproperty to get the parent node. The localname metaproperty is used to obtain the name of each element.

```
SELECT * FROM OPENXML( x, '//*' )
 WITH (id INT '@mp:id',
       parent INT '../@mp:id',
       name CHAR(20) '@mp:localname',
       text LONG VARCHAR 'text()' )
ORDER BY id
```

The result set generated by this query shows the id of each node, the id of the parent node, and the name and content for each element in the XML document.

id	parent	name	text
5	(NULL)	root	(NULL)
23	15	emp_id	299
47	15	manager_id	902
74	15	emp_fname	Rollin
...	...	...	...

Querying XML in a column

If you have a table with a column that contains XML, you can use OPENXML to query all the XML values in the column at once. This can be done using a lateral derived table.

The following statements create a table with two columns, manager_id and reports. The reports column contains XML data generated from the employee table.

```
CREATE TABLE t (manager_id INT, reports XML);
INSERT INTO t
SELECT manager_id, XMLELEMENT( NAME reports,
                    XMLAGG(
                     XMLELEMENT( NAME e, emp_id)))
FROM employee
GROUP BY manager_id;
```

Execute the following query to view the data in the t table:

```
SELECT * FROM t;
```

This query produces the following result:

manager_id	reports

1293	`<reports>`
	` <e>148</e>`
	` <e>390</e>`
	` <e>586</e>`
	` <e>757</e>`
	` ...`
	`</reports>`

1576	`<reports>`
	` <e>184</e>`
	` <e>207</e>`
	` <e>318</e>`
	` <e>409</e>`
	` ...`
	`</reports>`

manager_id	reports
902	<reports> <e>129</e> <e>195</e> <e>299</e> <e>467</e> ... </reports>
703	<reports> <e>191</e> <e>750</e> <e>868</e> <e>921</e> ... </reports>
...	...

The following query uses a lateral derived table to generate a result set with two columns: one that lists the id for each manager, and one that lists the id for each employee that reports to that manager:

```
SELECT manager_id, eid
FROM t, LATERAL( OPENXML( t.reports, '//e' )
WITH (eid INT '.') ) dt
```

This query generates the following result:

manager_id	eid
1293	148
1293	390
1293	586
1293	757
...	...

☞ For more information about lateral derived tables, see “FROM clause” [*ASA SQL Reference*, page 445].

Importing XML using the DataSet object

The ADO.NET DataSet object allows you to read the data and/or schema from an XML document into a DataSet.

- The ReadXml method populates a DataSet from an XML document that contains both a schema and data.
- The ReadXmlSchema method reads only the schema from an XML document. Once the DataSet is filled with data from the XML document, you can update the tables in your database with the changes from the DataSet.

DataSet objects can also be manipulated using the Adaptive Server Anywhere ADO.NET data provider.

☞ For information about using a DataSet to read the data and/or schema from an XML document using the Adaptive Server Anywhere .NET data provider, see “Getting data using the AsaDataAdapter object” [*ASA Programming Guide*, page 356].

Obtaining query results as XML

Adaptive Server Anywhere supports two different ways to obtain query results from your relational data as XML:

- **FOR XML clause** The FOR XML clause can be used in a SELECT statement to generate an XML document.

  ☞ For information about using the FOR XML clause, see "Using the FOR XML clause to retrieve query results as XML" on page 491 and "SELECT statement" [*ASA SQL Reference*, page 541].

- **SQL/XML** Adaptive Server Anywhere supports functions based on the draft SQL/XML standard that generate XML documents from relational data.

  ☞ For information about using one or more of these functions in a query, see "Using SQL/XML to obtain query results as XML" on page 510.

The FOR XML clause and the SQL/XML functions supported by Adaptive Server Anywhere give you two alternatives for generating XML from your relational data. In most cases, you can use either one to generate the same XML.

For example, this query uses FOR XML AUTO to generate XML,

```
SELECT id, name
FROM product
WHERE color='black'
FOR XML AUTO
```

and this query uses the XMLELEMENT function to generate XML:

```
SELECT XMLELEMENT(NAME product,
          XMLATTRIBUTES(id, name))
FROM product
WHERE color='black'
```

Both queries generate the following XML:

```
<product id="302" name="Tee Shirt"/>
<product id="400" name="Baseball Cap"/>
<product id="501" name="Visor"/>
<product id="700" name="Shorts"/>
```

Tip

If you are generating deeply-nested documents, a FOR XML EXPLICIT query will likely be more efficient than a SQL/XML query because EXPLICIT mode queries normally use a UNION to generate nesting, while SQL/XML uses subqueries to generate the required nesting.

Using the FOR XML clause to retrieve query results as XML

Adaptive Server Anywhere allows you to execute a SQL query against your database and return the results as an XML document by using the FOR XML clause in your SELECT statement. The XML document is of type XML.

☞ For information about the XML data type, see “XML data type [Character]” [*ASA SQL Reference*, page 55].

The FOR XML clause can be used in any SELECT statement, including subqueries, queries with a GROUP BY clause or aggregate functions, and view definitions.

☞ For examples of how the FOR XML clause can be used, see “FOR XML examples” on page 493.

Adaptive Server Anywhere does not generate a schema for XML documents generated by the FOR XML clause.

Within the FOR XML clause, you specify one of three XML modes that control the format of the XML that is generated:

- **RAW** represents each row that matches the query as an XML <row> element, and each column as an attribute.

  ☞ For more information, see “Using FOR XML RAW” on page 494.

- **AUTO** returns query results as nested XML elements. Each table referenced in the *select-list* is represented as an element in the XML. The order of nesting for the elements is based on the order of the tables in the *select-list*.

  ☞ For more information, see “Using FOR XML AUTO” on page 496.

- **EXPLICIT** allows you to write queries that contain information about the expected nesting so you can control the form of the resulting XML.

  ☞ For more information, see “Using FOR XML EXPLICIT” on page 499.

The following sections describe the behavior of all three modes of the FOR XML clause regarding binary data, NULL values, and invalid XML names, as well as providing examples of how the FOR XML clause can be used.

FOR XML and binary data

When you use the FOR XML clause in a SELECT statement, regardless of the mode used, any BINARY, LONG BINARY, IMAGE, and VARBINARY columns are output as attributes or elements that are automatically represented in base64-encoded format.

If you are using OPENXML to generate a result set from XML, OPENXML assumes that the types BINARY, LONG BINARY, IMAGE, and VARBINARY, are base64-encoded and decodes them automatically.

☞ For more information about OPENXML, see "OPENXML function [String]" [*ASA SQL Reference*, page 165].

FOR XML and NULL values

By default, elements and attributes that contain NULL values are omitted from the result. This behavior is controlled by the FOR_XML_NULL_TREATMENT option.

Consider a table that contains the following data:

id	fname	lname	company_name
100	Robert	Michaels	NULL
101	Michael	Devlin	The Power Group

If you execute the following query with the FOR_XML_NULL_TREATMENT option set to OMIT (the default)

```
SELECT id, fname, lname, company_name
FROM customer
FOR XML RAW
```

the company_name attribute is omitted from the result for Robert Michaels:

```
<row id="100" fname="Robert" lname="Michaels"/>
<row id="101" fname="Michaels" lname="Devlin"
 company_name="The Power Group"/>'
```

If the FOR_XML_NULL_TREATMENT option is set to EMPTY, then an empty attribute is included in the result:

```
<row id="100" fname="Robert" lname="Michaels"
 company_name=""/>
<row id="101" fname="Michaels" lname="Devlin"
 company_name="The Power Group"/>'
```

In this case, an empty company_name attribute is generated for Robert Michaels.

☞ For information about the FOR_XML_NULL_TREATMENT option, see "FOR_XML_NULL_TREATMENT option [database]" [*ASA Database Administration Guide*, page 594].

Invalid column names

Adaptive Server Anywhere uses the following rules for encoding names that are not legal XML names (for example, column names that include spaces):

- Unicode characters that are not valid XML name characters are escaped as _x*HHHH*_, where *HHHH* stands for the four digit hexadecimal codepoint for the character. Characters whose Unicode codepoint value cannot be specified in 16 bits are encoded.

  For example, the following query contains a column name with a space:

  ```
  SELECT emp_id AS "employee id"
  FROM employee
  FOR XML RAW
  ```

  and returns the following result:

  ```
  <row employee_x0020_id="102"/>
  <row employee_x0020_id="105"/>
  <row employee_x0020_id="129"/>
  <row employee_x0020_id="148"/>
  ...
  ```

- Non-Unicode characters are encoded as _x*HHHHHHHH*_, where *HHHHHHHH* stands for stands for the eight digit hexadecimal codepoint for the character.

- Underscores (_) are escaped if they are followed by the character x.

- Colons (:) are not escaped so that namespace declarations and qualified element and attribute names can be generated using a FOR XML query.

☞ For information about the syntax of the FOR XML clause, see “SELECT statement” [*ASA SQL Reference*, page 541].

> **Tip**
> When executing queries that contain a FOR XML clause in Interactive SQL, you may wish to increase the column length by setting the TRUNCATION_LENGTH option.
>
> ☞ For information about setting the truncation length, see “TRUNCATION_LENGTH option [ISQL]” [*ASA Database Administration Guide*, page 632] and “Options dialog: Results tab” [*SQL Anywhere Studio Help*, page 145].

FOR XML examples

The following examples show how the FOR XML clause can be used in a SELECT statement.

- The following example shows how the FOR XML clause can be used in a subquery:

```
SELECT XMLELEMENT(
   NAME root,
      (SELECT * FROM employee
       FOR XML RAW))
```

- The following example shows how the FOR XML clause can be used in a query with a GROUP BY clause and aggregate function:

```
SELECT name, AVG(unit_price) AS Price
FROM product
GROUP BY name
FOR XML RAW
```

- The following example shows how the FOR XML clause can be used in a view definition:

```
CREATE VIEW emp_dept
AS SELECT emp_lname, emp_fname, dept_name
FROM employee JOIN department
ON employee.dept_id = department.dept_id
FOR XML AUTO
```

Using FOR XML RAW

When you specify FOR XML RAW in a query, each row is represented as a <row> element, and each column is an attribute of the <row> element.

Syntax

FOR XML RAW[, **ELEMENTS**]

Parameters

ELEMENTS tells FOR XML RAW to generate an XML element, instead of an attribute, for each column in the result. If there are NULL values, the element is omitted from the generated XML document. The following query generates <emp_id> and <dept_name> elements:

```
SELECT employee.emp_id, department.dept_name
FROM employee JOIN department
   ON employee.dept_id=department.dept_id
FOR XML RAW, ELEMENTS
```

and gives the following result:

```
<row>
   <emp_id>102</emp_id>
   <dept_name>R &amp; D</dept_name>
</row>
<row>
   <emp_id>105</emp_id>
   <dept_name>R &amp; D</dept_name>
</row>
```

```
<row>
   <emp_id>160</emp_id>
   <dept_name>R &amp; D</dept_name>
</row>
<row>
   <emp_id>243</emp_id>
   <dept_name>R &amp; D</dept_name>
</row>
...
```

Usage

Data in BINARY, LONG BINARY, IMAGE, and VARBINARY columns is automatically returned in base64-encoded format when you execute a query that contains FOR XML RAW.

By default, NULL values are omitted from the result. This behavior is controlled by the FOR_XML_NULL_TREATMENT option.

☞ For information about how NULL values are returned in queries that contain a FOR XML clause, see “FOR XML and NULL values” on page 492.

FOR XML RAW does not return a well-formed XML document because the document does not have a single root node. If a <root> element is required, one way to insert one is to use the XMLELEMENT function. For example,

```
SELECT XMLELEMENT( NAME root,
                   (SELECT emp_id AS id, emp_fname AS name
                   FROM employee FOR XML RAW))
```

☞ For more information about the XMLELEMENT function, see “XMLELEMENT function [String]” [*ASA SQL Reference*, page 207].

The attribute or element names used in the XML document can be changed by specifying aliases. The following query renames the id attribute to product_id:

```
SELECT id AS product_id
FROM product
WHERE color='black'
FOR XML RAW
```

and gives the following result:

```
<row product_id="302"/>
<row product_id="400"/>
<row product_id="501"/>
<row product_id="700"/>
```

The order of the results depend on the plan chosen by the optimizer, unless you request otherwise. If you wish the results to appear in a particular order, you must include an ORDER BY clause in the query, for example,

```
SELECT employee.emp_id, department.dept_name
FROM employee JOIN department
   ON employee.dept_id=department.dept_id
ORDER BY emp_id
FOR XML RAW
```

Example Suppose you want to retrieve information about which department an employee belongs to, as follows:

```
SELECT employee.emp_id, department.dept_name
FROM employee JOIN department
   ON employee.dept_id=department.dept_id
FOR XML RAW
```

The following XML document is returned:

```
<row emp_id="102" dept_name="R &amp; D"/>
<row emp_id="105" dept_name="R &amp; D"/>
<row emp_id="160" dept_name="R &amp; D"/>
<row emp_id="243" dept_name="R &amp; D"/>
...
```

Using FOR XML AUTO

AUTO mode generates nested elements within the XML document. Each table referenced in the select list is represented as an element in the generated XML. The order of nesting is based on the order in which tables are referenced in the select list. When you specify AUTO mode, an element is created for each table in the select list, and each column in that table is a separate attribute.

Syntax **FOR XML AUTO**[, **ELEMENTS**]

Parameters **ELEMENTS** tells FOR XML AUTO to generate an XML element, instead of an attribute, for each column in the result. For example,

```
SELECT employee.emp_id, department.dept_name
FROM employee JOIN department
   ON employee.dept_id=department.dept_id
ORDER BY emp_id
FOR XML AUTO, ELEMENTS
```

In this case, each column in the result set is returned as a separate element, rather than as an attribute of the <employee> element. If there are NULL values, the element is omitted from the generated XML document.

```
<employee>
   <emp_id>102</emp_id>
   <department>
      <dept_name>R &amp; D</dept_name>
   </department>
</employee>
<employee>
   <emp_id>105</emp_id>
   <department>
      <dept_name>R &amp; D</dept_name>
   </department>
</employee>
<employee>
   <emp_id>160</emp_id>
   <department>
   <dept_name>R &amp; D</dept_name>
   </department>
</employee>
...
```

Usage

When you execute a query using FOR XML AUTO, data in BINARY, LONG BINARY, IMAGE, and VARBINARY columns is automatically returned in base64-encoded format. By default, NULL values are omitted from the result. You can return NULL values as empty attributes by setting the FOR_XML_NULL_TREATMENT option to EMPTY.

☞ For information about setting the FOR_XML_NULL_TREATMENT option, see "FOR_XML_NULL_TREATMENT option [database]" [*ASA Database Administration Guide*, page 594].

Unless otherwise requested, the database server returns the rows of a table in an order that has no meaning. If you wish the results to appear in a particular order, or for a parent element to have multiple children, you must include an ORDER BY clause in the query so that all children are adjacent. If you do not specify an ORDER BY clause, the nesting of the results depends on the plan chosen by the optimizer and you may not get the nesting you desire.

FOR XML AUTO does not return a well-formed XML document because the document does not have a single root node. If a <root> element is required, one way to insert one is to use the XMLELEMENT function. For example,

```
SELECT XMLELEMENT( NAME root,
                   (SELECT emp_id AS id, emp_fname AS name
                   FROM employee FOR XML AUTO ) )
```

☞ For more information about the XMLELEMENT function, see "XMLELEMENT function [String]" [*ASA SQL Reference*, page 207].

You can change the attribute or element names used in the XML document by specifying aliases. The following query renames the id attribute to product_id:

```
SELECT id AS product_id
FROM product
WHERE color='black'
FOR XML AUTO
```

The following XML is generated:

```
<product product_id="302"/>
<product product_id="400"/>
<product product_id="501"/>
<product product_id="700"/>
```

You can also rename the table with an alias. The following query renames the table to product_info:

```
SELECT id AS product_id
FROM product AS product_info
WHERE color='black'
FOR XML AUTO
```

The following XML is generated:

```
<product_info product_id="302"/>
<product_info product_id="400"/>
<product_info product_id="501"/>
<product_info product_id="700"/>
```

Example

The following query generates XML that contains both <employee> and <department> elements, and the <employee> element (the table listed first in the select list) is the parent of the <department> element.

```
SELECT employee.emp_id, department.dept_name
FROM employee JOIN department
   ON employee.dept_id=department.dept_id
ORDER BY emp_id
FOR XML AUTO
```

The following XML is generated by the above query:

```
<employee emp_id="102">
   <department dept_name="R &amp; D"/>
</employee>
<employee emp_id="105">
   <department dept_name="R &amp; D"/>
</employee>
```

```
<employee emp_id="160">
   <department dept_name="R &amp; D"/>
</employee>
<employee emp_id="243">
   <department dept_name="R &amp; D"/>
</employee>
...
```

If you change the order of the columns in the select list as follows:

```
SELECT department.dept_name, employee.emp_id
FROM employee JOIN department
   ON employee.dept_id=department.dept_id
ORDER BY 1, 2
FOR XML AUTO
```

the result is nested as follows:

```
<department dept_name="R &amp; D">
   <employee emp_id="102"/>
   <employee emp_id="105"/>
   <employee emp_id="160"/>
   ...
</department>
<department dept_name="Sales">
   <employee emp_id="129"/>
   <employee emp_id="195"/>
   <employee emp_id="299"/>
   ...
</department>
...
```

Again, the XML generated for the query contains both <employee> and <department> elements, but in this case the <department> element is the parent of the <employee> element.

Using FOR XML EXPLICIT

FOR XML EXPLICIT allows you to control the structure of the XML document returned by the query. The query must be written in a particular way so that information about the nesting you desire is specified within the query result. The optional directives supported by FOR XML EXPLICIT allow you to configure the treatment of individual columns. For example, you can control whether a column appears as element or attribute content, or whether a column is used only to order the result, rather than appearing in the generated XML.

☞ For an example of how to write a query using FOR XML EXPLICIT, see “Writing an EXPLICIT mode query” on page 502.

Parameters

In EXPLICIT mode, the first two columns in the SELECT statement must be named **Tag** and **Parent**, respectively. Tag and Parent are metadata columns, and their values are used to determine the parent-child relationship, or nesting, of the elements in the XML document that is returned by the query.

- **Tag column** This is the first column specified in the select list. The Tag column stores the tag number of the current element. Permitted values for tag numbers are 1 to 255.
- **Parent column** This column stores the tag number for the parent of the current element. If the value in this column is NULL, the row is placed at the top level of the XML hierarchy.

For example, consider a query that returns the following result set when FOR XML EXPLICIT is not specified. (The purpose of the **first_name!1** and **id!2** data columns is discussed in the following section, "Adding data columns to the query" on page 500).

Tag	Parent	first_name!1	id!2
1	NULL	'Beth'	NULL
2	NULL	NULL	'102'

In this example, the values in the Tag column are the tag numbers for each element in the result set. The Parent column for both rows contains the value NULL. This means that both elements are generated at the top level of the hierarchy, giving the following result when the query includes the FOR XML EXPLICIT clause:

```
<first_name>Beth</first_name>
<id>102</id>
```

However, if the second row had the value 1 in the Parent column, the result would look as follows:

```
<first_name>Beth
   <id>102</id>
</first_name>
```

☞ For an example of how to write a query using FOR XML EXPLICIT, see "Writing an EXPLICIT mode query" on page 502.

Adding data columns to the query

In addition to the Tag and Parent columns, the query must also contain one or more data columns. The names of these data columns control how the columns are interpreted during tagging. Each column name is split into fields separated by an exclamation mark (!). The following fields can be specified for data columns:

ElementName!*TagNumber*!*AttributeName*!*Directive*

ElementName the name of the element. For a given row, the name of the element generated for the row is taken from the *ElementName* field of the first column with a matching tag number. If there are multiple columns with the same *TagNumber*, the *ElementName* is ignored for subsequent columns with the same *TagNumber*. In the example above, the first row generates an element called <first_name>.

TagNumber the tag number of the element. For a row with a given tag value, all columns with the same value in their *TagNumber* field will contribute content to the element that corresponds to that row.

AttributeName specifies that the column value is an attribute of the *ElementName* element. For example, if a data column had the name prod_id!1!color, then color would appear as an attribute of the <prod_id> element.

Directive this optional field allows you to control the format of the XML document further. You can specify any one of the following values for *Directive*:

- **hide** indicates that this column is ignored for the purpose of generating the result. This directive can be used to include columns that are only used to order the table. The attribute name is ignored and does not appear in the result.

  ☞ For an example using the **hide** directive, see “Using the hide directive” on page 507.

- **element** indicates that the column value is inserted as a nested element with the name *AttributeName*, rather than as an attribute.

  ☞ For an example using the **element** directive, see “Using the element directive” on page 506.

- **xml** indicates that the column value is inserted with no quoting. If the *AttributeName* is specified, the value is inserted as an element with that name. Otherwise, it is inserted with no wrapping element. If this directive is not used, then markup characters are quoted unless the column is of type XML. For example, the value <**a/**> would be inserted as **<a/>**.

  ☞ For an example using the **xml** directive, see “Using the xml directive” on page 508.

- **cdata** indicates that the column value is to be inserted as a CDATA section. The *AttributeName* is ignored.

  ☞ For an example using the **cdata** directive, see “Using the cdata directive” on page 509.

Usage

Data in BINARY, LONG BINARY, IMAGE, and VARBINARY columns is automatically returned in base64-encoded format when you execute a query that contains FOR XML EXPLICIT. By default, any NULL values in the result set are omitted. You can change this behavior by changing the setting of the FOR_XML_NULL_TREATMENT option.

☞ For more information about the FOR_XML_NULL_TREATMENT option, see "FOR_XML_NULL_TREATMENT option [database]" [*ASA Database Administration Guide*, page 594] and "FOR XML and NULL values" on page 492.

Writing an EXPLICIT mode query

Suppose you want to write a query using FOR XML EXPLICIT that generates the following XML document:

```
<employee emp_id='129'>
   <customer cust_id='107' region='Eastern'/>
   <customer cust_id='119' region='Western'/>
   <customer cust_id='131' region='Eastern'/>
</employee>

<employee emp_id='195'>
   <customer cust_id='109' region='Eastern'/>
   <customer cust_id='121' region='Central'/>
</employee>
```

You do this by writing a SELECT statement that returns the following result set in the exact order specified, and then appending FOR XML EXPLICIT to the query.

Tag	Parent	employee!1!emp_id	customer!2!cust_id	customer!2!region
1	NULL	129	NULL	NULL
2	1	129	107	Eastern
2	1	129	119	Western
2	1	129	131	Central
1	NULL	195	NULL	NULL
2	1	195	109	Eastern
2	1	195	121	Central

When you write your query, only some of the columns for a given row become part of the generated XML document. A column is included in the XML document only if the value in the *TagNumber* field (the second field in the column name) matches the value in the Tag column.

In the example, the third column is used for the two rows that have the value

1 in their Tag column. In the fourth and fifth columns, the values are used for the rows that have the value 2 in their Tag column. The element names are taken from the first field in the column name. In this case, <employee> and <customer> elements are created.

The attribute names come from the third field in the column name, so an emp_id attribute is created for <employee> elements, while cust_id and region attributes are generated for <customer> elements.

The following steps explain how to construct the FOR XML EXPLICIT query that generates an XML document similar to the one found at the beginning of this section using the sample database.

❖ To write a FOR XML EXPLICIT query

1. Write a SELECT statement to generate the top-level elements.

   In this example, the first SELECT statement in the query generates the <employee> elements. The first two values in the query must be the Tag and Parent column values. The <employee> element is at the top of the hierarchy, so it is assigned a Tag value of 1, and a Parent value of NULL.

   > **Note**
   > If you are writing an EXPLICIT mode query that uses a UNION, then only the column names specified in the first SELECT statement are used. Column names that are to be used as element or attribute names must be specified in the first SELECT statement because column names specified in subsequent SELECT statements are ignored.

   To generate the <employee> elements for the table above, your first SELECT statement is as follows:

   ```
   SELECT
         1        AS tag,
         NULL     AS parent,
         emp_id   AS [employee!1!emp_id],
         NULL     AS [customer!2!cust_id],
         NULL     AS [customer!2!region]
   FROM employee
   ```

2. Write a SELECT statement to generate the child elements.

   The second query generates the <customer> elements. Because this is an EXPLICIT mode query, the first two values specified in all the SELECT statements must be the Tag and Parent values. The <customer> element is given the tag number 2, and because it is a child of the <employee> element, it has a Parent value of 1. The first SELECT statement has already specified that emp_id, cust_id, and region are attributes.

```
SELECT
      2,
      1,
      emp_id,
      cust_id,
      region
FROM employee KEY JOIN sales_order
```

3. Add a UNION ALL to the query to combine the two SELECT statements together:

```
SELECT
      1        AS tag,
      NULL     AS parent,
      emp_id   AS [employee!1!emp_id],
      NULL     AS [customer!2!cust_id],
      NULL     AS [customer!2!region]
FROM employee
UNION ALL
SELECT
      2,
      1,
      emp_id,
      cust_id,
      region
FROM employee KEY JOIN sales_order
```

4. Add an ORDER BY clause to specify the order of the rows in the result. The order of the rows is the order that is used in the resulting document.

```
SELECT
      1        AS tag,
      NULL     AS parent,
      emp_id   AS [employee!1!emp_id],
      NULL     AS [customer!2!cust_id],
      NULL     AS [customer!2!region]
FROM employee
UNION ALL
SELECT
      2,
      1,
      emp_id,
      cust_id,
      region
FROM employee KEY JOIN sales_order
ORDER BY 3, 1
FOR XML EXPLICIT
```

☞ For information about the syntax of EXPLICIT mode, see "Parameters" on page 500.

FOR XML EXPLICIT examples

The following example query retrieves information about the orders placed by employees. In this example, there are three types of elements: <emp>,

<order>, and <dept>. The <emp> element has id and name attributes, the <order> element has a name attribute, and the <dept> element has a date attribute.

```
SELECT
        1          tag,
        NULL       parent,
        emp_id     [emp!1!id],
        emp_fname  [emp!1!name],
        NULL       [order!2!date],
        NULL       [dept!3!name]
FROM employee
UNION ALL
SELECT
        2,
        1,
        emp_id,
        NULL,
        order_date,
        NULL
FROM employee KEY JOIN sales_order
UNION ALL
SELECT
        3,
        1,
        emp_id,
        NULL,
        NULL,
        dept_name
FROM employee e JOIN department d
   ON e.dept_id=d.dept_id
ORDER BY 3, 1
FOR XML EXPLICIT
```

You get the following result from this query:

```
<emp id="102" name="Fran">
   <dept name="R &amp; D"/>
</emp>
<emp id="105" name="Matthew">
   <dept name="R &amp; D"/>
</emp>
<emp id="129" name="Philip">
   <order date="2000-07-24"/>
   <order date="2000-07-13"/>
   <order date="2000-06-24"/>
   <order date="2000-06-08"/>
   ...
   <dept name="Sales"/>
</emp>
<emp id="148" name="Julie">
   <dept name="Finance"/>
</emp>
...
```

Using the element directive

If you wish to generate sub-elements rather than attributes, you can add the **element** directive to the query, as follows:

```
SELECT
        1          tag,
        NULL       parent,
        emp_id     [emp!1!id!element],
        emp_fname  [emp!1!name!element],
        NULL       [order!2!date!element],
        NULL       [dept!3!name!element]
FROM employee
UNION ALL
SELECT
        2,
        1,
        emp_id,
        NULL,
        order_date,
        NULL
FROM employee KEY JOIN sales_order
UNION ALL
SELECT
        3,
        1,
        emp_id,
        NULL,
        NULL,
        dept_name
FROM employee e JOIN department d
   ON e.dept_id=d.dept_id
ORDER BY 3, 1
FOR XML EXPLICIT
```

You get the following result from this query:

```
<emp>
   <id>102</id>
   <name>Fran</name>
   <dept>
      <name>R &amp; D</name>
   </dept>
</emp>
<emp>
   <id>105</id>
   <name>Matthew</name>
   <dept>
      <name>R &amp; D</name>
   </dept>
</emp>
```

```
<emp>
   <id>129</id>
   <name>Philip</name>
   <order>
      <date>2000-07-24</date>
   </order>
   <order>
      <date>2000-07-13</date>
   </order>
   <order>
      <date>2000-06-24</date>
   </order>
   ...
   <dept>
      <name>Sales</name>
   </dept>
</emp>
...
```

Using the hide directive

In the following query, the employee ID is used to order the result, but the employee ID does not appear in the result because the **hide** directive is specified:

```
SELECT
        1           tag,
        NULL        parent,
        emp_id      [emp!1!id!hide],
        emp_fname   [emp!1!name],
        NULL        [order!2!date],
        NULL        [dept!3!name]
FROM employee
UNION ALL
SELECT
        2,
        1,
        emp_id,
        NULL,
        order_date,
        NULL
FROM employee KEY JOIN sales_order
UNION ALL
SELECT
        3,
        1,
        emp_id,
        NULL,
        NULL,
        dept_name
FROM employee e JOIN department d
   ON e.dept_id=d.dept_id
ORDER BY 3, 1
FOR XML EXPLICIT
```

This query returns the following result:

```
<emp name="Fran">
   <dept name="R &amp; D"/>
</emp>
<emp name="Matthew">
   <dept name="R &amp; D"/>
</emp>
<emp name="Philip">
   <order date="2000-07-24"/>
   <order date="2000-07-13"/>
   <order date="2000-06-24"/>
   <order date="2000-06-08"/>
   ...
   <dept name="Sales"/>
</emp>
<emp name="Julie">
   <dept name="Finance"/>
</emp>
...
```

Using the xml directive

By default, when the result of a FOR XML EXPLICIT query contains characters that are not valid XML name characters, the invalid are escaped (for information see "Invalid column names" on page 493) unless the column is of type XML. For example, the following query generates XML that contains an ampersand (&):

```
SELECT
        1                AS tag,
        NULL             AS parent,
        id               AS [customer!1!id!element],
        company_name     AS [customer!1!company_name]
FROM customer
WHERE id = '115'
FOR XML EXPLICIT
```

In the result generated by this query, the ampersand is quoted because the column is not of type XML:

```
<customer company_name="Sterling &amp; Co.">
   <id>115</id>
</customer>
```

The **xml** directive indicates that the column value is inserted into the generated XML with no quoting. If you execute the same query as above with the **xml** directive:

```
SELECT
        1               AS tag,
        NULL            AS parent,
        id              AS [customer!1!id!element],
        company_name    AS [customer!1!company_name!xml]
FROM customer
WHERE id = '115'
FOR XML EXPLICIT
```

the ampersand is not quoted in the result:

```
<customer>
 <id>115</id>
 <company_name>Sterling & Co.</company_name>
</customer>
```

Note that this XML is not well-formed because it contains an ampersand, which is a special character in XML. When XML is generated by a query, it is your responsibility to ensure that the XML is well-formed and valid: Adaptive Server Anywhere does not check whether the XML being generated is well-formed or valid.

When you specify the **xml** directive, the *AttributeName* field is ignored, and elements are generated rather than attributes.

Using the cdata directive

The following query uses the **cdata** directive to return the customer name in a CDATA section:

```
SELECT
        1               AS tag,
        NULL            AS parent,
        id              AS [product!1!id],
        description     AS [product!1!cdata]
FROM product
FOR XML EXPLICIT
```

The result produced by this query lists the description for each product in a CDATA section. Data contained in the CDATA section is not quoted:

```
<product id="300">
   <![CDATA[Tank Top]]>
</product>
<product id="301">
   <![CDATA[V-neck]]>
</product>

<product id="302">
   <![CDATA[Crew Neck]]>
</product>
<product id="400">
   <![CDATA[Cotton Cap]]>
</product>
...
```

Using SQL/XML to obtain query results as XML

SQL/XML is a draft standard that describes a functional integration of XML into the SQL language: it describes the ways that SQL can be used in conjunction with XML. The supported functions allow you to write queries that construct XML documents from relational data.

Invalid names and SQL/XML

In SQL/XML, expressions that are not legal XML names, for example expressions that include spaces, are quoted in the same manner as the FOR XML clause. Element content of type XML is not quoted.

☞ For more information about quoting invalid expressions, see "Invalid column names" on page 493.

☞ For information about using the XML data type, see "Storing XML documents in relational databases" on page 481.

Using the XMLAGG function

The XMLAGG function is used to produce a forest of XML elements from a collection of XML elements. XMLAGG is an aggregate function, and produces a single aggregated XML result for all the rows in the query.

In the following query, XMLAGG is used to generate a <name> element for each row, and the <name> elements are ordered by employee name. The ORDER BY clause is specified to order the XML elements:

```
SELECT XMLELEMENT( NAME department,
                   XMLATTRIBUTES (dept_id ),
                   XMLAGG( XMLELEMENT( NAME name,
                             emp_lname )
                             ORDER BY emp_lname )
                 ) AS dept_list
FROM employee
GROUP BY dept_id
```

This query produces the following result:

dept_list

```
<department dept_id="100">
 <name>Breault</name>
 <name>Cobb</name>
 <name>Diaz</name>
 <name>Driscoll</name>
 ...
</department>
```

dept_list

```
<department dept_id="200">
 <name>Chao</name>
 <name>Chin</name>
 <name>Clark</name>
 <name>Dill</name>
 ...
</department>

<department dept_id="300">
 <name>Bigelow</name>
 <name>Coe</name>
 <name>Coleman</name>
 <name>Davidson</name>
 ...
</department>

...
```

☞ For more information about the XMLAGG function, see “XMLAGG function [String]” [*ASA SQL Reference*, page 205].

Using the XMLCONCAT function

The XMLCONCAT function creates a forest of XML elements by concatenating all the XML values passed in. For example, the following query concatenates the <first_name> and <last_name> elements for each employee in the employee table:

```
SELECT XMLCONCAT( XMLELEMENT( NAME first_name, emp_fname ),
                  XMLELEMENT( NAME last_name, emp_lname )
                ) AS "Employee_Name"
FROM employee
```

This query returns the following result:

Employee_Name

```
<first_name>Fran</first_name>
<last_name>Whitney</last_name>

<first_name>Matthew</first_name>
<last_name>Cobb</last_name>
```

Employee_Name
`<first_name>Philip</first_name>` `<last_name>Chin</last_name>`
`<first_name>Julie</first_name>` `<last_name>Jordan</last_name>`
...

☞ For more information, see “XMLCONCAT function [String]” [*ASA SQL Reference*, page 206].

Using the XMLELEMENT function

The XMLELEMENT function constructs an XML element from relational data. You can specify the content of the generated element and if you wish, you can also specify attributes and attribute content for the element.

Generating nested elements

The following query generates nested XML, producing a <product_info> element for each product, with elements that provide the name, quantity, and description of each product:

```
SELECT id,
       XMLELEMENT( NAME product_info,
       XMLELEMENT( NAME item_name, product.name ),
       XMLELEMENT( NAME quantity_left, product.quantity ),
       XMLELEMENT( NAME description, product.size || ' ' ||
                           product.color || ' ' ||
                        product.name )
       ) AS results
FROM product
WHERE quantity > 30
```

This query produces the following result:

id	results

301	`<product_info>`
	`<item_name>Tee Shirt`
	`</item_name>`
	`<quantity_left>54`
	`</quantity_left>`
	`<description>Medium Orange`
	`Tee Shirt</description>`
	`</product_info>`

302	`<product_info>`
	`<item_name>Tee Shirt`
	`</item_name>`
	`<quantity_left>75`
	`</quantity_left>`
	`<description>One size fits`
	`all Black Tee Shirt`
	`</description>`
	`</product_info>`

400	`<product_info>`
	`<item_name>Baseball Cap`
	`</item_name>`
	`<quantity_left>112`
	`</quantity_left>`
	`<description>One size fits`
	`all Black Baseball Cap`
	`</description>`
	`</product_info>`

...	...

Specifying element content

The XMLELEMENT function allows you to specify the content of an element. The following statement produces an XML element with the content hat.

```
SELECT id, XMLELEMENT( NAME product_type, 'hat' )
FROM product
WHERE name IN ( 'Baseball Cap', 'Visor' )
```

Generating elements with attributes

You can add attributes to the elements by including the *attribute-value-expression* argument in your query. This argument specifies the attribute name and content. The following statement produces an attribute for the name, color, and unit_price of each item.

```
SELECT id, XMLELEMENT( NAME item_description,
                       XMLATTRIBUTES( name,
                                      color,
                                      unit_price )
                     ) AS item_description_element
FROM product
WHERE id > 400
```

Attributes can be named by specifying the *attribute-name* argument:

```
SELECT id, XMLELEMENT( NAME item_description,
                       XMLATTRIBUTES ( unit_price AS
                        price ),
                       product.name
                    ) AS products
FROM product
WHERE id > 400
```

☞ For more information, see “XMLELEMENT function [String]” [*ASA SQL Reference*, page 207].

Using the XMLFOREST function

XMLFOREST constructs a forest of XML elements. An element is produced for each XMLFOREST argument.

The following query produces an <item_description> element, with <name>, <color>, and <price> elements:

```
SELECT id, XMLELEMENT( NAME item_description,
                       XMLFOREST( name,
                                  color,
                                  unit_price AS price )
                     ) AS product_info
FROM product
WHERE id > 400
```

The following result is generated by this query:

id	product_info
401	<item_description> <name>Baseball Cap</name> <color>White</color> <price>10.00</price> </item_description>
500	<item_description> <name>Visor</name> <color>White</color> <price>7.00</price> </item_description>
501	<item_description> <name>Visor</name> <color>Black</color> <price>7.00</price> </item_description>
...	...

☞ For more information, see “XMLFOREST function [String]” [*ASA SQL Reference*, page 208].

Using the XMLGEN function

The XMLGEN function is used to generate an XML value based on an XQuery constructor.

The XML generated by the following query provides information about customer orders in the sample database. It uses the following variable references:

- **{$id}** Generates content for the <id> element using values from the id column in the sales_order table.
- **{$order_date}** Generates content for the <date> element using vaues from the order_date column in the sales_order table.
- **{$customer}** Generates content for the <customer> element from the company_name column in the customer table.

```
SELECT XMLGEN ( '<order>
                 <id>{$id}</id>
                 <date>{$order_date}</date>
                 <customer>{$customer}</customer>
                 </order>',
                sales_order.id,
                sales_order.order_date,
                customer.company_name AS customer)
 FROM sales_order JOIN customer
 ON customer.id = sales_order.cust_id
```

This query generates the following result:

order_info

`<order>`
` <id>2131</id>`
` <date>2000-01-02</date>`
` <customer>BoSox Club</customer>`
`</order>`
 	
`<order>`
` <id>2126</id>`
` <date>2000-01-03</date>`
` <customer>Leisure Time</customer>`
`</order>`
 	
`<order>`
` <id>2065</id>`
` <date>2000-01-03</date>`
` <customer>Bloomfield's</custo`
`   mer>`
`</order>`
 	
`<order>`
` <id>2127</id>`
` <date>2000-01-06</date>`
` <customer>Creative Customs`
`   Inc.</customer>`
`</order>`
 	
`...`

Generating attributes

If you want the order ID number to appear as an attribute of the <order> element, you would write query as follows (note that the variable reference is contained in double quotes because it specifies an attribute value):

```
SELECT XMLGEN ( '<order id="{$id}">
                  <date>{$order_date}</date>
                  <customer>{$customer}</customer>
                  </order>',
                 sales_order.id,
                 sales_order.order_date,
                 customer.company_name AS customer
               ) AS order_info
FROM sales_order JOIN customer
 ON customer.id = sales_order.cust_id
 ORDER BY sales_order.order_date
```

This query generates the following result:

order_info
`<order id="2131"> <date>2000-01-02</date> <customer>BoSox Club</customer> </order>`
`<order id="2126"> <date>2000-01-03</date> <customer>Leisure Time</customer> </order>`
`<order id="2065"> <date>2000-01-03</date> <customer>Bloomfield's</customer> </order>`
`<order id="2127"> <date>2000-01-06</date> <customer>Creative Customs Inc.</customer> </order>`
...

In both result sets, the customer name Bloomfield’s is quoted as **Bloomfield's** because the apostrophe is a special character in XML and the column the <customer> element was generated from was not of type XML.

☞ For more information about quoting of invalid characters in XMLGEN, see “Invalid names and SQL/XML” on page 510.

Specifying header information for XML documents

The FOR XML clause and the SQL/XML functions supported by Adaptive Server Anywhere do not include header information in the XML documents they generate. You can use the XMLGEN function to generate header information.

```
SELECT XMLGEN( '<?xml version="1.0"
                 encoding="ISO-8859-1" ?>
                <r>{$x}</r>',
                (SELECT fname, lname FROM customer FOR XML RAW)
         AS x )
```

This produces the following result:

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
<r>
 <row fname="Michaels" lname="Devlin"/>
 <row fname="Beth" lname="Reiser"/>
 <row fname="Erin" lname="Niedringhaus"/>
 <row fname="Meghan" lname="Mason"/>
 ...
</r>
```

☞ For more information about the XMLGEN function, see “XMLGEN function [String]” [*ASA SQL Reference*, page 209].

Part V

Remote Data and Bulk Operations

This part describes how to load and unload your database, and how to access remote data.

CHAPTER 16

Importing and Exporting Data

About this chapter

This chapter describes the Adaptive Server Anywhere tools and utilities that help you achieve your importing and exporting goals, including SQL, Interactive SQL, the *dbunload* utility and Sybase Central wizards.

Contents

Topic:	page
Introduction to import and export	522
Importing and exporting data	524
Importing	528
Exporting	532
Rebuilding databases	539
Extracting data	547
Migrating databases to Adaptive Server Anywhere	548
Running SQL command files	553
Adaptive Server Enterprise compatibility	556

Introduction to import and export

Transferring large amounts of data into and from your database may be necessary in several situations. For example,

- Importing an initial set of data into a new database.
- Exporting data from your database for use with other applications, such as spreadsheets.
- Building new copies of a database, perhaps with a modified structure.
- Creating extractions of a database for replication or synchronization.

Performance considerations of moving data

The Interactive SQL INPUT and OUTPUT commands are external to the database (client-side). If ISQL is being run on a different machine than the database server, paths to files being read or written are relative to the client. An INPUT is recorded in the transaction log as a separate INSERT statement for each row read. As a result, INPUT is considerably slower than LOAD TABLE. This also means that ON INSERT triggers will fire during an INPUT. Missing values will be inserted as NULL on NULLABLE rows, as 0 (zero) on non-nullable numeric columns, and as an empty string on non-nullable non-numeric columns. The OUTPUT statement is useful when compatibility is an issue since it can write out the result set of a SELECT statement to any one of a number of file formats.

The LOAD TABLE, UNLOAD TABLE and UNLOAD statements, on the other hand, are internal to the database (server-side). Paths to files being written or read are relative to the database server. Only the command travels to the database server, where all processing happens. A LOAD table statement is recorded in the transaction log as a single command. The data file must contain the same number of columns as the table to be loaded. Missing values on columns with a default value will be inserted as NULL, zero or an empty string if the DEFAULTS option is set to OFF (default), or as the default value if the DEFAULTS value is set to ON. Internal importing and exporting only provides access to text and BCP formats, but it is a faster method.

Although loading large volumes of data into a database can be very time consuming, there are a few things you can do to save time:

- If you use the LOAD TABLE statement, then bulk mode (starting the server with the `-b` option) is not necessary.

- If you are using the INPUT command, run Interactive SQL or the client application on the same machine as the server. Loading data over the network adds extra communication overhead. This might mean loading new data during off hours.

- Place data files on a separate physical disk drive from the database. This could avoid excessive disk head movement during the load.

- If you are using the INPUT command, start the server with the `-b` option for bulk operations mode. In this mode, the server does not keep a rollback log or a transaction log, it does not perform an automatic COMMIT before data definition commands, and it does not lock any records.

  The server allows only one connection when you use the `-b` option.

  Without a rollback log, you cannot use savepoints and aborting a command always causes transactions to roll back. Without automatic COMMIT, a ROLLBACK undoes everything since the last explicit COMMIT.

  Without a transaction log, there is no log of the changes. You should back up the database before and after using bulk operations mode because, in this mode, your database is not protected against media failure. For more information, see "Backup and Data Recovery" [*ASA Database Administration Guide,* page 337].

  If you have data that requires many commits, running with the `-b` option may slow database operation. At each COMMIT, the server carries out a checkpoint; this frequent checkpointing can slow the server.

- Extend the size of the database, as described in "ALTER DBSPACE statement" [*ASA SQL Reference,* page 229]. This command allows a database to be extended in large amounts before the space is required, rather than the normal 256 kb at a time when the space is needed. As well as improving performance for loading large amounts of data, it also serves to keep the database more contiguous within the file system.

- You can use temporary tables to load data. Local or global temporary tables are useful when you need to load a set of data repeatedly, or when you need to merge tables with different structures.

Importing and exporting data

You can import individual tables or portions of tables from other database file formats, or from ASCII files. Depending on the format of the data you are inserting, there is some flexibility as to whether you create the table before the import or during the import. You may find importing a useful tool if you need to add large amounts of data to your database at a time.

You can export individual tables and query results in ASCII format, or in a variety of formats supported by other database programs. You may find exporting a useful tool if you need to share large portions of your database, or extract portions of your database according to particular criteria.

Although Adaptive Server Anywhere import and export procedures work on one table at a time, you can create scripts that effectively automate the importing or export procedure, allowing you to import and export data into or from a number of tables consecutively.

You can insert (append) data into tables, and you can replace data in tables. In some cases, you can also create new tables at the same time as you import the data. If you are trying to create a whole new database, however, consider loading the data instead of importing it, for performance reasons.

You can export query results, table data, or table schema. If you are trying to export a whole database, however, consider unloading the database instead of exporting data, for performance reasons.

☞ For more information about loading and unloading complete databases, see "Rebuilding databases" on page 539.

You can import and export files between Adaptive Server Anywhere and Adaptive Server Enterprise using the BCP FORMAT clause.

☞ For more information, see "Adaptive Server Enterprise compatibility" on page 556.

Data formats

Interactive SQL supports the following import and export file formats:

File Format	Description	Available for Importing	Available for Exporting
ASCII	A text file, one row per line, with values separated by a delimiter. String values optionally appear enclosed in apostrophes (single quotes). This is the same as the format used by LOAD TABLE and UNLOAD TABLE.	✔	✔
DBASEII	DBASE II format	✔	✔
DBASEIII	DBASE III format	✔	✔
Excel 2.1	Excel format 2.1	✔	✔
FIXED	Data records appear in fixed format with the width of each column either the same as defined by the column's type or specified as a parameter.	✔	✔
FOXPRO	FoxPro format	✔	✔
HTML	HTML (Hyper Text Markup Language) format	No	✔
LOTUS	Lotus workspace format	✔	✔
SQL Statements	The SQL statement format. This format can be used as an argument in a READ statement.	Using the READ statement only	✔
XML	The generated XML file is encoded in UTF-8 and contains an embedded DTD. Binary values are encoded in CDATA blocks with the binary data rendered as 2-hex-digit strings.	No	✔

Table structures for import

The structure of the data you want to load into a table does not always match the structure of the destination table itself, which may present problems during importing. For example, the column data types may be different or in a different order, or there may be extra values in the import data that do not match columns in the destination table.

Rearranging the table or data

If you know that the structure of the data you want to import does not match the structure of the destination table, you have several options. You can rearrange the columns in your table using the LOAD TABLE statement; you can rearrange the import data to fit the table using a variation of the INSERT statement and a global temporary table; or you can use the INPUT statement to specify a specific set or order of columns.

Allowing columns to contain NULLs

If the file you are importing contains data for a subset of the columns in a table, or if the columns are in a different order, you can also use the LOAD TABLE statement DEFAULTS option to fill in the blanks and merge non-matching table structures.

If DEFAULTS is OFF, any column not present in the column list is assigned NULL. If DEFAULTS is OFF and a non-nullable column is omitted from the column list, the database server attempts to convert the empty string to the column's type. If DEFAULTS is ON and the column has a default value, that value is used.

For example, to load two columns into the employee table, and set the remaining column values to the default values if there are any, the LOAD TABLE statement should look like this:

```
LOAD TABLE employee (emp_lname, emp_fname)
FROM 'new_employees.txt'
DEFAULTS ON
```

Merging different table structures

You can rearrange the import data to fit the table using a variation of the INSERT statement and a global temporary table.

❖ To load data with a different structure using a global temporary table

1. In the SQL Statements pane of the Interactive SQL window, create a global temporary table with a structure matching that of the input file.

   You can use the CREATE TABLE statement to create the global temporary table.

2. Use the LOAD TABLE statement to load your data into the global temporary table.

   When you close the database connection, the data in the global temporary table disappears. However, the table definition remains. You can use it the next time you connect to the database.

3. Use the INSERT statement with a FROM SELECT clause to extract and

summarize data from the temporary table and put it into one or more permanent database tables.

Conversion errors during import

When you load data from external sources, there may be errors in the data. For example, there may be dates that are not valid dates and numbers that are not valid numbers. The CONVERSION_ERROR database option allows you to ignore conversion errors by converting them to NULL values.

☞ For more information about setting Interactive SQL database options, see "SET OPTION statement" [*ASA SQL Reference*, page 556], or "CONVERSION_ERROR option [compatibility]" [*ASA Database Administration Guide*, page 585].

Outputting NULLs

Users often want to extract data for use in other software products. Since the other software package may not understand NULL values, there are two ways of specifying how NULL values are output. You can use either the Interactive SQL NULLS option, or the IFNULL function. Both options allow you to output a specific value in place of a NULL value.

Use the Interactive SQL NULLS option to set the default behavior, or to change the output value for a particular session. Use the IFNULL function to apply the output value to a particular instance or query.

Specifying how NULL values are output provides for greater compatibility with other software packages.

❖ To specify NULL value output (Interactive SQL)

1. From the Interactive SQL window, choose Tools ➤ Options to display the Options dialog.

2. Click the Results tab.

3. In the Display Null Values As field, type the value you want to replace null values with.

4. Click Make Permanent if you want the changes to become the default, or click OK if you want the changes to be in effect only for this session.

For more information on setting Interactive SQL options, see "SET OPTION statement" [*ASA SQL Reference*, page 556].

Importing

Following is a summary of import tools, followed by instructions for importing databases, data, and tables.

Import tools

There are a variety of tools available to help you import your data.

Interactive SQL Import wizard

You can access the import wizard by choosing Data ➤ Import from the Interactive SQL menu. The wizard provides an interface to allow you to choose a file to import, a file format, and a destination table to place the data in. You can choose to import this data into an existing table, or you can use the wizard to create and configure a completely new table.

Choose the Interactive SQL Import wizard when you prefer using a graphical interface to import data in a format other than text, or when you want to create a table at the same time you import the data.

INPUT statement

You execute the INPUT statement from the SQL Statements pane of the Interactive SQL window. The INPUT statement allows you to import data in a variety of file formats into one or more tables. You can choose a default input format, or you can specify the file format on each INPUT statement. Interactive SQL can execute a command file containing multiple INPUT statements.

If a data file is in DBASE, DBASEII, DBASEIII, FOXPRO, or LOTUS format and the table does not exist, it will be created. There are performance impacts associated with importing large amounts of data with the INPUT statement, since the INPUT statement writes everything to the Transaction log.

Choose the Interactive SQL INPUT statement when you want to import data into one or more tables, when you want to automate the import process using a command file, or when you want to import data in a format other than text.

☞ For more information, see “INPUT statement [Interactive SQL]” [*ASA SQL Reference*, page 472].

LOAD TABLE statement

The LOAD TABLE statement allows you to import data only, into a table, in an efficient manner in text/ASCII/FIXED formats. The table must exist and have the same number of columns as the input file has fields, defined on compatible data types. The LOAD TABLE statement imports with one row per line, with values separated by a delimiter.

Use the LOAD TABLE statement when you want to import data in text format. If you have a choice between using the INPUT statement or the

LOAD TABLE statement, choose the LOAD TABLE statement for better performance.

☞ For more information, see “LOAD TABLE statement” [*ASA SQL Reference,* page 486].

INSERT statement

Since you include the data you want to place in your table directly in the INSERT statement, it is considered interactive input. File formats are not an issue. You can also use the INSERT statement with remote data access to import data from another database rather than a file.

Choose the INSERT statement when you want to import small amounts of data into a single table.

☞ For more information, see “INSERT statement” [*ASA SQL Reference,* page 476].

Proxy Tables

You can import data directly from another database. Using the Adaptive Server Anywhere remote data access feature, you can create a proxy table, which represents a table from the remote database, and then use an INSERT statement with a SELECT clause to insert data from the remote database into a permanent table in your database.

☞ For more information about remote data access, see “Accessing Remote Data” on page 557.

Importing databases

You can use either the Interactive SQL Import wizard or the INPUT statement to create a database by importing one table at a time. You can also create a script that automates this process. However, for more efficient results, consider reloading a database whenever possible.

☞ For more information about importing a database that was previously unloaded, see “Reloading a Database” on page 543.

Importing data

❖ To import data (Interactive SQL Data Menu)

1. From the Interactive SQL window, choose Data ➤ Import.

   The Open dialog appears.

2. Locate the file you want to import and click Open.

   You can import data in text, DBASEII, Excel 2.1, FOXPRO, and Lotus formats.

   The Import wizard appears.

3. Specify how the database values are stored in the file you are importing.
4. Select the Use An Existing Table option and then enter the name and location of the existing table. Click Next.

   You can click the Browse button and locate the table you want to import the data into.
5. Follow the remaining instructions in the wizard.

   In this case, importing appends the new data to the existing table. If the import is successful, the Messages pane displays the amount of time it to took to import the data. If the import is unsuccessful, a message appears indicating the import was unsuccessful. The Results tab in the Results pane displays what execution plan was used.

❖ To import data (INSERT statement)

1. Ensure that the table you want to place the data in exists.
2. Execute an INSERT statement. For example,

```
INSERT INTO t1
VALUES ( ... )
```

   Inserting values appends the new data to the existing table.

❖ To import data (Interactive SQL INPUT statement)

1. Ensure that the table you want to place the data in exists.
2. Enter an INPUT statement in the SQL Statements pane of the Interactive SQL window. For example,

```
INPUT INTO t1
FROM file1
FORMAT ASCII;
```

   Where *t1* is the name of the table you want to place the data in, and *file1* is the name of the file that holds the data you want to import.
3. Execute the statement.

   If the import is successful, the Messages pane displays the amount of time it to took to import the data. If the import is unsuccessful, a message appears indicating the import was unsuccessful. The Results tab in the Results pane displays what execution plan was used.

☞ For more information about using the INPUT statement to import data, see “INPUT statement [Interactive SQL]” [*ASA SQL Reference*, page 472].

Importing a table

❖ To import a table (Interactive SQL Data Menu)

1. Ensure that the table you want to place the data in exists.
2. From the Interactive SQL window, choose Data ➤ Import.

   The Open dialog appears.
3. Locate the file you want to import and click Open.

   You can import data in text, DBASEII, Excel 2.1, FOXPRO, and Lotus formats.

   The Import wizard appears.
4. Select the Create A New Table With The Following Name option and enter a name for the new table in the field.
5. Follow the remaining instructions in the wizard.

   If the import is successful, the Messages pane displays the amount of time it to took to import the data. If the import is unsuccessful, a message appears indicating the import was unsuccessful. The Results tab in the Results pane displays what execution plan was used.

❖ To import a table (Interactive SQL)

1. In the SQL Statements pane of the Interactive SQL window, create the table you want to load data into.

   You can use the CREATE TABLE statement to create the table.
2. Execute a LOAD TABLE statement. For example,

   ```
   LOAD TABLE department
   FROM 'dept.txt'
   ```

   The LOAD TABLE statement appends the contents of the file to the existing rows of the table; it does not replace the existing rows in the table. You can use the TRUNCATE TABLE statement to remove all the rows from a table.

   Neither the TRUNCATE TABLE statement nor the LOAD TABLE statement fires triggers, including referential integrity actions such as cascaded deletes.

   The LOAD TABLE statement has an optional STRIP clause. The default setting (STRIP ON) strips trailing blanks from values before inserting them. To keep trailing blanks, use the STRIP OFF clause in your LOAD TABLE statement.

   For more information about the LOAD TABLE statement syntax, see "LOAD TABLE statement" [*ASA SQL Reference*, page 486].

Exporting

Following is a summary of export tools, followed by instructions for exporting query results, databases, and tables.

Export tools

There are a variety of tools available to help you export your data.

Exporting data from Interactive SQL

You can export data from Interactive SQL by choosing Export from the Data menu. This allows you to choose the format of the exported query results.

OUTPUT statement

You can export query results, tables or views from your database using the Interactive SQL OUTPUT statement. The Interactive SQL OUTPUT statement supports several different file formats. You can either specify the default output format, or you can specify the file format on each OUTPUT statement. Interactive SQL can execute a command file containing multiple OUTPUT statements.

There are performance impacts associated with exporting large amounts of data with the OUTPUT statement. As well, you should use the OUTPUT statement on the same machine as the server if possible to avoid sending large amounts of data across the network.

Choose the Interactive SQL OUTPUT statement when you want to export all or part of a table or view in a format other than text, or when you want to automate the export process using a command file.

☞ For more information, see “OUTPUT statement [Interactive SQL]” [*ASA SQL Reference*, page 501].

UNLOAD TABLE statement

You execute the UNLOAD TABLE statement from the SQL Statements pane of the Interactive SQL window. It allows you to export data only, in an efficient manner in text/ASCII/FIXED formats. The UNLOAD TABLE statement exports with one row per line, and values separated by a comma delimiter. The data exports in order by primary key values to make reloading quicker.

Choose the UNLOAD TABLE statement when you want to export entire tables in text format. If you have a choice between using the OUTPUT statement, UNLOAD statement, or UNLOAD TABLE statement, choose the UNLOAD TABLE statement for performance reasons.

☞ For more information, see “UNLOAD TABLE statement” [*ASA SQL Reference*, page 590].

UNLOAD statement

The UNLOAD statement is similar to the OUTPUT statement in that they both export query results to a file. The UNLOAD statement, however, allows you to export data in a more efficient manner and in text/ASCII/FIXED formats only. The UNLOAD statement exports with one row per line, with values separated by a comma delimiter.

To use the UNLOAD statement, the user must have ALTER or SELECT permission on the table. For more information about controlling who can use the UNLOAD statement, see "-gl server option" [*ASA Database Administration Guide,* page 147].

Choose the UNLOAD statement when you want to export query results if performance is an issue, and if output in text format is acceptable. The UNLOAD statement is also a good choice when you want to embed an export command in an application.

When unloading and reloading a database that has proxy tables, you must create an external login to map the local user to the remote user, even if the user has the same password on both the local and remote databases. If you do not have an external login, the reload may fail because you cannot connect to the remote server.

☞ For more information, see "UNLOAD statement" [*ASA SQL Reference,* page 588].

Dbunload utility

The *dbunload* utility and Sybase Central are graphically different, and functionally equivalent. You can use either one interchangeably to produce the same results. These tools are different from Interactive SQL statements in that they can operate on several tables at once. And in addition to exporting table data, both tools can also export table schema.

If you want to rearrange your tables in the database, you can use *dbunload* to create the necessary command files and modify them as needed. Sybase Central provides wizards and a GUI interface for unloading one, many, or all of the tables in a database, and dbunload provides command line options for the same activities. Tables can be unloaded with structure only, data only or both structure and data. To unload fewer than all of the tables in a database, a connection must be established beforehand.

You can also extract one or many tables with or without command files. These files can be used to create identical tables in different databases.

Choose Sybase Central or the *dbunload* utility when you want to export in text format, when you need to process large amounts of data quickly, when your file format requirements are flexible, or when your database needs to be rebuilt or extracted.

☞ For more information, see "Unloading a database using the dbunload command-line utility" [*ASA Database Administration Guide,* page 534].

Exporting query results

You can export queries (including queries on views) to a file from Interactive SQL using the Data menu or the OUTPUT statement.

You can import and export files between Adaptive Server Anywhere and Adaptive Server Enterprise using the BCP FORMAT clause.

☞ For more information, see "Adaptive Server Enterprise compatibility" on page 556.

❖ To export query results (Interactive SQL Data menu)

1. Enter your query in the SQL Statements pane of the Interactive SQL window.

2. Click Execute SQL statement(s) to display the result set.

3. Choose Data ➤ Export.

   The Save As dialog appears.

4. Specify a name and location for the exported data.

5. Specify the file format and click Save.

   If the export is successful, the Messages pane displays the amount of time it to took to export the query result set, the filename and path of the exported data, and the number of rows written.

   If the export is unsuccessful, a message appears indicating the export was unsuccessful.

❖ To export query results (Interactive SQL OUTPUT statement)

1. Enter your query in the SQL Statements pane of the Interactive SQL window.

2. At the end of the query, type **OUTPUT TO** *'c:\filename'*.

   For example, to export the entire employee table to the file *employee.dbf,* enter the following query:

   ```
   SELECT *
   FROM employee;
   OUTPUT TO 'c:\employee.dbf'
   ```

3. If you want to export query results and append the results to another file, add the APPEND statement to the end of the OUTPUT statement.

- For example,

```
SELECT *
FROM employee;
OUTPUT TO 'c:\employee.dbf' APPEND
```

4. If you want to export query results and include messages, add the VERBOSE statement to the end of the OUTPUT statement.

   For example,

```
SELECT *
FROM employee;
OUTPUT TO 'c:\employee.dbf' VERBOSE
```

5. If you want to specify a format other than ASCII, add a FORMAT clause to the end of the query.

   For example,

```
SELECT *
FROM employee;
OUTPUT TO 'c:\employee.dbf'
FORMAT dbaseiii;
```

   where *c:\employee.dbf* is the path, name, and extension of the new file and *dbaseiii* is the file format for this file. You can enclose the string in single or double quotation marks, but they are only required if the path contains embedded spaces.

   Where *dbaseiii* is the file format for this file. If you leave the FORMAT option out, the file type defaults to ASCII.

6. Execute the statement.

   If the export is successful, the Messages pane displays the amount of time it to took to export the query result set, the filename and path of the exported data, and the number of rows written. If the export is unsuccessful, a message appears indicating the export was unsuccessful.

   For more information about exporting query results using the OUTPUT statement, see "OUTPUT statement [Interactive SQL]" [*ASA SQL Reference*, page 501].

Tips

You can combine the APPEND and VERBOSE statements to append both results and messages to an existing file. For example, type `OUTPUT TO 'filename.sql' APPEND VERBOSE`. For more information about APPEND and VERBOSE, see the "OUTPUT statement [Interactive SQL]" [*ASA SQL Reference*, page 501].

The OUTPUT TO, APPEND, and VERBOSE statements are equivalent to the >#, >>#, >&, and >>& operators of earlier versions of Interactive SQL. You can still use these operators to redirect data, but the new Interactive SQL statements allow for more precise output and easier to read code.

❖ To export query results (UNLOAD statement)

1. Execute an UNLOAD statement. For example,

   ```
   UNLOAD
   SELECT *
   FROM employee;
   TO 'c:\employee.dbf'
   ```

   If the export is successful, the Messages pane displays the amount of time it to took to export the query result set, the filename and path of the exported data, and the number of rows written. If the export is unsuccessful, a message appears indicating the export was unsuccessful.

Exporting databases

❖ To unload all or part of a database (Sybase Central)

1. In the left pane, select the Adaptive Server Anywhere 9 plug-in.

2. In the right pane, click the Utilities tab.

   All of the operations you can perform on a database appear in the right pane.

3. Double-click Unload Database in the right pane.

   The Unload Database wizard appears.

   You can also open the Unload Database wizard by right-clicking the database in the left pane, and choosing Unload Database from the popup menu, or by choosing the Tools ➤ Adaptive Server Anywhere 9 ➤ Unload Database command.

4. Follow the instructions in the wizard.

❖ To unload all or part of a database (command line)

1. At a command prompt, enter the *dbunload* command and specify connection parameters using the `-c` option.

   For example, the following command unloads the entire database to c:\temp:

   ```
   dbunload -c "dbn=asademo;uid=DBA;pwd=SQL" c:\temp
   ```

2. If you want to export data only, add the `-d` option.

   For example, if you want to export data only, your final command would look like this:

   ```
   dbunload -c "dbn=asademo;uid=DBA;pwd=SQL" -d c:\temp
   ```

3. If you want to export schema only, add the `-n` option instead.

   For example, if you want to export schema only, your final command would look like this:

   ```
   dbunload -c "dbn=asademo;uid=DBA;pwd=SQL" -n c:\temp
   ```

4. Press Enter to execute the command.

For more information about additional command line options you can apply to the *dbunload* utility, see “Unloading a database using the dbunload command-line utility” [*ASA Database Administration Guide*, page 534].

Exporting tables

In addition to the methods described below, you can also export a table by selecting all the data in a table and exporting the query results. For more information, see “Exporting query results” on page 534.

> **Tip**
> You can export views just as you would export tables.

❖ To export a table (Command line)

1. At a command prompt, enter the following *dbunload* command and press Enter:

   ```
   dbunload -c "dbn=asademo;uid=DBA;pwd=SQL" -t employee c:\
           temp
   ```

   where `-c` specifies the database connection parameters and `-t` specifies the name of the table(s) you want to export. This *dbunload* command unloads the data from the sample database (assumed to be running on the default database server with the default database name) into a set of files in the *c:\temp* directory. A command file to rebuild the database from the data files is created with the default name *reload.SQL* in the current directory.

You can unload more than one table by separating the table names with a comma (,) delimiter.

❖ To export a table (SQL)

1. Execute an UNLOAD TABLE statement. For example,

   ```
   UNLOAD TABLE department
   TO 'dept.txt'
   ```

   This statement unloads the department table from the sample database into the file *dept.txt* in the server's current working directory. If you are running against a network server, the command unloads the data into a file on the server machine, not the client machine. Also, the file name passes to the server as a string. Using escape backslash characters in the file name prevents misinterpretation if a directory of file name begins with an n (\n is a newline character) or any other special characters.

   Each row of the table is output on a single line of the output file, and no column names are exported. The columns are separated, or delimited, by a comma. The delimiter character can be changed using the DELIMITED BY clause. The fields are not fixed-width fields. Only the characters in each entry are exported, not the full width of the column.

☞ For more information about the UNLOAD TABLE statement syntax, see "UNLOAD TABLE statement" [*ASA SQL Reference*, page 590].

Rebuilding databases

Rebuilding a database is a specific type of import and export involving unloading and reloading your entire database. Rebuilding your database takes all the information out of your database and puts it back in, in a uniform fashion, thus filling space and improving performance much like defragmenting your disk drive.

It is good practice to make backups of your database before rebuilding.

Loading and unloading are most useful for improving performance, reclaiming fragmented space, or upgrading your database to a newer version of Adaptive Server Anywhere.

Rebuilding is different from exporting in that rebuilding exports and imports table definitions and schema in addition to the data. The unload portion of the rebuild process produces ASCII format data files and a ‘ *reload.SQL* ‘ file which contains table and other definitions. Running the *reload.SQL* script recreates the tables and loads the data into them.

You can carry out this operation from Sybase Central or using the *dbunload* command line utility.

When unloading and reloading a database that has proxy tables, you must create an external login to map the local user to the remote user, even if the user has the same password on both the local and remote databases. If you do not have an external login, the reload may fail because you cannot connect to the remote server.

☞ For more information about external logins, see “Working with external logins” on page 567.

Consider rebuilding your database if you want to upgrade your database, reclaim disk space or improve performance. You might consider extracting a database (creating a new database from an old database) if you are using SQL Remote or MobiLink.

If you need to defragment your database, and a full rebuild is not possible due to requirements for continuous access to the database, consider reorganizing the table instead of rebuilding.

☞ For more information about reorganizing tables, see the “REORGANIZE TABLE statement” [*ASA SQL Reference*, page 522].

Rebuilding a database involved in replication

If a database is participating in replication, particular care needs to be taken if you wish to rebuild the database.

Replication is based on the offsets in the transaction log. When you rebuild a database, the offsets in the old transaction log are different than the offsets in the new log, making the old log unavailable For this reason, good backup practices are especially important when participating in replication.

There are two ways of rebuilding a database involved in replication. The first method uses the *dbunload* utility `-ar` option to make the unload and reload occur in a way that does not interfere with replication. The second method is a manual method of accomplishing the same task.

The rebuild (load/unload) and extract procedures are used to rebuild databases and to create new databases from part of an old one.

With importing and exporting, the destination of the data is either into your database or out of your database. Importing reads data into your database. Exporting writes data out of your database. Often the information is either coming from or going to another non-Adaptive Server Anywhere database.

Rebuilding, however, combines two functions: loading and unloading. Loading and Unloading takes data and schema out of an Adaptive Anywhere database and then places the data and schema back into an Adaptive Server Anywhere database. The unloading procedure produces fixed format data files and a *reload.SQL* file which contains table definitions required to recreate the table exactly. Running the *reload.SQL* script recreates the tables and loads the data back into them.

Rebuilding a database can be a time consuming operation, and can require a large amount of disk space. As well, the database is unavailable for use while being unloaded and reloaded. For these reasons, rebuilding a database is not advised in a production environment unless you have a definite goal in mind.

Rebuilding a database involved in replication
The procedure for rebuilding a database depends on whether the database is involved in replication or not. If the database is involved in replication, you must preserve the transaction log offsets across the operation, as the Message Agent and Replication Agent require this information. If the database is not involved in replication, the process is simpler.

Rebuild tools

LOAD/UNLOAD TABLE statement

UNLOAD TABLE allows you to export data only, in an efficient manner in text/ASCII/FIXED formats. The UNLOAD TABLE statement exports with one row per line, with values separated by a comma delimiter. To make reloading quicker, the data exports in order by primary key values.

To use the UNLOAD TABLE statement, the user must have ALTER or SELECT permission on the table.

Choose the UNLOAD TABLE statement when you want to export data in text format or when performance is an issue.

☞ For more information, see "UNLOAD statement" [*ASA SQL Reference*, page 588].

dbunload/dbisql utilities and Sybase Central

The *dbunload/dbisql* utilities and Sybase Central are graphically different, and functionally equivalent. You can use either one interchangeably to produce the same results.

You can use the Sybase Central Unload Database wizard or the *dbunload* utility to unload an entire database in ASCII comma-delimited format and to create the necessary Interactive SQL command files to completely recreate your database. This may be useful for creating SQL Remote extractions or building new copies of your database with the same or a slightly modified structure. The *dbunload* utility and Sybase Central are useful for exporting Adaptive Server Anywhere files intended for reuse within Adaptive Server Anywhere.

Choose Sybase Central or the *dbunload* utility when you want to rebuild your or extract from your database, export in text format, when you need to process large amounts of data quickly, or when your file format requirements are flexible.

☞ For more information, see "Rebuilding a database not involved in replication" on page 543 and "Rebuilding a database involved in replication" on page 544.

Rebuild file formats

From one ASA database to another

Rebuilding generally takes data out of an Adaptive Server Anywhere database and then places that data back into an Adaptive Server Anywhere database. The unloading and reloading are closely tied together since you usually perform both tasks, rather than just one or the other.

Rebuilding a database

You might rebuild your database if you wanted to:

- ♦ **Upgrade your database file format** Some new features are made available by applying the Upgrade utility, but others require a database file format upgrade, which is carried out by unloading and reloading the database. The New Features documentation will state if an unload and reload is required to obtain a particular feature.

- ♦ **Reclaim disk space** Databases do not shrink if you delete data. Instead, any empty pages are simply marked as free so they can be used again. They are not removed from the database unless you rebuild it. Rebuilding a database can reclaim disk space if you have deleted a large amount of data from your database and do not anticipate adding more.

- **Improve performance** Rebuilding databases can improve performance for the following reasons:
  - If data on pages within the database is fragmented, unloading and reloading can eliminate the fragmentation.
  - Since the data can be unloaded and reloaded in order by primary keys, access to related information can be faster, as related rows may appear on the same or adjacent pages.

Upgrading a database

New versions of the Adaptive Server Anywhere database server can be used without upgrading your database. If you want to use features of the new version that require access to new system tables or database options, you must use the upgrade utility to upgrade your database. The upgrade utility does not unload or reload any data.

If you want to use features of the new version that rely on changes in the database file format, you must unload and reload your database. You should back up your database after rebuilding the database.

To upgrade your database file, use the new version of Adaptive Server Anywhere.

For more information about upgrading your database, see "Upgrading Adaptive Server Anywhere" [*What's New in SQL Anywhere Studio,* page 176].

Exporting table data or table schema

❖ To export table data or table schema (Command line)

1. At a command prompt, enter the *dbunload* command and specify connection parameters using the `-c` option.

2. Specify the table(s) you want to export data or schema for, using the `-t` option.

   For example, to export part of the employee table, enter

   ```
   dbunload -c "dbn=asademo;uid=DBA;pwd=SQL" -t employee c:\
            temp
   ```

   You can unload more than one table by separating the table names with a comma delimiter.

3. If you want to export data only, add the `-d` option.

   For example, if you want to export data only, your final command would look like this:

   ```
   dbunload -c "dbn=asademo;uid=DBA;pwd=SQL" -d -t employee c:\
            temp
   ```

4. If you want to export schema only, add the `-n` option instead.

   For example, if you want to export schema only, your final command would look like this:

```
dbunload -c "dbn=asademo;uid=DBA;pwd=SQL" -n -t employee c:\
         temp
```

5. Press Enter to execute the command.

   The *dbunload* commands in these examples unload the data or schema from the sample database table (assumed to be running on the default database server with the default database name) into a file in the *c:\temp* directory. A command file to rebuild the database from the data files is created with the default name *reload.SQL* in the current directory.

Reloading a Database

❖ To reload a database (Command line)

1. At a command prompt, execute the *reload.SQL* script.

   For example, the following command loads the *reload.SQL* script in the current directory.

```
dbisql -c "dbn=asademo;uid=DBA;pwd=SQL" reload.SQL
```

Rebuilding a database not involved in replication

The following procedures should be used only if your database is not involved in replication.

☞ For instructions about rebuilding a database not involved in replication from Sybase Central, see "Upgrading the database file format" [*What's New in SQL Anywhere Studio*, page 178].

❖ To rebuild a database not involved in replication (Command line)

1. At a command prompt, execute the *dbunload* command line utility using one of the following options:

   ♦ The `-an` option rebuilds to a new database.

```
dbunload -c "dbf=asademo.db;uid=DBA;pwd=SQL"
   -an  asacopy.db
```

   ♦ The `-ac` option reloads to an existing database.

```
dbunload -c "dbf=asademo.db;uid=DBA;pwd=SQL"
   -ac "uid=DBA;pwd=SQL;dbf=newdemo.db"
```

- The `-ar` option replaces the existing database.

```
dbunload -c "dbf=asademo.db;uid=DBA;pwd=SQL"
   -ar "uid=DBA;pwd=SQL;dbf=newdemo.db"
```

  If you use one these options, no interim copy of the data is created on disk, so you do not specify an unload directory on the command line. This provides greater security for your data. The `-ar` and `-an` options should also execute more quickly than Sybase Central, but `-ac` is slower.

2. Shut down the database and archive the transaction log, before using the reloaded database.

Notes

The `-an` and `-ar` options only apply to connections to a personal server, or connections to a network server over shared memory.

There are additional options available for the *dbunload* utility that allow you to tune the unload, as well as connection parameter options that allow you to specify a running or non-running database and database parameters.

Rebuilding a database involved in replication

❖ To rebuild a database involved in replication

1. Shut down the database.

2. Perform a full off-line backup by copying the database and transaction log files to a secure location.

3. At a command prompt, run dbunload to rebuild the database:

```
dbunload -c connection_string -ar directory
```

   where *connection_string* is a connection with DBA authority, *directory* is the directory used in your replication environment for old transaction logs, and there are no other connections to the database.

   The `-ar` option only applies to connections to a personal server, or connections to a network server over shared memory.

   ☞ For more information, see “Unload utility options” [*ASA Database Administration Guide*, page 537].

4. Shut down the new database. Perform validity checks that you would usually perform after restoring a database.

5. Start the database using any production options you need. You can now allow user access to the reloaded database.

Notes

There are additional options available for the *dbunload* utility that allow you to tune the unload, as well as connection parameter options that allow you to specify a running or non-running database and database parameters.

If the above procedure does not meet your needs, you can manually adjust the transaction log offsets. The following procedure describes how to carry out that operation.

❖ To rebuild a database involved in replication, with manual intervention

1. Shut down the database.
2. Perform a full off-line backup by copying the database and transaction log files to a secure location.
3. Run the *dbtran* utility to display the starting offset and ending offset of the database's current transaction log file. Note the ending offset for later use.
4. Rename the current transaction log file so that it is not modified during the unload process, and place this file in the dbremote off-line logs directory.
5. Rebuild the database.

   ☞ For information on this step, see "Rebuilding databases" on page 539.
6. Shut down the new database.
7. Erase the current transaction log file for the new database.
8. Use *dblog* on the new database with the ending offset noted in step 3 as the `-z` parameter, and also set the relative offset to zero.

   ```
   dblog -x 0 -z 137829 database-name.db
   ```
9. When you run the Message Agent, provide it with the location of the original off-line directory on its command line.
10. Start the database. You can now allow user access to the reloaded database.

Minimizing downtime during rebuilding

The following steps help you rebuild a database while minimizing downtime. This can be especially useful if your database is in operation 24 hours a day.

It's wise to do a practice run of steps 1-4, and determine the times required for each step, prior to beginning the actual backup. You may also want to save copies of your files at various points during the rebuild.

Make sure that no other scheduled backups rename the production database's log. If this happens in error, you will need to apply the transactions from these renamed logs to the rebuilt database in the correct order.

❖ To rebuild a database and minimize the downtime

1. Using DBBACKUP -r, create a backup of the database and log, and rename the log.
2. Rebuild the backed up database on another machine.
3. Do another DBBACKUP -r on the production server to rename the log.
4. Run DBTRAN on the log from step 3 and apply the transactions to the rebuilt server.

   You now have a rebuilt database that contains all transactions up to the end of the backup in step 3.
5. Shut down the production server and make copies of the database and log.
6. Copy the rebuilt database onto the production server.
7. Run DBTRAN on the log from step 5.

   This should be a relatively small file.
8. Start the server on the rebuilt database, but don't allow users to connect.
9. Apply the transactions from step 8.
10. Allow users to connect.

Extracting data

Extracting removes a remote Adaptive Server Anywhere database from a consolidated Adaptive Server Enterprise or Adaptive Server Anywhere database.

You can use the Sybase Central Extract Database wizard or the Extraction utility to extract databases. The Extraction utility is the recommended way of creating and synchronizing remote databases from a consolidated database.

For more information about how to perform database extractions, see:

- "The Database Extraction utility" [*SQL Remote User's Guide*, page 302]
- "Using the extraction utility" [*SQL Remote User's Guide*, page 191]
- "Extraction utility options" [*SQL Remote User's Guide*, page 305]
- "Extracting groups" [*SQL Remote User's Guide*, page 195]
- "Deploying remote databases" [*MobiLink Synchronization User's Guide*, page 168]
- "Extracting a remote database in Sybase Central" [*SQL Remote User's Guide*, page 302]

Migrating databases to Adaptive Server Anywhere

You can import tables from remote Oracle, DB2, Microsoft SQL Server, Sybase Adaptive Server Enterprise, Adaptive Server Anywhere, and Microsoft Access databases into Adaptive Server Anywhere using the sa_migrate set of stored procedures or the Data Migration wizard.

If you do not want to modify the tables in any way, you can use the single step method. Alternatively, if you would like to remove tables or foreign key mappings, you can use the extended method.

When using the sa_migrate set of stored procedures, you must complete the following steps before you can import a remote database:

- Create a target database.

  ☞ For information about creating a database, see "Creating a database" on page 27.

- Create a remote server to connect to the remote database.

  ☞ For information about creating a remote server, see "Creating remote servers" on page 562.

- Create an external login to connect to the remote database. This is only required when the user has a different passwords on the target and remote databases, or when you want to login using a different user ID on the remote database than the one you are using on the target database.

  ☞ For information about creating an external login, see "Creating external logins" on page 567.

- Create a local user who will own the migrated tables in the target database.

  ☞ For information about creating a user, see "Creating new users" [*ASA Database Administration Guide*, page 394].

If you use the Data Migration wizard, you can perform all these steps, except creating the target database, from the wizard in Sybase Central.

❖ To import remote tables (Sybase Central)

1. From Sybase Central, connect to the target database.

2. In the left pane of the Sybase Central window, select the Adaptive Server Anywhere 9 plug-in.

3. In the right pane, click the Utilities tab.

   All the operations you can perform on a database appear in the right pane.

4. Double-click Migrate Database in the right pane.

   The Database Migration wizard appears.

   You can also open the Database Migration wizard by right-clicking on the target database in the left pane and choosing Migrate Database from the popup menu, or by choosing the Tools ➤ Adaptive Server Anywhere 9 ➤ Migrate Database command.

5. Select the target database from the list, and then click Next.

6. Select the remote server you want to use to connect to the remote database from which you want to migrate data, and then click Next.

   If you have not already created a remote server, click Create Remote Server Now to open the Remote Server Creation wizard.

   ☞ For more information about creating a remote server, see "Creating remote servers" on page 562.

7. Select the tables that you want to migrate, and then click Next.

8. Select whether you want to migrate the data and the foreign keys from the remote tables and whether you want to keep the proxy tables that are created for the migration process, and then click Next.

   If the target database is version 8.0.0 or earlier, the Migrate the foreign keys option is not enabled. You must upgrade the database to version 8.0.1 or later to use this option.

   ☞ For more information about upgrading, see "Upgrading a database" [*What's New in SQL Anywhere Studio*, page 177].

9. Select the user that will own the tables on the target database, and then click Finish to complete the migration.

   If you have not already created a user, click Create User Now to open the User Creation wizard.

10. Click Finish.

The following example uses the sa_migrate stored procedure to import all the tables that belong to one owner on the remote database in one step.

Supplying NULL for both the *table_name* and *owner_name* parameters migrates all the tables in the database, including system tables. As well, tables that have the same name, but different owners, in the remote database all belong to one owner in the target database. For these reasons, it is recommended that you migrate tables associated with one owner at a time.

❖ To import remote tables (single step)

1. From Interactive SQL, connect to the target database.

2. In the Interactive SQL Statements pane, run the sa_migrate stored procedure. For example,

```
CALL sa_migrate( 'local_a', 'ase', NULL, l_smith, NULL, 1,
          1, 1 )
```

   This procedure calls several procedures in turn and migrates all the remote tables belonging to the user l_smith using the specified criteria.

If you do not want all the migrated tables to be owned by the same user on the target database, you must run the sa_migrate procedure for each owner on the target database, specifying the *local_table_owner* and *owner_name* arguments. It is recommended that you migrate tables associated with one owner at a time.

☞ For more information, see "sa_migrate system procedure" [*ASA SQL Reference*, page 724].

For target databases that are version 8.0.0 or earlier, foreign keys are migrated automatically. If you do not want to migrate the foreign keys, you must upgrade the database file format to version 8.0.1 or later.

☞ For more information about upgrading, see "Upgrading a database" [*What's New in SQL Anywhere Studio*, page 177].

❖ To import remote tables (with modifications)

1. From Interactive SQL, connect to the target database.

2. Run the sa_migrate_create_remote_table_list stored procedure. For example,

```
CALL sa_migrate_create_remote_table_list( 'ase',
     NULL, 'remote_a', 'mydb' )
```

   You must specify a database name for Adaptive Server Enterprise and Microsoft SQL Server databases.

   This populates the dbo.migrate_remote_table_list table with a list of remote tables to migrate. You can delete rows from this table for remote tables you do not wish to migrate.

   Do not supply NULL for both the *table_name* and *owner_name* parameters. Doing so migrates all the tables in the database, including system tables. As well, tables that have the same name but different owners in the remote database all belong to one owner in the target database. It is recommended that you migrate tables associated with one owner at a time.

☞ For more information about the sa_migrate_create_remote_table_list stored procedure, see "sa_migrate_create_remote_table_list system procedure" [*ASA SQL Reference*, page 729].

3. Run the sa_migrate_create_tables stored procedure. For example,

   ```
   CALL sa_migrate_create_tables( 'local_a', )
   ```

   This procedure takes the list of remote tables from dbo.migrate_remote_table_list and creates a proxy table and a base table for each remote table listed. This procedure also creates all primary key indexes for the migrated tables.

   ☞ For more information about the sa_migrate_create_tables stored procedure, see "sa_migrate_create_tables system procedure" [*ASA SQL Reference*, page 731].

4. If you want to migrate the data from the remote tables into the base tables on the target database, run the sa_migrate_data stored procedure. For example,

   Enter the following stored procedure:

   ```
   CALL sa_migrate_data( 'local_a' )
   ```

   This procedure migrates the data from each remote table into the base table created by the sa_migrate_create_tables procedure.

   ☞ For more information about the sa_migrate_data stored procedure, see "sa_migrate_data system procedure" [*ASA SQL Reference*, page 733].

   If you do not want to migrate the foreign keys from the remote database, you can skip to step 7.

5. Run the sa_migrate_create_remote_fks_list stored procedure. For example,

   ```
   CALL sa_migrate_create_remote_fks_list( 'ase' )
   ```

   This procedure populates the table dbo.migrate_remote_fks_list with the list of foreign keys associated with each of the remote tables listed in dbo.migrate_remote_table_list.

   You can remove any foreign key mappings you do not want to recreate on the local base tables.

   ☞ For more information about the sa_migrate_create_remote_fks_list stored procedure, see "sa_migrate_create_remote_fks_list system procedure" [*ASA SQL Reference*, page 728].

6. Run the sa_migrate_create_fks stored procedure. For example,

   ```
   CALL sa_migrate_create_fks( 'local_a' )
   ```

   This procedure creates the foreign key mappings defined in dbo.migrate_remote_fks_list on the base tables.

   ☞ For more information about the sa_migrate_create_fks stored procedure, see "sa_migrate_create_fks system procedure" [*ASA SQL Reference*, page 727].

7. If you want to drop the proxy tables that were created for migration purposes, run the sa_drop_proxy_tables stored procedure. For example,

   ```
   CALL sa_migrate_drop_proxy_tables( 'local_a' )
   ```

   This procedure drops all proxy tables created for migration purposes and completes the migration process.

   ☞ For more information about the sa_migrate_drop_proxy_tables stored procedure, see "sa_migrate_drop_proxy_tables system procedure" [*ASA SQL Reference*, page 734].

Running SQL command files

This section describes how to process files consisting of a set of commands.

Writing output to a file

In Interactive SQL, the data for each command remains on the Results tab in the Results pane only until the next command is executed. To keep a record of your data, you can save the output of each statement to a separate file. If *statement1* and *statement2* are two SELECT statements, then you can output them to *file1* and *file2*, respectively, as follows:

Statement1; OUTPUT TO
file1;
statement2; OUTPUT TO
file2;

For example, the following command saves the result of a query:

```
SELECT * FROM EMPLOYEE;
OUTPUT TO "C:\\My Documents\\Employees.txt"
```

☞ For more information, see "OUTPUT statement [Interactive SQL]" [*ASA SQL Reference*, page 501].

Executing command files

You can execute command files in the following ways:

- You can use the Interactive SQL READ command to execute command files.

  The following statement executes the file *temp.sql*:

  ```
  READ temp.sql
  ```

  ☞ For more information, see "READ statement [Interactive SQL]" [*ASA SQL Reference*, page 517].

- You can load a command file into the SQL Statements pane and execute it directly from there.

  You load command files back into the SQL Statements pane by choosing File ➤ Open. Enter *temp.sql* when prompted for the file name.

  On Windows platforms you can make Interactive SQL the default editor for *.SQL* files so that you can double-click the file and it appears in the SQL Statements pane of Interactive SQL.

  ☞ For more information about making Interactive SQL the default editor for *.SQL* files, see “Options dialog: General tab” [*SQL Anywhere Studio Help*, page 144].

♦ You can supply a command file as a command-line argument for Interactive SQL.

Saving, loading, and running command files

You can save the commands currently present in the SQL Statements pane so that they are available for future Interactive SQL sessions. The file in which you save them is called a command file.

Command files are text files containing SQL statements. You can use any editor you like to create command files. You can include comment lines along with the SQL statements to be executed. Command files are also commonly called **scripts**.

When you begin a new session, you can load the contents of a command file into the SQL Statements pane, or you can run the contents immediately.

❖ To save the commands from the SQL Statements pane to a file

1. Choose File ➤ Save As.
2. In the Save dialog, specify a location, name and format for the file. Click Save when finished.

❖ To load commands from a file into the SQL Statements pane

1. Choose File ➤ Open.
2. In the Open dialog, find and select the file. Click Open when finished.

❖ To run a command file immediately

1. Choose File ➤ Run Script.
2. In the Open dialog, find and select the file. Click Open when finished.

   The Run Script menu item is the equivalent of a READ statement. For example, in the SQL Statements pane, you can also run a command file by typing:

   ```
   READ 'c:\filename.sql'
   ```

   where *c:\filename.sql* is the path, name, and extension of the file. Single quotation marks (as shown) are required only if the path contains spaces.

❖ To run a command file in batch mode

1. Supply a command file as a command-line argument for Interactive SQL.

   For example, the following command runs the command file *myscript.sql* against the sample database.

   ```
   dbisql -c "dsn= ASA 9.0 Sample" myscript.sql
   ```

Adaptive Server Enterprise compatibility

You can import and export files between Adaptive Server Anywhere and Adaptive Server Enterprise using the BCP FORMAT clause. Simply make sure the BCP output is in delimited ASCII format. If you are exporting BLOB data from Adaptive Server Anywhere for use in Adaptive Server Enterprise, use the BCP format clause with the UNLOAD TABLE statement.

☞ For more information about BCP and the FORMAT clause, see "LOAD TABLE statement" [*ASA SQL Reference*, page 486] or "UNLOAD TABLE statement" [*ASA SQL Reference*, page 590].

CHAPTER 17

Accessing Remote Data

About this chapter

Adaptive Server Anywhere can access data located on different servers, both Sybase and non-Sybase, as if the data were stored on the local server.

This chapter describes how to configure Adaptive Server Anywhere to access remote data.

Contents

Topic:	page
Introduction	558
Basic concepts to access remote data	560
Working with remote servers	562
Working with external logins	567
Working with proxy tables	569
Joining remote tables	574
Joining tables from multiple local databases	576
Sending native statements to remote servers	577
Using remote procedure calls (RPCs)	578
Transaction management and remote data	581
Internal operations	583
Troubleshooting remote data access	587

Introduction

Adaptive Server Anywhere remote data access give you access to data in othe data sources. You can use this feature to migrate data into an Adaptive Server Anywhere database. You can also use the feature to query data across databases, although performance for such multi-database queries is much slower than when all the data is in a single Adaptive Server Anywhere database.

With remote data access you can:

- Use Adaptive Server Anywhere to move data from one location to another using insert-select.
- Access data in relational databases such as Sybase, Oracle, and DB2.
- Access desktop data such as Excel spreadsheets, MS-Access databases, FoxPro, and text files.
- Access any other data source that supports an ODBC interface.
- Perform joins between local and remote data, although performance is much slower than if all the data is in a single Adaptive Server Anywhere database.
- Perform joins between tables in separate Adaptive Server Anywhere databases. Performance limitations here are the same as with other remote data sources.
- Use Adaptive Server Anywhere features on data sources that would normally not have that ability. For instance, you could use a Java function against data stored in Oracle, or perform a subquery on spreadsheets. Adaptive Server Anywhere compensates for features not supported by a remote data source by operating on the data after it is retrieved.
- Access remote servers directly using passthrough mode.
- Execute remote procedure calls to other servers.

Adaptive Server Anywhere allows access to the following external data sources:

- Adaptive Server Anywhere
- Adaptive Server Enterprise
- Oracle
- IBM DB2

- Microsoft SQL Server
- Other ODBC data sources

☞ For platform availability, see "Windows and NetWare operating systems" [*Introducing SQL Anywhere Studio*, page 125].

Accessing remote data from PowerBuilder DataWindows

You can access remote data from a PowerBuilder DataWindow by setting the DBParm Block parameter to 1 on connect.

- In the design environment, you can set the Block parameter by accessing the Transaction tab in the Database Profile Setup dialog and setting the Retrieve Blocking Factor to 1.
- In a connection string, use the following phrase:

```
DBParm="Block=1"
```

Basic concepts to access remote data

This section describes the basic concepts required to access remote data.

Remote table mappings

Adaptive Server Anywhere presents tables to a client application as if all the data in the tables were stored in the database to which the application is connected. Internally, when a query involving remote tables is executed, the storage location is determined, and the remote location is accessed so that data can be retrieved.

To have remote tables appear as local tables to the client, you create local proxy tables that map to the remote data.

❖ To create a proxy table

1. Define the server where the remote data is located. This specifies the type of server and location of the remote server.

   ☞ For more information, see "Working with remote servers" on page 562.

2. Map the local user login information to the remote server user login information if the logins on the two servers are different.

   ☞ For more information, see "Working with external logins" on page 567.

3. Create the proxy table definition. This specifies the mapping of a local proxy table to the remote table. This includes the server where the remote table is located, the database name, owner name, table name, and column names of the remote table.

☞ For more information, see "Working with proxy tables" on page 569.

Administering remote table mappings

To manage remote table mappings and remote server definitions, you can use Sybase Central or you can use a tool such as Interactive SQL and execute the SQL statements directly.

Server classes

A **server class** is assigned to each remote server. The server class specifies the access method used to interact with the server. Different types of remote servers require different access methods. The server classes provide Adaptive Server Anywhere detailed server capability information. Adaptive Server Anywhere adjusts its interaction with the remote server based on those capabilities.

There are currently two groups of server classes. The first is JDBC-based; the second is ODBC-based.

The JDBC-based server classes are:

- **asajdbc** for Adaptive Server Anywhere (version 6 and later)
- **asejdbc** for Adaptive Server Enterprise and SQL Server (version 10 and later)

The ODBC-based server classes are:

- **asaodbc** for Adaptive Server Anywhere (version 5.5 and later)
- **aseodbc** for Adaptive Server Enterprise and SQL Server (version 10 and later)
- **db2odbc** for IBM DB2
- **mssodbc** for Microsoft SQL Server
- **oraodbc** for Oracle servers (version 8.0 and later)
- **odbc** for all other ODBC data sources

☞ For a full description of remote server classes, see "Server Classes for Remote Data Access" on page 589.

Working with remote servers

Before you can map remote objects to a local proxy table, you must define the remote server where the remote object is located. When you define a remote server, an entry is added to the sysservers table for the remote server. This section describes how to create, alter, and delete a remote server definition.

Creating remote servers

Use the CREATE SERVER statement to set up remote server definitions. You can execute the statements directly, or use Sybase Central.

For ODBC connections, each remote server corresponds to an ODBC data source. For some systems, including Adaptive Server Anywhere, each data source describes a database, so a separate remote server definition is needed for each database.

You must have RESOURCE authority to create a server.

On UNIX platforms, you need to reference the ODBC driver manager as well.

☞ For a full description of the CREATE SERVER statement, see "CREATE SERVER statement" [*ASA SQL Reference*, page 341].

Example 1

The following statement creates an entry in the sysservers table for the Adaptive Server Enterprise server called ASEserver:

```
CREATE SERVER ASEserver
CLASS 'ASEJDBC'
USING 'rimu:6666'
```

where:

- **ASEserver** is the name of the remote server
- **ASEJDBC** is a keyword indicating that the server is Adaptive Server Enterprise and the connection to it is JDBC-based
- **rimu:6666** is the machine name and the TCP/IP port number where the remote server is located

Example 2

The following statement creates an entry in the sysservers table for the ODBC-based Adaptive Server Anywhere server named testasa:

```
CREATE SERVER testasa
CLASS 'ASAODBC'
USING 'test4'
```

where:

- **testasa** is the name by which the remote server is known within this database.
- **ASAODBC** is a keyword indicating that the server is Adaptive Server Anywhere and the connection to it uses ODBC.
- **test4** is the ODBC data source name.

Example 3

On Unix platforms, the following statement creates an entry in the sysservers table for the ODBC-based Adaptive Server Anywhere server named remasa:

```
CREATE SERVER remasa
CLASS 'asaodbc'
USING 'driver=/opt/sybase/SYBSsa9/lib/dbodbc9_r.so;dsn=my_asa_
         dsn'
```

where:

- **remasa** is the name by which the remote server is known within this database.
- **ASAODBC** is a keyword indicating that the server is Adaptive Server Anywhere and the connection to it uses ODBC.
- **USING** is the reference to the ODBC driver manager.

Example 4

On Unix platforms the following statement creates an entry in the sysservers table for the ODBC-based Adaptive Server Enterprise server named remase:

```
CREATE SERVER remase
CLASS 'aseodbc'
USING 'driver=/opt/sybase/SYBSsa9/drivers/lib/libodbc.so;dsn=my_
         ase_dsn'
```

where:

- **remase** is the name by which the remote server is known within this database
- **ASEODBC** is a keyword indicating that the server is Adaptive Server Enterprise and the connection to it uses ODBC
- **USING** is thereference to the ODBC driver manager.

Creating remote servers using Sybase Central

You can create a remote server using a wizard in Sybase Central. For more information, see "Creating remote servers" on page 562.

❖ To create a remote server (Sybase Central)

1. Connect to the host database from Sybase Central.
2. Open the Remote Servers folder for that database.
3. From the File menu, choose New ➤ Remote Server.

   The Remote Server Creation wizard appears.
4. On the first page of the wizard, enter a name to use for the remote server. This name simply refers to the remote server from within the local database; it does not need to correspond with the name the server supplies. Click Next.
5. Select an appropriate type of server and click Next.
6. Select a data access method (ODBC or JDBC), and supply connection information.
   - For ODBC, supply a data source name.
   - For JDBC, supply a URL in the form *machine-name*:*port-number*

   The data access method (JDBC or ODBC) is the method used by Adaptive Server Anywhere to access the remote database. This is not related to the method used by Sybase Central to connect to your database.
7. Click Next. Specify whether you want the remote server to be read-only.
8. Click Finish to create the remote server definition.

Deleting remote servers

You can use Sybase Central or a DROP SERVER statement to delete a remote server from the Adaptive Server Anywhere system tables. All remote tables defined on that server must already be dropped for this action to succeed.

You must have DBA authority to delete a remote server.

❖ To delete a remote server (Sybase Central)

1. Connect to the host database from Sybase Central.
2. Open the Remote Servers folder.
3. Right-click the remote server you want to delete and choose Delete from the popup menu.

❖ To delete a remote server (SQL)

1. Connect to the host database from Interactive SQL.

2. Execute a DROP SERVER statement.

☞ For more information, see "DROP SERVER statement" [*ASA SQL Reference*, page 415].

Example The following statement drops the server named testasa:

```
DROP SERVER testasa
```

Altering remote servers

You can use Sybase Central or an ALTER SERVER statement to modify the attributes of a server. These changes do not take effect until the next connection to the remote server.

You must have RESOURCE authority to alter a server.

❖ To alter the properties of a remote server (Sybase Central)

1. Connect to the host database from Sybase Central.

2. Open the Remote Servers folder for that database.

3. Right-click the remote server and choose Properties from the popup menu.

4. Configure the various remote server properties.

❖ To alter the properties of a remote server (SQL)

1. Connect to the host database from Interactive SQL.

2. Execute an ALTER SERVER statement.

Example The following statement changes the server class of the server named ASEserver to aseodbc. In this example, the Data Source Name for the server is ASEserver.

```
ALTER SERVER ASEserver
CLASS 'aseodbc'
```

The ALTER SERVER statement can also be used to enable or disable a server's known capabilities.

☞ For more information, see "ALTER SERVER statement" [*ASA SQL Reference*, page 241].

Listing the remote tables on a server

It may be helpful when you are configuring Adaptive Server Anywhere to get a list of the remote tables available on a particular server. The sp_remote_tables procedure returns a list of the tables on a server.

```
sp_remote_tables servername
                 [,tablename]
                 [, owner ]
                 [, database]
```

If *tablename*, *owner*, or *database* is given, the list of tables is limited to only those that match.

For example, to get a list of all of the Microsoft Excel worksheets available from an ODBC data source named excel:

```
sp_remote_tables  excel
```

Or to get a list of all of the tables in the production database in an ASE named asetest, owned by 'fred':

```
sp_remote_tables  asetest, null, fred, production
```

☞ For more information, see "sp_remote_tables system procedure" [*ASA SQL Reference*, page 749].

Listing remote server capabilities

The sp_servercaps procedure displays information about a remote server's capabilities. Adaptive Server Anywhere uses this capability information to determine how much of a SQL statement can be passed off to a remote server.

The system tables which contain server capabilities are not populated until after Adaptive Server Anywhere first connects to the remote server. This information comes from the SYSCAPABILITY and SYSCAPABILITYNAME system tables. The servername specified must be the same servername used in the CREATE SERVER statement.

Issue the stored procedure sp_servercaps as follows:

```
sp_servercaps  servername
```

☞ For more information, see "sp_servercaps system procedure" [*ASA SQL Reference*, page 751].

Working with external logins

By default, Adaptive Server Anywhere uses the names and passwords of its clients whenever it connects to a remote server on behalf of those clients. However, this default can be overridden by creating external logins. External logins are alternate login names and passwords to be used when communicating with a remote server.

☞ For more information, see "Using integrated logins" [*ASA Database Administration Guide*, page 85].

Creating external logins

You can create an external login using either Sybase Central or the CREATE EXTERNLOGIN statement.

Only the login-name and the DBA account can add or modify an external login.

❖ To create an external login (Sybase Central)

1. Connect to the host database from Sybase Central.
2. Open the Remote Servers folder for that database and select the remote server.
3. From the File menu, choose New ➤ External Login.

   The External Login Creation wizard appears.
4. Follow the instructions in the wizard.

❖ To create an external login (SQL)

1. Connect to the host database from Interactive SQL.
2. Execute a CREATE EXTERNLOGIN statement.

Example

The following statement allows the local user **fred** to gain access to the server **ASEserver**, using the remote login **frederick** with password **banana**.

```
CREATE EXTERNLOGIN fred
TO ASEserver
REMOTE LOGIN frederick
IDENTIFIED BY banana
```

☞ For more information, see "CREATE EXTERNLOGIN statement" [*ASA SQL Reference*, page 313].

Dropping external logins

You can use either Sybase Central or a DROP EXTERNLOGIN statement to delete an external login from the Adaptive Server Anywhere system tables.

Only the login-name and the DBA account can delete an external login.

❖ To delete an external login (Sybase Central)

1. Connect to the host database from Sybase Central.
2. Open the Remote Servers folder.
3. In the left pane, select the remote server and then click the External Logins tab in the right pane.
4. Right-click the external login and choose Delete from the popup menu.

❖ To delete an external login (SQL)

1. Connect to the host database from Interactive SQL.
2. Execute a DROP EXTERNLOGIN statement.

Example

The following statement drops the external login for the local user fred created in the example above:

```
DROP EXTERNLOGIN fred TO ASEserver
```

☞ See also

- “DROP EXTERNLOGIN statement” [*ASA SQL Reference*, page 412]

Working with proxy tables

Location transparency of remote data is enabled by creating a local **proxy table** that maps to the remote object. Use one of the following statements to create a proxy table:

- If the table already exists at the remote storage location, use the CREATE EXISTING TABLE statement. This statement defines the proxy table for an existing table on the remote server.
- If the table does not exist at the remote storage location, use the CREATE TABLE statement. This statement creates a new table on the remote server, and also defines the proxy table for that table.

Specifying proxy table locations

The AT keyword is used with both CREATE TABLE and CREATE EXISTING TABLE to define the location of an existing object. This location string has four components, each separated by either a period or a semicolon. The semicolon delimiter allows filenames and extensions to be used in the database and owner fields.

The syntax of the AT clause is

```
... AT 'server.database.owner.table-name'
```

- **Server** This is the name by which the server is known in the current database, as specified in the CREATE SERVER statement. This field is mandatory for all remote data sources.
- **Database** The meaning of the database field depends on the data source. In some cases this field does not apply and should be left empty. The periods are still required, however.

  In Adaptive Server Enterprise, *database* specifies the database where the table exists. For example master or pubs2.

  In Adaptive Server Anywhere, this field does not apply; leave it empty.

  In Excel, Lotus Notes, and Access, you must include the name of the file containing the table. If the file name includes a period, use the semicolon delimiter.
- **Owner** If the database supports the concept of ownership, this field represents the owner name. This field is only required when several owners have tables with the same name.
- **Table-name** This specifies the name of the table. In the case of an Excel spreadsheet, this is the name of the "sheet" in the workbook. If the table

name is left empty, the remote table name is assumed to be the same as the local proxy table name.

Examples: The following examples illustrate the use of location strings:

- Adaptive Server Anywhere:

```
'testasa..DBA.employee'
```

- Adaptive Server Enterprise:

```
'ASEServer.pubs2.dbo.publishers'
```

- Excel:

```
'excel;d:\pcdb\quarter3.xls;;sheet1$'
```

- Access:

```
'access;\\server1\production\inventory.mdb;;parts'
```

Creating proxy tables (Sybase Central)

You can create a proxy table using either Sybase Central or a CREATE EXISTING TABLE statement.

The CREATE EXISTING TABLE statement creates a proxy table that maps to an existing table on the remote server. Adaptive Server Anywhere derives the column attributes and index information from the object at the remote location.

❖ To create a proxy table (Sybase Central)

1. Connect to the host database from Sybase Central.
2. In the left pane, open the Remote Servers folder.
3. In the right pane, click the Proxy Tables tab.
4. From the File menu choose New ➤ Proxy Table.
5. Follow the instructions in the wizard.

Tip
Proxy tables are displayed in the right pane on the Proxy Tables tab when their remote server is selected in the left pane. They also appear in the Tables folder. They are distinguished from other tables by a letter P on their icon.

Creating proxy tables with the CREATE EXISTING TABLE statement

The CREATE EXISTING TABLE statement creates a proxy table that maps to an existing table on the remote server. Adaptive Server Anywhere derives the column attributes and index information from the object at the remote location.

❖ To create a proxy table with the CREATE EXISTING TABLE statement (SQL)

1. Connect to the host database.

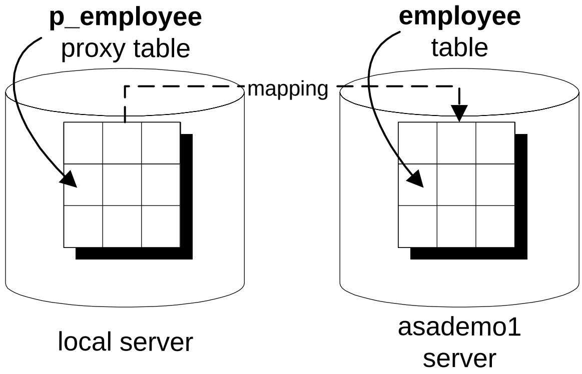
2. Execute a CREATE EXISTING TABLE statement.

☞ For more information, see the "CREATE EXISTING TABLE statement" [*ASA SQL Reference*, page 310].

Example 1

To create a proxy table called p_employee on the current server to a remote table named employee on the server named asademo1, use the following syntax:

```
CREATE EXISTING TABLE p_employee
AT 'asademo1..DBA.employee'
```



Example 2

The following statement maps the proxy table a1 to the Microsoft Access file mydbfile.mdb. In this example, the AT keyword uses the semicolon (;) as a delimiter. The server defined for Microsoft Access is named access.

```
CREATE EXISTING TABLE a1
AT'access;d:\mydbfile.mdb;;a1'
```

Creating a proxy table with the CREATE TABLE statement

The CREATE TABLE statement creates a new table on the remote server, and defines the proxy table for that table when you use the AT option. You enter the CREATE TABLE statement using Adaptive Server Anywhere data types. Adaptive Server Anywhere automatically converts the data into the remote server's native types.

☞ If you use the CREATE TABLE statement to create both a local and remote table, and then subsequently use the DROP TABLE statement to drop the proxy table, then the remote table also gets dropped. You can, however, use the DROP TABLE statement to drop a proxy table created using the CREATE EXISTING TABLE statement if you do not want to drop the remote table.

☞ For more information, see the "CREATE TABLE statement" [*ASA SQL Reference*, page 361].

❖ To create a proxy table with the CREATE EXISTING TABLE statement (SQL)

1. Connect to the host database.

2. Execute a CREATE TABLE statement.

☞ For more information, see the "CREATE TABLE statement" [*ASA SQL Reference*, page 361].

Example

The following statement creates a table named employee on the remote server asademo1, and creates a proxy table named members that maps to the remote location:

```
CREATE TABLE members
( membership_id INTEGER NOT NULL,
member_name CHAR(30) NOT NULL,
office_held CHAR( 20 ) NULL)
AT 'asademo1..DBA.employee'
```

Listing the columns on a remote table

If you are entering a CREATE EXISTING statement and you are specifying a column list, it may be helpful to get a list of the columns that are available on a remote table. The sp_remote_columns system procedure produces a list of the columns on a remote table and a description of those data types.

```
sp_remote_columns servername, tablename [, owner ]
[, database]
```

If a table name, owner, or database name is given, the list of columns is limited to only those that match.

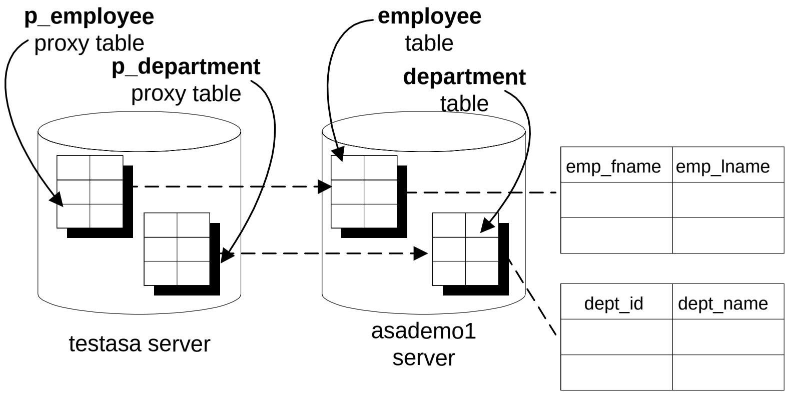
For example, the following returns a list of the columns in the sysobjects table in the production database on an Adaptive Server Enterprise server named asetest:

```
sp_remote_columns  asetest, sysobjects, null, production
```

☞ For more information, see “sp_remote_columns system procedure” [*ASA SQL Reference*, page 746].

Joining remote tables

The following figure illustrates the remote Adaptive Server Anywhere tables employee and department in the sample database mapped to the local server named testasa.



In real-world cases, you may use joins between tables on different Adaptive Server Anywhere databases. Here we describe a simple case using just one database to illustrate the principles.

❖ To perform a join between two remote tables (SQL)

1. Create a new database named *empty.db*.

   This database holds no data. We will use it only to define the remote objects, and access the sample database from it.

2. Start a database server running both empty.db and the sample database. You can do this using the following command line, executed from the installation directory:

   ```
   dbeng9 asademo empty
   ```

3. Connect to *empty.db* from Interactive SQL using the user ID **DBA** and the password **SQL**.

4. In the new database, create a remote server named testasa. Its server class is asaodbc, and the connection information is **'ASA 9.0 Sample'**:

   ```
   CREATE SERVER testasa
   CLASS 'asaodbc'
   USING 'ASA 9.0 Sample'
   ```

5. In this example, we use the same user ID and password on the remote database as on the local database, so no external logins are needed.

6. Define the employee proxy table:

```
CREATE EXISTING TABLE employee
AT 'testasa..DBA.employee'
```

7. Define the department proxy table:

```
CREATE EXISTING TABLE department
AT 'testasa..DBA.department'
```

8. Use the proxy tables in the SELECT statement to perform the join.

```
SELECT emp_fname, emp_lname, dept_name
FROM employee JOIN department
ON employee.dept_id = department.dept_id
ORDER BY emp_lname
```

Joining tables from multiple local databases

An Adaptive Server Anywhere server may have several local databases running at one time. By defining tables in other local Adaptive Server Anywhere databases as remote tables, you can perform cross database joins.

☞ For more information about specifying multiple databases, see "USING parameter value in the CREATE SERVER statement" on page 592.

Example

For example, if you are using database db1 and you want to access data in tables in database db2, you need to set up proxy table definitions that point to the tables in database db2. For instance, on an Adaptive Server Anywhere named testasa, you might have three databases available, db1, db2, and db3.

- If using ODBC, create an ODBC data source name for each database you will be accessing.
- Connect to one of the databases that you will be performing joins from. For example, connect to db1.
- Perform a CREATE SERVER for each other local database you will be accessing. This sets up a **loopback** connection to your Adaptive Server Anywhere server.

```
CREATE SERVER local_db2
CLASS 'asaodbc'
USING 'testasa_db2'
CREATE SERVER local_db3
CLASS 'asaodbc'
USING    'testasa_db3'
```

  Alternatively, using JDBC:

```
CREATE SERVER local_db2
CLASS 'asajdbc'
USING 'mypc1:2638/db2'
CREATE SERVER local_db3
CLASS 'asajdbc'
USING 'mypc1:2638/db3'
```

- Create proxy table definitions using CREATE EXISTING to the tables in the other databases you want to access.

```
CREATE EXISTING TABLE employee
AT 'local_db2...employee'
```

Sending native statements to remote servers

Use the FORWARD TO statement to send one or more statements to the remote server in its native syntax. This statement can be used in two ways:

- To send a statement to a remote server.
- To place Adaptive Server Anywhere into passthrough mode for sending a series of statements to a remote server.

If a connection cannot be made to the specified server, a message is sent to the user explaining why. If a connection is made, any results are converted into a form that can be recognized by the client program.

The FORWARD TO statement can be used to verify that a server is configured correctly. If you send a statement to the remote server and Adaptive Server Anywhere does not return an error message, the remote server is configured correctly.

☞ For more information, see “FORWARD TO statement” [*ASA SQL Reference,* page 443].

Example 1

The following statement verifies connectivity to the server named ASEserver by selecting the version string:

```
FORWARD TO ASEserver {SELECT @@version}
```

Example 2

The following statements show a passthrough session with the server named ASEserver:

```
FORWARD TO ASEserver
select * from titles
select * from authors
FORWARD TO
```

Using remote procedure calls (RPCs)

Adaptive Server Anywhere users can issue procedure calls to remote servers that support the feature.

This feature is supported by Sybase Adaptive Server Anywhere, Sybase Adaptive Server Enterprise, Oracle, and DB2. Issuing a remote procedure call is similar to using a local procedure call.

Creating remote procedures

You can issue a remote procedure call using either Sybase Central or the CREATE PROCEDURE statement.

You must have DBA authority to create a remote procedure.

❖ To issue a remote procedure call (Sybase Central)

1. Connect to the host database from Sybase Central.
2. Open the Remote Servers folder.
3. In the left pane, select the remote server for which you want to create a remote procedure.
4. In the right pane, click the Remote Procedures tab.
5. From the File menu, choose New ➤ Remote Procedure.

   The Remote Procedure Creation wizard appears.
6. Follow the instructions in the wizard.

❖ To issue a remote procedure call (SQL)

1. First define the procedure to Adaptive Server Anywhere.

   The syntax is the same as a local procedure definition except instead of using SQL statements to make up the body of the call, a location string is given defining the location where the procedure resides.

   ```
   CREATE PROCEDURE remotewho ()
   AT 'bostonase.master.dbo.sp_who'
   ```
2. Execute the procedure as follows:

   ```
   call remotewho()
   ```

☞ For more information, see “CREATE PROCEDURE statement” [*ASA SQL Reference*, page 324].

Example

Here is an example with a parameter:

```
CREATE PROCEDURE remoteuser (IN uname char(30))
AT 'bostonase.master.dbo.sp_helpuser'
call remoteuser('joe')
```

Data types for remote procedures

The following data types are allowed for RPC parameters. Other data types are disallowed:

- [UNSIGNED] SMALLINT
- [UNSIGNED] INT
- [UNSIGNED] BIGINT
- TINYINT
- REAL
- DOUBLE
- CHAR
- BIT

NUMERIC and DECIMAL data types are allowed for IN parameters, but not for OUT or INOUT parameters.

Dropping remote procedures

You can delete a remote procedure using either Sybase Central or the DROP PROCEDURE statement.

You must have DBA authority to delete a remote procedure.

❖ To delete a remote procedure (Sybase Central)

1. Open the Remote Servers folder.
2. In the left pane, select the remote server.
3. In the right pane, click the Remote Procedures tab.
4. On the Remote Procedures tab, right-click the remote procedure and choose Delete from the popup menu.

❖ To delete a remote procedure (SQL)

1. Connect to a database.

2. Execute a DROP PROCEDURE statement.

☞ For more information, see “DROP statement” [*ASA SQL Reference,* page 408].

Example

Delete a remote procedure called remoteproc.

```
DROP PROCEDURE remoteproc
```

Transaction management and remote data

Transactions provide a way to group SQL statements so that they are treated as a unit—either all work performed by the statements is committed to the database, or none of it is.

For the most part, transaction management with remote tables is the same as transaction management for local tables in Adaptive Server Anywhere, but there are some differences. They are discussed in the following section.

☞ For a general discussion of transactions, see "Using Transactions and Isolation Levels" on page 99.

Remote transaction management overview

The method for managing transactions involving remote servers uses a two-phase commit protocol. Adaptive Server Anywhere implements a strategy that ensures transaction integrity for most scenarios. However, when more than one remote server is invoked in a transaction, there is still a chance that a distributed unit of work will be left in an undetermined state. Even though two-phase commit protocol is used, no recovery process is included.

The general logic for managing a user transaction is as follows:

1. Adaptive Server Anywhere prefaces work to a remote server with a BEGIN TRANSACTION notification.

2. When the transaction is ready to be committed, Adaptive Server Anywhere sends a PREPARE TRANSACTION notification to each remote server that has been part of the transaction. This ensures the that remote server is ready to commit the transaction.

3. If a PREPARE TRANSACTION request fails, all remote servers are told to roll back the current transaction.

   If all PREPARE TRANSACTION requests are successful, the server sends a COMMIT TRANSACTION request to each remote server involved with the transaction.

Any statement preceded by BEGIN TRANSACTION can begin a transaction. Other statements are sent to a remote server to be executed as a single, remote unit of work.

Restrictions on transaction management

Restrictions on transaction management are as follows:

♦ Savepoints are not propagated to remote servers.

- If nested BEGIN TRANSACTION and COMMIT TRANSACTION statements are included in a transaction that involves remote servers, only the outermost set of statements is processed. The innermost set, containing the BEGIN TRANSACTION and COMMIT TRANSACTION statements, is not transmitted to remote servers.

Internal operations

This section describes the underlying operations on remote servers performed by Adaptive Server Anywhere on behalf of client applications.

Query parsing

When a statement is received from a client, it is parsed. An error is raised if the statement is not a valid Adaptive Server Anywhere SQL statement.

Query normalization

The next step is called query normalization. During this step, referenced objects are verified and some data type compatibility is checked.

For example, consider the following query:

```
SELECT *
FROM t1
WHERE c1 = 10
```

The query normalization stage verifies that table t1 with a column c1 exists in the system tables. It also verifies that the data type of column c1 is compatible with the value 10. If the column's data type is datetime, for example, this statement is rejected.

Query preprocessing

Query preprocessing prepares the query for optimization. It may change the representation of a statement so that the SQL statement Adaptive Server Anywhere generates for passing to a remote server will be syntactically different from the original statement.

Preprocessing performs view expansion so that a query can operate on tables referenced by the view. Expressions may be reordered and subqueries may be transformed to improve processing efficiency. For example, some subqueries may be converted into joins.

Server capabilities

The previous steps are performed on all queries, both local and remote.

The following steps depend on the type of SQL statement and the capabilities of the remote servers involved.

Each remote server defined to Adaptive Server Anywhere has a set of capabilities associated with it. These capabilities are stored in the syscapabilities system table. These capabilities are initialized during the first connection to a remote server. The generic server class odbc relies strictly on information returned from the ODBC driver to determine these capabilities. Other server classes such as db2odbc have more detailed knowledge of the capabilities of a remote server type and use that knowledge to supplement what is returned from the driver.

Once syscapabilities is initialized for a server, the capability information is retrieved only from the system table. This allows a user to alter the known capabilities of a server.

Since a remote server may not support all of the features of a given SQL statement, Adaptive Server Anywhere must break the statement into simpler components to the point that the query can be given to the remote server. SQL features not passed off to a remote server must be evaluated by Adaptive Server Anywhere itself.

For example, a query may contain an ORDER BY statement. If a remote server cannot perform ORDER BY, the statement is sent to the remote server without it and Adaptive Server Anywhere performs the ORDER BY on the result returned, before returning the result to the user. The result is that the user can employ the full range of Adaptive Server Anywhere supported SQL without concern for the features of a particular back end.

Complete passthrough of the statement

The most efficient way to handle a statement is usually to hand as much of the original statement as possible off to the remote server involved. Adaptive Server Anywhere will attempt to pass off as much of the statement as is possible. In many cases this will be the complete statement as originally given to Adaptive Server Anywhere.

Adaptive Server Anywhere will hand off the complete statement when:

- Every table in the statement resides in the same remote server.
- The remote server is capable of processing all of the syntax in the statement.

In rare conditions, it may actually be more efficient to let Adaptive Server Anywhere do some of the work instead of passing it off. For example, Adaptive Server Anywhere may have a better sorting algorithm. In this case you may consider altering the capabilities of a remote server using the ALTER SERVER statement.

☞ For more information, see “ALTER SERVER statement” [*ASA SQL Reference*, page 241].

Partial passthrough of the statement

If a statement contains references to multiple servers, or uses SQL features not supported by a remote server, the query is decomposed into simpler parts.

Select

SELECT statements are broken down by removing portions that cannot be passed on and letting Adaptive Server Anywhere perform the feature. For example, let's say a remote server can not process the atan2() function in the following statement:

```
select a,b,c where atan2(b,10) > 3 and c = 10
```

The statement sent to the remote server would be converted to:

```
select a,b,c where c = 10
```

Locally, Adaptive Server Anywhere would apply "where atan2(b,10) > 3" to the intermediate result set.

Joins

When two tables are joined, one table is selected to be the outer table. The outer table is scanned based on the WHERE conditions that apply to it. For every qualifying row found, the other table, known as the inner table is scanned to find a row that matches the join condition.

This same algorithm is used when remote tables are referenced. Since the cost of searching a remote table is usually much higher than a local table (due to network I/O), every effort is made to make the remote table the outermost table in the join.

Update and delete

If Adaptive Server Anywhere cannot pass off an UPDATE or DELETE statement entirely to a remote server, it must change the statement into a table scan containing as much of the original WHERE clause as possible, followed by positioned UPDATE or DELETE "where current of cursor" when a qualifying row is found.

For example, when the function **atan2** is not supported by a remote server:

```
UPDATE t1
SET a = atan2(b, 10)
WHERE b > 5
```

Would be converted to the following:

```
SELECT a,b
FROM t1
WHERE  b > 5
```

Each time a row is found, Adaptive Server Anywhere would calculate the new value of a and issue:

```
UPDATE t1
SET a = 'new value'
WHERE CURRENT OF CURSOR
```

If a already has a value that equals the "new value", a positioned UPDATE would not be necessary and would not be sent remotely.

In order to process an UPDATE or DELETE that requires a table scan, the remote data source must support the ability to perform a positioned UPDATE or DELETE ("where current of cursor"). Some data sources do not support this capability.

Temporary tables cannot be updated
In this release of Adaptive Server Anywhere, an UPDATE or DELETE cannot be performed if an intermediate temporary table is required in Adaptive Server Anywhere. This occurs in queries with ORDER BY and some queries with subqueries.

Troubleshooting remote data access

This section provides some hints for troubleshooting remote servers.

Features not supported for remote data

The following Adaptive Server Anywhere features are not supported on remote data. Attempts to use these features will therefore run into problems:

- ALTER TABLE statement against remote tables
- Triggers defined on proxy tables will not fire
- SQL Remote
- Foreign keys that refer to remote tables are ignored
- The READTEXT, WRITETEXT, and TEXTPTR functions.
- Positioned UPDATE and DELETE
- UPDATE and DELETE requiring an intermediate temporary table.
- Backwards scrolling on cursors opened against remote data. Fetch statements must be NEXT or RELATIVE 1.
- If a column on a remote table has a name that is a keyword on the remote server, you cannot access data in that column. Adaptive Server Anywhere cannot know all of the remote server reserved words. You can execute a CREATE EXISTING TABLE statement, and import the definition but you cannot select that column.

Case sensitivity

The case sensitivity setting of your Adaptive Server Anywhere database should match the settings used by any remote servers accessed.

Adaptive Server Anywhere databases are created case insensitive by default. With this configuration, unpredictable results may occur when selecting from a case sensitive database. Different results will occur depending on whether ORDER BY or string comparisons are pushed off to a remote server or evaluated by the local Adaptive Server Anywhere.

Connectivity problems

Take the following steps to be sure you can connect to a remote server:

- Determine that you can connect to a remote server using a client tool such as Interactive SQL before configuring Adaptive Server Anywhere.

- Perform a simple passthrough statement to a remote server to check your connectivity and remote login configuration. For example:

  ```
  FORWARD TO testasa {select @@version}
  ```

- Turn on remote tracing for a trace of the interactions with remote servers.

  ```
  SET OPTION cis_option = 7
  ```

General problems with queries

If you are faced with some type of problem with the way Adaptive Server Anywhere is handling a query against a remote table, it is usually helpful to understand how Adaptive Server Anywhere is executing that query. You can display remote tracing as well as a description of the query execution plan:

```
SET OPTION cis_option = 7
```

Queries blocked on themselves

If you access multiple databases on a single Adaptive Server Anywhere server, you may need to increase the number of threads used by the database server on Windows using the `-gx` command-line switch.

You must have enough threads available to support the individual tasks that are being run by a query. Failure to provide the number of required tasks can lead to a query becoming blocked on itself.

Managing remote data access connections

If you access remote databases via ODBC, the connection to the remote server is given a name. The name can be used to drop the connection as one way to cancel a remote request.

The connections are named ASACIS_*conn-name*, where *conn-name* is the connection ID of the local connection. The connection ID can be obtained from the sa_conn_info stored procedure.

CHAPTER 18

Server Classes for Remote Data Access

About this chapter

This chapter describes how Adaptive Server Anywhere interfaces with different classes of servers. It describes

- Types of servers that each server class supports
- The USING clause value for the CREATE SERVER statement for each server class
- Special configuration requirements

Contents

Topic:	page
Overview	590
JDBC-based server classes	591
ODBC-based server classes	594

Overview

The server class you specify in the CREATE SERVER statement determines the behavior of a remote connection. The server classes give Adaptive Server Anywhere detailed server capability information. Adaptive Server Anywhere formats SQL statements specific to a server's capabilities.

There are two categories of server classes:

- JDBC-based server classes
- ODBC-based server classes

Each server class has a set of unique characteristics that database administrators and programmers need to know to configure the server for remote data access.

When using this chapter, refer both to the section generic to the server class category (JDBC-based or ODBC-based), and to the section specific to the individual server class.

JDBC-based server classes

JDBC-based server classes are used when Adaptive Server Anywhere internally uses a Java virtual machine and jConnect 4.0 to connect to the remote server. The JDBC-based server classes are:

- **asajdbc** Adaptive Server Anywhere (version 6 and later).
- **asejdbc** Adaptive Server Enterprise and SQL Server (version 10 and later).

If you are using NetWare, only the asajdbc class is supported.

Configuration notes for JDBC classes

When you access remote servers defined with JDBC-based classes, consider that:

- Your local database must be enabled for Java.

  ☞ For more information, see “Java-enabling a database” [*ASA Programming Guide*, page 84].

- The Java virtual machine needs more than the default amount of memory to load and run jConnect. Set these memory options to at least the following values:

```
SET OPTION PUBLIC.JAVA_NAMESPACE_SIZE = 3000000
SET OPTION PUBLIC.JAVA_HEAP_SIZE = 1000000
```

- Since jConnect 4.0 is automatically installed with Adaptive Server Anywhere, no additional drivers need to be installed.
- For optimum performance, Sybase recommends an ODBC-based class (asaodbc or aseodbc).
- Any remote server that you access using the asejdbc or asajdbc server class must be set up to handle a jConnect 4.x based client. The jConnect setup scripts are *SQL_anywhere.SQL* for Adaptive Server Anywhere or *SQL_server.SQL* for Adaptive Server Enterprise. Run these against any remote server you will be using.

Server class asajdbc

A server with server class asajdbc is Adaptive Server Anywhere (version 6 and later). No special requirements exist for the configuration of an Adaptive Server Anywhere data source.

USING parameter value in the CREATE SERVER statement

You must perform a separate CREATE SERVER for each Adaptive Server Anywhere database you intend to access. For example, if an Adaptive Server Anywhere server named testasa is running on the machine 'banana' and owns three databases (db1, db2, db3), you would configure the local Adaptive Server Anywhere similar to this:

```
CREATE SERVER testasadb1
CLASS 'asajdbc'
USING 'banana:2638/db1'
CREATE SERVER testasadb2
CLASS 'asajdbc'
USING 'banana:2638/db2'
CREATE SERVER testasadb2
CLASS 'asajdbc'
USING 'banana:2638/db3'
```

If you do not specify a */databasename* value, the remote connection uses the remote Adaptive Server Anywhere default database.

☞ For more information about the CREATE SERVER statement, see "CREATE SERVER statement" [*ASA SQL Reference*, page 341].

Server class asejdbc

A server with server class asejdbc is Adaptive Server Enterprise, SQL Server (version 10 and later). No special requirements exist for the configuration of an Adaptive Server Enterprise data source.

Data type conversions: JDBC and Adaptive Server Enterprise

When you issue a CREATE TABLE statement, Adaptive Server Anywhere automatically converts the data types to the corresponding Adaptive Server Enterprise data types. The following table describes the Adaptive Server Anywhere to Adaptive Server Enterprise data type conversions.

Adaptive Server Anywhere data type	ASE default data type
bit	bit
tinyint	tinyint
smallint	smallint
int	int
integer	integer

Adaptive Server Anywhere data type	**ASE default data type**
decimal [defaults p=30, s=6]	numeric(30,6)
decimal(128,128)	not supported
numeric [defaults p=30 s=6]	numeric(30,6)
numeric(128,128)	not supported
float	real
real	real
double	float
smallmoney	numeric(10,4)
money	numeric(19,4)
date	datetime
time	datetime
timestamp	datetime
smalldatetime	datetime
datetime	datetime
char(n)	varchar(n)
character(n)	varchar(n)
varchar(n)	varchar(n)
character varying(n)	varchar(n)
long varchar	text
text	text
binary(n)	binary(n)
long binary	image
image	image
bigint	numeric(20,0)

ODBC-based server classes

The ODBC-based server classes include:

- asaodbc
- aseodbc
- db2odbc
- mssodbc
- oraodbc
- odbc

Defining ODBC external servers

☞ The most common way of defining an ODBC-based server bases it on an ODBC data source. To do this, you must create a data source in the ODBC Administrator.

Once you have the data source defined, the USING clause in the CREATE SERVER statement should match the ODBC data source name.

For example, to configure a DB2 server named **mydb2** whose Data Source Name is also **mydb2**, use:

```
CREATE SERVER mydb2
CLASS 'db2odbc'
USING 'mydb2'
```

☞ For more information on creating data sources, see “Creating an ODBC data source” [*ASA Database Administration Guide*, page 53].

Using connection strings instead of data sources

An alternative, which avoids using data sources, is to supply a connection string in the USING clause of the CREATE SERVER statement. To do this, you must know the connection parameters for the ODBC driver you are using. For example, a connection to an ASA may be as follows:

```
CREATE SERVER testasa
CLASS 'asaodbc'
USING 'driver=adaptive server anywhere
         9.0;eng=testasa;dbn=sample;links=tcpip{}'
```

This defines a connection to an Adaptive Server Anywhere database server named **testasa**, database **sample**, and using the TCP-IP protocol.

See also

For information specific to particular ODBC server classes, see:

- “Server class asaodbc” on page 595

- “Server class aseodbc” on page 595
- “Server class db2odbc” on page 597
- “Server class oraodbc” on page 599
- “Server class mssodbc” on page 600
- “Server class odbc” on page 602

Server class asaodbc

A server with server class asaodbc is Adaptive Server Anywhere version 5.5 or later. No special requirements exist for the configuration of an Adaptive Server Anywhere data source.

To access Adaptive Server Anywhere servers that support multiple databases, create an ODBC data source name defining a connection to each database. Issue a CREATE SERVER statement for each of these ODBC data source names.

Server class aseodbc

A server with server class aseodbc is Adaptive Server Enterprise, SQL Server (version 10 and later). Adaptive Server Anywhere requires the installation of the Adaptive Server Enterprise ODBC driver and Open Client connectivity libraries to connect to a remote Adaptive Server with class aseodbc. However, the performance is better than with the asejdbc class.

Notes

- Open Client should be version 11.1.1, EBF 7886 or above. Install Open Client and verify connectivity to the Adaptive Server before you install ODBC and configure Adaptive Server Anywhere. The Sybase ODBC driver should be version 11.1.1, EBF 7911 or above.
- Configure a User Data Source in the Configuration Manager with the following attributes:
  - Under the General tab:

    Enter any value for Data Source Name. This value is used in the USING clause of the CREATE SERVER statement.

    The server name should match the name of the server in the Sybase interfaces file.
  - Under the Advanced tab, check the Application Using Threads box and check the Enable Quoted Identifiers box.
  - Under the Connection tab:

    Set the charset field to match your Adaptive Server Anywhere character set.

    Set the language field to your preferred language for error messages.

- Under the Performance tab:

  Set Prepare Method to “2-Full.”

  Set Fetch Array Size as large as possible for best performance. This increases memory requirements since this is the number of rows that must be cached in memory. Sybase recommends using a value of 100.

  Set Select Method to “0-Cursor.”

  Set Packet Size to as large as possible. Sybase recommends using a value of -1.

  Set Connection Cache to 1.

Data type conversions: ODBC and Adaptive Server Enterprise

When you issue a CREATE TABLE statement, Adaptive Server Anywhere automatically converts the data types to the corresponding Adaptive Server Enterprise data types. The following table describes the Adaptive Server Anywhere to Adaptive Server Enterprise data type conversions.

Adaptive Server Anywhere data type	Adaptive Server Enterprise default data type
Bit	bit
Tinyint	tinyint
Smallint	smallint
Int	int
Integer	integer
decimal [defaults p=30, s=6]	numeric(30,6)
decimal(128,128)	not supported
numeric [defaults p=30 s=6]	numeric(30,6)
numeric(128,128)	not supported
Float	real
Real	real
Double	float
Smallmoney	numeric(10,4)
Money	numeric(19,4)
Date	datetime
Time	datetime

Adaptive Server Anywhere data type	Adaptive Server Enterprise default data type
Timestamp	datetime
Smalldatetime	datetime
Datetime	datetime
char(n)	varchar(n)
Character(n)	varchar(n)
varchar(n)	varchar(n)
Character varying(n)	varchar(n)
long varchar	text
Text	text
binary(n)	binary(n)
long binary	image
Image	image
Bigint	numeric(20,0)

Server class db2odbc

A server with server class db2odbc is IBM DB2

Notes

- Sybase certifies the use of IBM's DB2 Connect version 5, with fix pack WR09044. Configure and test your ODBC configuration using the instructions for that product. Adaptive Server Anywhere has no specific requirements on configuration of DB2 data sources.
- The following is an example of a CREATE EXISTING TABLE statement for a DB2 server with an ODBC data source named mydb2:

```
CREATE EXISTING TABLE ibmcol
AT 'mydb2..sysibm.syscolumns'
```

Data type conversions: DB2

When you issue a CREATE TABLE statement, Adaptive Server Anywhere automatically converts the data types to the corresponding DB2 data types. The following table describes the Adaptive Server Anywhere to DB2 data type conversions.

Adaptive Server Anywhere data type	DB2 default data type
Bit	smallint
Tinyint	smallint
Smallint	smallint
Int	int
Integer	int
Bigint	decimal(20,0)
char(1–254)	varchar(n)
char(255–4000)	varchar(n)
char(4001–32767)	long varchar
Character(1–254)	varchar(n)
Character(255–4000)	varchar(n)
Character(4001–32767)	long varchar
varchar(1–4000)	varchar(n)
varchar(4001–32767)	long varchar
Character varying(1–4000)	varchar(n)
Character varying(4001–32767)	long varchar
long varchar	long varchar
text	long varchar
binary(1–4000)	varchar for bit data
binary(4001–32767)	long varchar for bit data
long binary	long varchar for bit data
image	long varchar for bit data
decimal [defaults p=30, s=6]	decimal(30,6)
numeric [defaults p=30 s=6]	decimal(30,6)
decimal(128, 128)	NOT SUPPORTED
numeric(128, 128)	NOT SUPPORTED
real	real

Adaptive Server Anywhere data type	DB2 default data type
float	float
double	float
smallmoney	decimal(10,4)
money	decimal(19,4)
date	date
time	time
smalldatetime	timestamp
datetime	timestamp
timestamp	timestamp

Server class oraodbc

A server with server class **oraodbc** is Oracle version 8.0 or later.

Notes

- Sybase certifies the use of version 8.0.03 of Oracle's ODBC driver. Configure and test your ODBC configuration using the instructions for that product.
- The following is an example of a CREATE EXISTING TABLE statement for an Oracle server named myora:

```
CREATE EXISTING TABLE employees
AT 'myora.database.owner.employees'
```

- Due to Oracle ODBC driver restrictions, you cannot issue a CREATE EXISTING TABLE for system tables. A message returns stating that the table or columns cannot be found.

Data type conversions: Oracle

When you issue a CREATE TABLE statement, Adaptive Server Anywhere automatically converts the data types to the corresponding Oracle data types. The following table describes the Adaptive Server Anywhere to Oracle data type conversions.

Adaptive Server Anywhere data type	Oracle data type
bit	number(1,0)

Adaptive Server Anywhere data type	Oracle data type
tinyint	number(3,0)
smallint	number(5,0)
int	number(11,0)
bigint	number(20,0)
decimal(prec, scale)	number(prec, scale)
numeric(prec, scale)	number(prec, scale)
float	float
real	real
smallmoney	numeric(13,4)
money	number(19,4)
date	date
time	date
timestamp	date
smalldatetime	date
datetime	date
char(n)	if (n > 255) long else varchar(n)
varchar(n)	if (n > 2000) long else varchar(n)
long varchar	long or clob
binary(n)	if (n > 255) long raw else raw(n)
varbinary(n)	if (n > 255) long raw else raw(n)
long binary	long raw

Server class mssodbc

A server with server class **mssodbc** is Microsoft SQL Server version 6.5, Service Pack 4.

Notes

- Sybase certifies the use of version 3.60.0319 of Microsoft SQL Server's ODBC driver (included in MDAC 2.0 release). Configure and test your ODBC configuration using the instructions for that product.

- The following is an example of a CREATE EXISTING TABLE statement for a Microsoft SQL Server named mymssql:

```
CREATE EXISTING TABLE accounts,
AT 'mymssql.database.owner.accounts'
```

Data type conversions: Microsoft SQL Server

When you issue a CREATE TABLE statement, Adaptive Server Anywhere automatically converts the data types to the corresponding Microsoft SQL Server data types. The following table describes the Adaptive Server Anywhere to Microsoft SQL Server data type conversions.

Adaptive Server Anywhere data type	Microsoft SQL Server default data type
bit	bit
tinyint	tinyint
smallint	smallint
int	int
bigint	numeric(20,0)
decimal [defaults p=30, s=6]	decimal(prec, scale)
numeric [defaults p=30 s=6]	numeric(prec, scale)
float	if (prec) float(prec) else float
real	real
smallmoney	smallmoney
money	money
date	datetime
time	datetime
timestamp	datetime
smalldatetime	datetime
datetime	datetime
char(n)	if (length > 255) text else varchar(length)
character(n)	char(n)

Adaptive Server Anywhere data type	Microsoft SQL Server default data type
varchar(n)	if (length > 255) text else varchar(length)
long varchar	text
binary(n)	if (length > 255) image else binary(length)
long binary	image
double	float
uniqueidentifierstr	uniqueidentifier

The SQL Server uniqueidentifier columns is mapped to an Adaptive Server Anywhere uniqueidentifierstr column. The resulting string can be converted to a binary UUID value using the STRTOUUID function. See "STRTOUUID function [STRING]" [*ASA SQL Reference*, page 192].

Server class odbc

ODBC data sources that do not have their own server class use server class **odbc**. You can use any ODBC driver that complies with ODBC version 2.0 compliance level 1 or higher. Sybase certifies the following ODBC data sources:

- "Microsoft Excel (Microsoft 3.51.171300)" on page 602
- "Microsoft Access (Microsoft 3.51.171300)" on page 603
- "Microsoft FoxPro (Microsoft 3.51.171300)" on page 604
- "Lotus Notes SQL 2.0" on page 604

The latest versions of Microsoft ODBC drivers can be obtained through the Microsoft Data Access Components (MDAC) distribution found at *www.microsoft/data/download.htm*. The Microsoft driver versions listed below are part of MDAC 2.0.

The following sections provide notes on accessing these data sources.

Microsoft Excel (Microsoft 3.51.171300)

With Excel, each Excel workbook is logically considered to be a database holding several tables. Tables are mapped to sheets in a workbook. When you configure an ODBC data source name in the ODBC driver manager, you specify a default workbook name associated with that data source. However, when you issue a CREATE TABLE statement, you can override the default and specify a workbook name in the location string. This allows you to use a single ODBC DSN to access all of your excel workbooks.

In this example, an ODBC data source named **excel** was created. To create a workbook named *work1.xls* with a sheet (table) called mywork:

```
CREATE TABLE mywork (a int, b char(20))
AT 'excel;d:\work1.xls;;mywork'
```

To create a second sheet (or table) execute a statement such as:

```
CREATE TABLE mywork2 (x float, y int)
AT 'excel;d:\work1.xls;;mywork2'
```

You can import existing worksheets into Adaptive Server Anywhere using CREATE EXISTING, under the assumption that the first row of your spreadsheet contains column names.

```
CREATE EXISTING TABLE mywork
AT'excel;d:\work1;;mywork'
```

If Adaptive Server Anywhere reports that the table is not found, you may need to explicitly state the column and row range you wish to map to. For example:

```
CREATE EXISTING TABLE mywork
AT 'excel;d:\work1;;mywork$'
```

Adding the $ to the sheet name indicates that the entire worksheet should be selected.

Note in the location string specified by AT that a semicolon is used instead of a period for field separators. This is because periods occur in the file names. Excel does not support the owner name field so leave this blank.

Deletes are not supported. Also some updates may not be possible since the Excel driver does not support positioned updates.

Microsoft Access (Microsoft 3.51.171300)

Access databases are stored in a *.mdb* file. Using the ODBC manager, create an ODBC data source and map it to one of these files. A new *.mdb* file can be created through the ODBC manager. This database file becomes the default if you don't specify a different default when you create a table through Adaptive Server Anywhere.

Assuming an ODBC data source named access.

```
CREATE TABLE tab1 (a int, b char(10))
AT 'access...tab1'
```

or

```
CREATE TABLE tab1 (a int, b char(10))
AT 'access;d:\pcdb\data.mdb;;tab1'
```

or

```
CREATE EXISTING TABLE tab1
AT 'access;d:\pcdb\data.mdb;;tab1'
```

Access does not support the owner name qualification; leave it empty.

Microsoft FoxPro (Microsoft 3.51.171300)

You can store FoxPro tables together inside a single FoxPro database file (.dbc), or, you can store each table in its own separate .dbf file. When using .dbf files, be sure the file name is filled into the location string; otherwise the directory that Adaptive Server Anywhere was started in is used.

```
CREATE TABLE fox1 (a int, b char(20))
AT 'foxpro;d:\pcdb;;fox1'
```

This statement creates a file named *d:\pcdb\fox1.dbf* when you choose the "free table directory" option in the odbc driver manager.

Lotus Notes SQL 2.0

You can obtain this driver (version 2.04.0203) from the Lotus Web site. Read the documentation that comes with it for an explanation of how Notes data maps to relational tables. You can easily map Adaptive Server Anywhere tables to Notes forms.

Here is how to set up Adaptive Server Anywhere to access the Address sample file.

- ♦ Create an ODBC data source using the NotesSQL driver. The database will be the sample names file: *c:\notes\data\names.nsf*. The Map Special Characters option should be turned on. For this example, the Data Source Name is *my_notes_dsn*.
- ♦ Create a server in Adaptive Server Anywhere:

  ```
  CREATE SERVER names
  CLASS 'odbc'
  USING 'my_notes_dsn'
  ```

- ♦ Map the Person form into an Adaptive Server Anywhere table:

```
CREATE EXISTING TABLE Person
AT 'names...Person'
```

♦ Query the table

```
SELECT * FROM Person
```

Avoiding password prompts

Lotus Notes does not support sending a user name and password through the ODBC API. If you try to access Lotus notes using a password protected ID, a window appears on the machine where Adaptive Server Anywhere is running, and prompts you for a password. Avoid this behavior in multi-user server environments.

To access Lotus Notes unattended, without ever receiving a password prompt, you must use a non-password-protected ID. You can remove password protection from your ID by clearing it (File ➤ Tools ➤ User ID ➤ Clear Password), unless your Domino administrator required a password when your ID was created. In this case, you will not be able to clear it.

Part VI

Stored Procedures and Triggers

This part describes how to build logic into your database using SQL stored procedures and triggers. Storing logic in the database makes it available automatically to all applications, providing consistency, performance, and security benefits. The Stored Procedure debugger is a powerful tool for debugging all kinds of logic.

CHAPTER 19

Using Procedures, Triggers, and Batches

About this chapter

Procedures and triggers store procedural SQL statements in the database for use by all applications. They enhance the security, efficiency, and standardization of databases. User-defined functions are one kind of procedures that return a value to the calling environment for use in queries and other SQL statements. Batches are sets of SQL statements submitted to the database server as a group. Many features available in procedures and triggers, such as control statements, are also available in batches.

☞ For many purposes, server-side JDBC provides a more flexible way to build logic into the database than SQL stored procedures. For information about JDBC, see “JDBC Programming” [*ASA Programming Guide*, page 103].

Contents

Topic:	page
Procedure and trigger overview	611
Benefits of procedures and triggers	612
Introduction to procedures	613
Introduction to user-defined functions	620
Introduction to triggers	624
Introduction to batches	631
Control statements	633
The structure of procedures and triggers	636
Returning results from procedures	640
Using cursors in procedures and triggers	646
Errors and warnings in procedures and triggers	649
Using the EXECUTE IMMEDIATE statement in procedures	658
Transactions and savepoints in procedures and triggers	660
Tips for writing procedures	661
Statements allowed in batches	663

Topic:	page
Calling external libraries from procedures	664

Procedure and trigger overview

Procedures and triggers store procedural SQL statements in a database for use by all applications. They can include control statements that allow repetition (LOOP statement) and conditional execution (IF statement and CASE statement) of SQL statements.

Procedures are invoked with a CALL statement, and use parameters to accept values and return values to the calling environment. SELECT statements can also operate on procedure result sets by including the procedure name in the FROM clause.

Procedures can return result sets to the caller, call other procedures, or fire triggers. For example, a user-defined function is a type of stored procedure that returns a single value to the calling environment. User-defined functions do not modify parameters passed to them, but rather, they broaden the scope of functions available to queries and other SQL statements.

Triggers are associated with specific database tables. They fire automatically whenever someone inserts, updates or deletes rows of the associated table. Triggers can call procedures and fire other triggers, but they have no parameters and cannot be invoked by a CALL statement.

Procedure debugger

☞ You can debug stored procedures and triggers using the database object debugger. For more information, see "Debugging Logic in the Database" on page 673.

☞ You can profile stored procedures to analyze performance characteristics in Sybase Central. For more information, see "Profiling database procedures" on page 197.

Benefits of procedures and triggers

Definitions for procedures and triggers appear in the database, separately from any one database application. This separation provides a number of advantages.

Standardization

Procedures and triggers standardize actions performed by more than one application program. By coding the action once and storing it in the database for future use, applications need only call the procedure or fire the trigger to achieve the desired result repeatedly. And since changes occur in only one place, all applications using the action automatically acquire the new functionality if the implementation of the action changes.

Efficiency

Procedures and triggers used in a network database server environment can access data in the database without requiring network communication. This means they execute faster and with less impact on network performance than if they had been implemented in an application on one of the client machines.

When you create a procedure or trigger, it is automatically checked for correct syntax, and then stored in the system tables. The first time any application calls or fires a procedure or trigger, it is compiled from the system tables into the server's virtual memory and executed from there. Since one copy of the procedure or trigger remains in memory after the first execution, repeated executions of the same procedure or trigger happen instantly. As well, several applications can use a procedure or trigger concurrently, or one application can use it recursively.

Procedures are less efficient if they contain simple queries and have many arguments. For complex queries, procedures are more efficient.

Security

Procedures and triggers provide security by allowing users limited access to data in tables that they cannot directly examine or modify.

Triggers, for example, execute under the table permissions of the owner of the associated table, but any user with permissions to insert, update or delete rows in the table can fire them. Similarly, procedures (including user-defined functions) execute with permissions of the procedure owner, but any user granted permissions can call them. This means that procedures and triggers can (and usually do) have different permissions than the user ID that invoked them.

Introduction to procedures

To use procedures, you need to understand how to:

- Create procedures
- Call procedures from a database application
- Drop or remove procedures
- Control who has permissions to use procedures

This section discusses the above aspects of using procedures, as well as some different applications of procedures.

Creating procedures

Adaptive Server Anywhere provides a number of tools that let you create a new procedure.

In Sybase Central, you can use a wizard to provide necessary information. The Procedure Creation wizard also provides the option of using procedure templates.

Alternatively, you use the CREATE PROCEDURE statement to create procedures. However, you must have RESOURCE authority. Where you enter the statement depends on which tool you use.

❖ To create a new procedure (Sybase Central)

1. Connect to a database as a user with DBA or Resource authority.
2. Open the Procedures & Functions folder of the database.
3. From the File menu, choose New ➤ Procedure.

   The Procedure Creation wizard appears.
4. Follow the instructions in the wizard.
5. When the wizard finishes, you can complete the code of the procedure on the SQL tab in the right pane.

   The new procedure appears in the Procedures & Functions folder.

❖ To create a new remote procedure (Sybase Central)

1. Connect to a database as a user with DBA authority.
2. Open the Procedures & Functions folder of the database.
3. From the File menu, choose New ➤ Remote Procedure.

   The Remote Procedure Creation wizard appears.
4. Follow the instructions in the wizard.
5. When the wizard finishes, you can complete the code on the SQL tab in the right pane.

   The new remote procedure appears in the Procedures and Functions folder.

❖ To create a procedure using a different tool

1. Follow the instructions for your tool. You may need to change the command delimiter away from the semicolon before entering the CREATE PROCEDURE statement.

☞ For more information about connecting, see “Connecting to a Database” [*ASA Database Administration Guide*, page 37].

Example

The following simple example creates the procedure new_dept, which carries out an INSERT into the department table of the sample database, creating a new department.

```
CREATE PROCEDURE new_dept (
   IN id INT,
   IN name CHAR(35),
   IN head_id INT )
BEGIN
   INSERT
   INTO DBA.department ( dept_id,
       dept_name, dept_head_id )
   VALUES ( id, name, head_id );
END
```

The body of a procedure is a compound statement. The compound statement starts with a BEGIN statement and concludes with an END statement. In the case of new_dept, the compound statement is a single INSERT bracketed by BEGIN and END statements.

Parameters to procedures are marked as one of IN, OUT, or INOUT. All parameters to the new_dept procedure are IN parameters, as they are not changed by the procedure.

☞ For more information, see “CREATE PROCEDURE statement” [*ASA SQL Reference*, page 324], “ALTER PROCEDURE statement” [*ASA SQL Reference*, page 236], and “Using compound statements” on page 634.

Altering procedures

You can modify an existing procedure using either Sybase Central or Interactive SQL. You must have DBA authority or be the owner of the procedure.

In Sybase Central, you cannot rename an existing procedure directly. Instead, you must create a new procedure with the new name, copy the previous code to it, and then delete the old procedure.

Alternatively, you can use an ALTER PROCEDURE statement to modify an existing procedure. You must include the entire new procedure in this statement (in the same syntax as in the CREATE PROCEDURE statement that created the procedure). You must also reassign user permissions on the procedure.

☞ For more information on altering database object properties, see “Setting properties for database objects” on page 32.

☞ For more information on granting or revoking permissions for procedures, see “Granting permissions on procedures” [*ASA Database Administration Guide*, page 400] and “Revoking user permissions” [*ASA Database Administration Guide*, page 402].

❖ To alter the code of a procedure (Sybase Central)

1. Open the Procedures & Functions folder.
2. Select the desired procedure. You can then do one of the following:
   - ♦ Edit the code directly on the SQL tab in the right pane.
   - ♦ Translate the code to Watcom-SQL or Transact-SQL prior to editing it:
     - Right-click the desired procedure and choose Open as Watcom-SQL or Open as Transact-SQL from the popup menu.
     - Edit the code on the SQL tab in the right pane.
   - ♦ Edit the code in a separate window by right-clicking the procedure in the right pane and choose Edit In New Window from the popup menu.

> **Tip**
> If you wish to copy code between procedures, you can open a separate window for each procedure.

❖ **To alter the code of a procedure (SQL)**

1. Connect to the database.

2. Execute an ALTER PROCEDURE statement. Include the entire new procedure in this statement.

☞ For more information, see "ALTER PROCEDURE statement" [*ASA SQL Reference*, page 236], "CREATE PROCEDURE statement" [*ASA SQL Reference*, page 324], and "Creating procedures" on page 613.

Calling procedures

CALL statements invoke procedures. Procedures can be called by an application program, or by other procedures and triggers.

☞ For more information, see "CALL statement" [*ASA SQL Reference*, page 273].

The following statement calls the new_dept procedure to insert an Eastern Sales department:

```
CALL new_dept( 210, 'Eastern Sales', 902 );
```

After this call, you may wish to check the department table to see that the new department has been added.

All users who have been granted EXECUTE permissions for the procedure can call the new_dept procedure, even if they have no permissions on the department table.

☞ For more information about EXECUTE permissions, see "EXECUTE statement [ESQL]" [*ASA SQL Reference*, page 425].

Another way of calling a procedure that returns a result set is to call it in a query. You can execute queries on result sets of procedures and apply WHERE clauses and other SELECT features to limit the result set.

```
SELECT t.id, t.quantity_ordered AS q
FROM sp_customer_products( 149 ) t
```

☞ For more information, see "FROM clause" [*ASA SQL Reference*, page 445].

Copying procedures in Sybase Central

In Sybase Central, you can copy procedures between databases. To do so, select the procedure in the left pane of Sybase Central and drag it to the Procedures & Functions folder of another connected database. A new procedure is then created, and the original procedure's code is copied to it.

Note that only the procedure code is copied to the new procedure. The other procedure properties (permissions, etc.) are not copied. A procedure can be copied to the same database, provided it is given a new name.

Deleting procedures

Once you create a procedure, it remains in the database until someone explicitly removes it. Only the owner of the procedure or a user with DBA authority can drop the procedure from the database.

❖ To delete a procedure (Sybase Central)

1. Connect to a database as a user with DBA authority or as the owner of the procedure.
2. Open the Procedures & Functions folder.
3. Right-click the desired procedure and choose Delete from the popup menu.

❖ To delete a procedure (SQL)

1. Connect to a database as a user with DBA authority or as the owner of the procedure.
2. Execute a DROP PROCEDURE statement.

Example

The following statement removes the procedure new_dept from the database:

```
DROP PROCEDURE new_dept
```

☞ For more information, see “DROP statement” [*ASA SQL Reference*, page 408].

Returning procedure results in parameters

Procedures return results to the calling environment in one of the following ways:

- Individual values are returned as OUT or INOUT parameters.
- Result sets can be returned.
- A single result can be returned using a RETURN statement.

This section describes how to return results from procedures as parameters.

The following procedure on the sample database returns the average salary of employees as an OUT parameter.

```
CREATE PROCEDURE AverageSalary( OUT avgsal
   NUMERIC (20,3) )
BEGIN
   SELECT AVG( salary )
   INTO avgsal
   FROM employee;
END
```

❖ To run this procedure and display its output (SQL)

1. Connect to the sample database from Interactive SQL with a user ID of **DBA** and a password of **SQL**. For more information about connecting, see "Connecting to a Database" [*ASA Database Administration Guide,* page 37].

2. In the SQL Statements pane, type the above procedure code.

3. Create a variable to hold the procedure output. In this case, the output variable is numeric, with three decimal places, so create a variable as follows:

   ```
   CREATE VARIABLE Average NUMERIC(20,3)
   ```

4. Call the procedure using the created variable to hold the result:

   ```
   CALL AverageSalary(Average)
   ```

   If the procedure was created and run properly, the Interactive SQL Messages pane does not display any errors.

5. Execute the SELECT Average statement to inspect the value of the variable.

   Look at the value of the output variable Average. The Results tab in the Results pane displays the value 49988.623 for this variable, the average employee salary.

Returning procedure results in result sets

In addition to returning results to the calling environment in individual parameters, procedures can return information in result sets. A result set is typically the result of a query. The following procedure returns a result set containing the salary for each employee in a given department:

```
CREATE PROCEDURE SalaryList ( IN department_id INT)
RESULT ( "Employee ID" INT, Salary NUMERIC(20,3) )
BEGIN
    SELECT emp_id, salary
    FROM employee
    WHERE employee.dept_id = department_id;
END
```

If Interactive SQL calls this procedure, the names in the RESULT clause are matched to the results of the query and used as column headings in the displayed results.

To test this procedure from Interactive SQL, you can CALL it, specifying one of the departments of the company. In Interactive SQL, the results appear on the Results tab in the Results pane.

Example

To list the salaries of employees in the R & D department (department ID 100), type the following:

```
CALL SalaryList (100)
```

Employee ID	Salary
102	45700
105	62000
160	57490
243	72995
…	…

Interactive SQL can only return multiple result sets if you have this option enabled on the Results tab of the Options dialog. Each result set appears on a separate tab in the Results pane.

☞ For more information, see "Returning multiple result sets from procedures" on page 643.

Introduction to user-defined functions

User-defined functions are a class of procedures that return a single value to the calling environment. Adaptive Server Anywhere treats all user-defined functions as **idempotent** unless they are declared NOT DETERMINISTIC.

Idempotent functions return a consistent result for the same parameters and are free of side effects. Two successive calls to an idempotent function with the same parameters return the same result, and have no unwanted side-effects on the query's semantics.

☞ For more information about non-deterministic and deterministic functions, see "Function caching" on page 418.

This section introduces creating, using, and dropping user-defined functions.

Creating user-defined functions

You use the CREATE FUNCTION statement to create user-defined functions. However, you must have RESOURCE authority.

The following simple example creates a function that concatenates two strings, together with a space, to form a full name from a first name and a last name.

```
CREATE FUNCTION fullname (firstname CHAR(30),
   lastname CHAR(30))
RETURNS CHAR(61)
BEGIN
     DECLARE name CHAR(61);
     SET name = firstname || ' ' || lastname;
     RETURN ( name );
END
```

❖ To create this example using Interactive SQL

1. Connect to the sample database from Interactive SQL with a user ID of **DBA** and a password of **SQL**. For more information about connecting, see "Connecting to a Database" [*ASA Database Administration Guide,* page 37].

2. In the SQL Statements pane, type the above function code.

Note
If you are using a tool other than Interactive SQL or Sybase Central, you may need to change the command delimiter to something other than the semicolon.

For more information, see "CREATE FUNCTION statement" [*ASA SQL Reference*, page 315].

The CREATE FUNCTION syntax differs slightly from that of the CREATE PROCEDURE statement. The following are distinctive differences:

- No IN, OUT, or INOUT keywords are required, as all parameters are IN parameters.
- The RETURNS clause is required to specify the data type being returned.
- The RETURN statement is required to specify the value being returned.

Calling user-defined functions

A user-defined function can be used, subject to permissions, in any place you would use a built-in non-aggregate function.

The following statement in Interactive SQL returns a full name from two columns containing a first and last name:

```
SELECT fullname (emp_fname, emp_lname)
FROM employee;
```

fullname (emp_fname, emp_lname)
Fran Whitney
Matthew Cobb
Philip Chin
...

The following statement in Interactive SQL returns a full name from a supplied first and last name:

```
SELECT fullname ('Jane', 'Smith');
```

fullname ('Jane','Smith')
Jane Smith

Any user who has been granted EXECUTE permissions for the function can use the fullname function.

Example

The following user-defined function illustrates local declarations of variables.

The customer table includes some Canadian customers sprinkled among those from the USA, but there is no country column. The user-defined function nationality uses the fact that the US zip code is numeric while the Canadian postal code begins with a letter to distinguish Canadian and US customers.

```
CREATE FUNCTION nationality( cust_id INT )
RETURNS CHAR( 20 )
BEGIN
   DECLARE natl CHAR(20);
   IF cust_id IN ( SELECT id FROM customer
    WHERE LEFT(zip,1) > '9') THEN
          SET natl = 'CDN';
   ELSE
        SET natl = 'USA';
   END IF;
   RETURN ( natl );
END
```

This example declares a variable natl to hold the nationality string, uses a SET statement to set a value for the variable, and returns the value of the natl string to the calling environment.

The following query lists all Canadian customers in the customer table:

```
SELECT *
FROM customer
WHERE nationality(id) = 'CDN'
```

Declarations of cursors and exceptions are discussed in later sections.

The same query restated without the function would perform better, especially if an index on zip existed. For example,

```
Select *
FROM customer
WHERE zip > '99999'
```

Notes

While this function is useful for illustration, it may perform very poorly if used in a SELECT involving many rows. For example, if you used the SELECT query on a table containing 100 000 rows, of which 10 000 are returned, the function will be called 10 000 times. If you use it in the WHERE clause of the same query, it would be called 100 000 times.

Dropping user-defined functions

Once you create a user-defined function, it remains in the database until someone explicitly removes it. Only the owner of the function or a user with DBA authority can drop a function from the database.

The following statement removes the function fullname from the database:

```
DROP FUNCTION fullname
```

Permissions to execute user-defined functions

Ownership of a user-defined function belongs to the user who created it, and that user can execute it without permission. The owner of a user-defined function can grant permissions to other users with the GRANT EXECUTE command.

For example, the creator of the function fullname could allow another_user to use fullname with the statement:

```
GRANT EXECUTE ON fullname TO another_user
```

The following statement revokes permissions to use the function:

```
REVOKE EXECUTE ON fullname FROM another_user
```

☞ For more information on managing user permissions on functions, see "Granting permissions on procedures" [*ASA Database Administration Guide*, page 400].

Introduction to triggers

A trigger is a special form of stored procedure that is executed automatically when a query that modifies data is executed. You use triggers whenever referential integrity and other declarative constraints are insufficient.

☞ For more information on referential integrity, see "Ensuring Data Integrity" on page 75 and "CREATE TABLE statement" [*ASA SQL Reference*, page 361].

You may want to enforce a more complex form of referential integrity involving more detailed checking, or you may want to enforce checking on new data but allow legacy data to violate constraints. Another use for triggers is in logging the activity on database tables, independent of the applications using the database.

Trigger execution permissions
Triggers execute with the permissions of the owner of the associated table, not the user ID whose actions cause the trigger to fire. A trigger can modify rows in a table that a user could not modify directly.

Trigger events

Triggers can be defined on one or more of the following triggering events:

Action	Description
INSERT	Invokes the trigger whenever a new row is inserted into the table associated with the trigger
DELETE	Invokes the trigger whenever a row of the associated table is deleted.
UPDATE	Invokes the trigger whenever a row of the associated table is updated.
UPDATE OF column-list	Invokes the trigger whenever a row of the associated table is updated such that a column in the *column-list* has been modified

You may write separate triggers for each event that you need to handle or, if you have some shared actions and some actions that depend on the event, you can create a trigger for all events and use an IF statement to distinguish the action taking place.

☞ For more information, see "Trigger operation conditions" [*ASA SQL Reference*, page 28].

Trigger times

Triggers can be either **row-level** or **statement-level**:

- A row-level trigger executes once for each row that is changed. Row-level triggers execute BEFORE or AFTER the row is changed.
- A statement-level trigger executes after the entire triggering statement is completed.

Flexibility in trigger execution time is particularly useful for triggers that rely on referential integrity actions such as cascaded updates or deletes being carried out (or not) as they execute.

If an error occurs while a trigger is executing, the operation that fired the trigger fails. INSERT, UPDATE, and DELETE are atomic operations (see "Atomic compound statements" on page 634). When they fail, all effects of the statement (including the effects of triggers and any procedures called by triggers) revert back to their pre-operation state.

☞ For a full description of trigger syntax, see "CREATE TRIGGER statement" [*ASA SQL Reference*, page 373].

Creating triggers

You create triggers using either Sybase Central or Interactive SQL. In Sybase Central, you can use a wizard to provide necessary information. In Interactive SQL, you can use a CREATE TRIGGER statement. For both tools, you must have DBA or RESOURCE authority to create a trigger and you must have ALTER permissions on the table associated with the trigger.

The body of a trigger consists of a compound statement: a set of semicolon-delimited SQL statements bracketed by a BEGIN and an END statement.

You cannot use COMMIT and ROLLBACK and some ROLLBACK TO SAVEPOINT statements within a trigger.

☞ For more information, see the list of cross-references at the end of this section.

❖ To create a new trigger for a given table (Sybase Central)

1. Open the Triggers folder of the desired table.
2. From the File menu, choose New ➤ Trigger.

   The Trigger Creation wizard appears.
3. Follow the instructions in the wizard.
4. When the wizard finishes, you can complete the code of the trigger on the SQL tab in the right pane.

❖ To create a new trigger for a given table (SQL)

1. Connect to a database.

2. Execute a CREATE TRIGGER statement.

Example 1: A row-level INSERT trigger

The following trigger is an example of a row-level INSERT trigger. It checks that the birth date entered for a new employee is reasonable:

```
CREATE TRIGGER check_birth_date
    AFTER INSERT ON Employee
REFERENCING NEW AS new_employee
FOR EACH ROW
BEGIN
     DECLARE err_user_error EXCEPTION
     FOR SQLSTATE '99999';
     IF new_employee.birth_date > 'June 6, 2001' THEN
          SIGNAL err_user_error;
     END IF;
END
```

This trigger fires after any row is inserted into the employee table. It detects and disallows any new rows that correspond to birth dates later than June 6, 2001.

The phrase REFERENCING NEW AS new_employee allows statements in the trigger code to refer to the data in the new row using the alias new_employee.

Signaling an error causes the triggering statement, as well as any previous effects of the trigger, to be undone.

For an INSERT statement that adds many rows to the employee table, the check_birth_date trigger fires once for each new row. If the trigger fails for any of the rows, all effects of the INSERT statement roll back.

You can specify that the trigger fires before the row is inserted rather than after by changing the first line of the example to:

```
CREATE TRIGGER mytrigger BEFORE INSERT ON Employee
```

The REFERENCING NEW clause refers to the inserted values of the row; it is independent of the timing (BEFORE or AFTER) of the trigger.

You may find it easier in some cases to enforce constraints using declaration referential integrity or CHECK constraints, rather than triggers. For example, implementing the above example with a column check constraint proves more efficient and concise:

```
CHECK (@col <= 'June 6, 2001')
```

Example 2: A row-level DELETE trigger example

The following CREATE TRIGGER statement defines a row-level DELETE trigger:

```
CREATE TRIGGER mytrigger BEFORE DELETE ON employee
REFERENCING OLD AS oldtable
FOR EACH ROW
BEGIN
     ...
END
```

The REFERENCING OLD clause enables the delete trigger code to refer to the values in the row being deleted using the alias oldtable.

You can specify that the trigger fires after the row is deleted rather than before, by changing the first line of the example to:

```
CREATE TRIGGER check_birth_date AFTER DELETE ON employee
```

The REFERENCING OLD clause is independent of the timing (BEFORE or AFTER) of the trigger.

Example 3: A statement-level UPDATE trigger example

The following CREATE TRIGGER statement is appropriate for statement-level UPDATE triggers:

```
CREATE TRIGGER mytrigger AFTER UPDATE ON employee
REFERENCING NEW AS table_after_update
            OLD AS table_before_update
FOR EACH STATEMENT
BEGIN
     ...
END
```

The REFERENCING NEW and REFERENCING OLD clause allows the UPDATE trigger code to refer to both the old and new values of the rows being updated. The table alias table_after_update refers to columns in the new row and the table alias table_before_update refers to columns in the old row.

The REFERENCING NEW and REFERENCING OLD clause has a slightly different meaning for statement-level and row-level triggers. For statement-level triggers the REFERENCING OLD or NEW aliases are table aliases, while in row-level triggers they refer to the row being altered.

☞ For more information, see “CREATE TRIGGER statement” [*ASA SQL Reference*, page 373], and “Using compound statements” on page 634.

Executing triggers

Triggers execute automatically whenever an INSERT, UPDATE, or DELETE operation is performed on the table named in the trigger. A row-level trigger fires once for each row affected, while a statement-level trigger fires once for the entire statement.

When an INSERT, UPDATE, or DELETE fires a trigger, the order of operation is as follows:

1. BEFORE triggers fire.
2. Referential actions are performed.
3. The operation itself is performed.
4. AFTER triggers fire.

If any of the steps encounter an error not handled within a procedure or trigger, the preceding steps are undone, the subsequent steps are not performed, and the operation that fired the trigger fails.

Altering triggers

You can modify an existing trigger using either Sybase Central or Interactive SQL. You must be the owner of the table on which the trigger is defined, or be DBA, or have ALTER permissions on the table and have RESOURCE authority.

In Sybase Central, you cannot rename an existing trigger directly. Instead, you must create a new trigger with the new name, copy the previous code to it, and then delete the old trigger.

Alternatively, you can use an ALTER TRIGGER statement to modify an existing trigger. You must include the entire new trigger in this statement (in the same syntax as in the CREATE TRIGGER statement that created the trigger).

☞ For more information on altering database object properties, see "Setting properties for database objects" on page 32.

❖ To alter the code of a trigger (Sybase Central)

1. Open the Triggers folder.
2. Select the desired trigger. You can then do one of the following:
   - ♦ Edit the code directly on the SQL tab in the right pane.
   - ♦ Translate the code to Watcom-SQL or Transact-SQL prior to editing it:
     - Right-click the desired trigger and choose Open as Watcom-SQL or Open as Transact-SQL from the popup menu.
     - Edit the code on the SQL tab in the right pane.

- Edit the code in a separate window by right-clicking the procedure in the right pane and choose Edit In New Window from the popup menu.

> **Tip**
> If you wish to copy code between triggers, you can open a separate window for each trigger.

❖ To alter the code of a trigger (SQL)

1. Connect to the database.
2. Execute an ALTER TRIGGER statement. Include the entire new trigger in this statement.

☞ For more information, see “ALTER TRIGGER statement” [*ASA SQL Reference*, page 258].

Dropping triggers

Once you create a trigger, it remains in the database until someone explicitly removes it. You must have ALTER permissions on the table associated with the trigger to drop the trigger.

❖ To delete a trigger (Sybase Central)

1. Open the Triggers folder.
2. Right-click the desired trigger and choose Delete from the popup menu.

❖ To delete a trigger (SQL)

1. Connect to a database.
2. Execute a DROP TRIGGER statement.

Example

The following statement removes the trigger mytrigger from the database:

```
DROP TRIGGER mytrigger
```

☞ For more information, see “DROP statement” [*ASA SQL Reference*, page 408].

Trigger execution permissions

You cannot grant permissions to execute a trigger, since users cannot execute triggers: Adaptive Server Anywhere fires them in response to actions on the database. Nevertheless, a trigger does have permissions associated with it as it executes, defining its right to carry out certain actions.

Triggers execute using the permissions of the owner of the table on which they are defined, not the permissions of the user who caused the trigger to fire, and not the permissions of the user who created the trigger.

When a trigger refers to a table, it uses the group memberships of the table creator to locate tables with no explicit owner name specified. For example, if a trigger on user_1.Table_A references Table_B and does not specify the owner of Table_B, then either Table_B must have been created by user_1 or user_1 must be a member of a group (directly or indirectly) that is the owner of Table_B. If neither condition is met, a **table not found** message results when the trigger fires.

Also, user_1 must have permissions to carry out the operations specified in the trigger.

Introduction to batches

A simple batch consists of a set of SQL statements, separated by semicolons or separated by a separate line with just the word **go** on it. The use of **go** is recommended. For example, the following set of statements form a batch, which creates an Eastern Sales department and transfers all sales reps from Massachusetts to that department.

```
INSERT
INTO department ( dept_id, dept_name )
VALUES ( 220, 'Eastern Sales' )
go
UPDATE employee
SET dept_id = 220
WHERE dept_id = 200
AND state = 'MA'
go
COMMIT
go
```

You can include this set of statements in an application and execute them together.

Interactive SQL and batches
Interactive SQL parses a list of semicolon-separated statements, such as the above, before sending them to the server. In this case, Interactive SQL sends each statement to the server individually, not as a batch. Unless you have such parsing code in your application, the statements would be sent and treated as a batch. Putting a BEGIN and END around a set of statements causes Interactive SQL to treat them as a batch.

Many statements used in procedures and triggers can also be used in batches. You can use control statements (CASE, IF, LOOP, and so on), including compound statements (BEGIN and END), in batches. Compound statements can include declarations of variables, exceptions, temporary tables, or cursors inside the compound statement.

The following batch creates a table only if a table of that name does not already exist:

```
IF NOT EXISTS (
   SELECT * FROM SYSTABLE
   WHERE table_name = 't1' ) THEN
      CREATE TABLE t1 (
      firstcol INT PRIMARY KEY,
      secondcol CHAR( 30 )
      )
      go
ELSE
   MESSAGE 'Table t1 already exists' TO CLIENT;
END IF
```

If you run this batch twice from Interactive SQL, it creates the table the first time you run it and displays the message in the Interactive SQL Messages pane the next time you run it.

Control statements

There are a number of control statements for logical flow and decision making in the body of the procedure or trigger, or in a batch. Available control statements include:

<table>
<tr><th>Control statement</th><th>Syntax</th></tr>
<tr><td>Compound statements

For more information, see “BEGIN statement” [ASA SQL Reference, page 267].</td><td><pre>BEGIN [ATOMIC]
   Statement-list
END</pre></td></tr>
<tr><td>Conditional execution: IF

For more information, see “IF statement” [ASA SQL Reference, page 467].</td><td><pre>IF condition THEN
   Statement-list
ELSEIF condition THEN
   Statement-list
ELSE
   Statement-list
END IF</pre></td></tr>
<tr><td>Conditional execution: CASE

For more information, see “CASE statement” [ASA SQL Reference, page 275].</td><td><pre>CASE expression
WHEN value THEN
   Statement-list
WHEN value THEN
   Statement-list
ELSE
   Statement-list
END CASE</pre></td></tr>
<tr><td>Repetition: WHILE, LOOP

For more information, see “LOOP statement” [ASA SQL Reference, page 495].</td><td><pre>WHILE condition LOOP
   Statement-list
END LOOP</pre></td></tr>
<tr><td>Repetition: FOR cursor loop

For more information, see “FOR statement” [ASA SQL Reference, page 441].</td><td><pre>FOR loop-name
   AS cursor-name
   CURSOR FOR select statement
DO
   Statement-list
END FOR</pre></td></tr>
<tr><td>Break: LEAVE

For more information, see “LEAVE statement” [ASA SQL Reference, page 483].</td><td><pre>LEAVE label</pre></td></tr>
</table>

Control statement	Syntax
CALL For more information, see "CALL statement" [*ASA SQL Reference*, page 273].	`CALL procname( arg, ... )`

For more information about each statement, see the entries in "SQL Statements" [*ASA SQL Reference*, page 213]

Using compound statements

A compound statement starts with the keyword BEGIN and concludes with the keyword END. The body of a procedure or trigger is a **compound statement**. Compound statements can also be used in batches. Compound statements can be nested, and combined with other control statements to define execution flow in procedures and triggers or in batches.

A compound statement allows a set of SQL statements to be grouped together and treated as a unit. Delimit SQL statements within a compound statement with semicolons.

☞ For more information about compound statements, see the "BEGIN statement" [*ASA SQL Reference*, page 267].

Declarations in compound statements

Local declarations in a compound statement immediately follow the BEGIN keyword. These local declarations exist only within the compound statement. Within a compound statement you can declare:

- Variables
- Cursors
- Temporary tables
- Exceptions (error identifiers)

Local declarations can be referenced by any statement in that compound statement, or in any compound statement nested within it. Local declarations are not visible to other procedures called from the compound statement.

Atomic compound statements

An **atomic** statement is a statement executed completely or not at all. For example, an UPDATE statement that updates thousands of rows might encounter an error after updating many rows. If the statement does not complete, all changes revert back to their original state. The UPDATE statement is atomic.

All non-compound SQL statements are atomic. You can make a compound statement atomic by adding the keyword ATOMIC after the BEGIN keyword.

```
BEGIN ATOMIC
    UPDATE employee
    SET manager_ID = 501
    WHERE emp_ID = 467;
    UPDATE employee
    SET birth_date = 'bad_data';
END
```

In this example, the two update statements are part of an atomic compound statement. They must either succeed or fail as one. The first update statement would succeed. The second one causes a data conversion error since the value being assigned to the birth_date column cannot be converted to a date.

The atomic compound statement fails and the effect of both UPDATE statements is undone. Even if the currently executing transaction is eventually committed, neither statement in the atomic compound statement takes effect.

If an atomic compound statement succeeds, the changes made within the compound statement take effect only if the currently executing transaction is committed.

You cannot use COMMIT and ROLLBACK and some ROLLBACK TO SAVEPOINT statements within an atomic compound statement (see "Transactions and savepoints in procedures and triggers" on page 660).

There is a case where some, but not all, of the statements within an atomic compound statement are executed. This happens when an exception handler within the compound statement deals with an error.

☞ For more information, see "Using exception handlers in procedures and triggers" on page 654.

The structure of procedures and triggers

The body of a procedure or trigger consists of a compound statement as discussed in "Using compound statements" on page 634. A compound statement consists of a BEGIN and an END, enclosing a set of SQL statements. Semicolons delimit each statement.

SQL statements allowed in procedures and triggers

You can use almost all SQL statements within procedures and triggers, including the following:

- SELECT, UPDATE, DELETE, INSERT and SET VARIABLE.
- The CALL statement to execute other procedures.
- Control statements (see "Control statements" on page 633).
- Cursor statements (see "Using cursors in procedures and triggers" on page 646).
- Exception handling statements (see "Using exception handlers in procedures and triggers" on page 654).
- The EXECUTE IMMEDIATE statement.

Some SQL statements you cannot use within procedures and triggers include:

- CONNECT statement
- DISCONNECT statement.

You can use COMMIT, ROLLBACK and SAVEPOINT statements within procedures and triggers with certain restrictions (see "Transactions and savepoints in procedures and triggers" on page 660).

For more information, see the Usage for each SQL statement in the chapter "SQL Statements" [*ASA SQL Reference*, page 213].

Declaring parameters for procedures

Procedure parameters appear as a list in the CREATE PROCEDURE statement. Parameter names must conform to the rules for other database identifiers such as column names. They must have valid data types (see "SQL Data Types" [*ASA SQL Reference*, page 51]), and must be prefixed with one of the keywords IN, OUT or INOUT. These keywords have the following meanings:

- **IN** The argument is an expression that provides a value to the procedure.

- **OUT** The argument is a variable that could be given a value by the procedure.
- **INOUT** The argument is a variable that provides a value to the procedure, and could be given a new value by the procedure.

You can assign default values to procedure parameters in the CREATE PROCEDURE statement. The default value must be a constant, which may be NULL. For example, the following procedure uses the NULL default for an IN parameter to avoid executing a query that would have no meaning:

```
CREATE PROCEDURE
CustomerProducts( IN customer_id
                  INTEGER DEFAULT NULL )
RESULT ( product_id INTEGER,
         quantity_ordered INTEGER )
BEGIN
    IF customer_id IS NULL THEN
        RETURN;
    ELSE
        SELECT    product.id,
                 sum( sales_order_items.quantity )
        FROM   product,
                 sales_order_items,
                 sales_order
        WHERE sales_order.cust_id = customer_id
        AND sales_order.id = sales_order_items.id
        AND sales_order_items.prod_id = product.id
        GROUP BY product.id;
    END IF;
END
```

The following statement assigns the DEFAULT NULL, and the procedure RETURNs instead of executing the query.

```
CALL customerproducts();
```

Passing parameters to procedures

You can take advantage of default values of stored procedure parameters with either of two forms of the CALL statement.

If the optional parameters are at the end of the argument list in the CREATE PROCEDURE statement, they may be omitted from the CALL statement. As an example, consider a procedure with three INOUT parameters:

```
CREATE PROCEDURE SampleProc( INOUT var1 INT
                               DEFAULT 1,
                     INOUT var2 int DEFAULT 2,
                     INOUT var3 int DEFAULT 3 )
...
```

We assume that the calling environment has set up three variables to hold the values passed to the procedure:

```
CREATE VARIABLE V1 INT;
CREATE VARIABLE V2 INT;
CREATE VARIABLE V3 INT;
```

The procedure SampleProc may be called supplying only the first parameter as follows:

```
CALL SampleProc( V1 )
```

in which case the default values are used for *var2* and *var3.*

A more flexible method of calling procedures with optional arguments is to pass the parameters by name. The SampleProc procedure may be called as follows:

```
CALL SampleProc( var1 = V1, var3 = V3 )
```

or as follows:

```
CALL SampleProc( var3 = V3, var1 = V1 )
```

Passing parameters to functions

User-defined functions are not invoked with the CALL statement, but are used in the same manner that built-in functions are. For example, the following statement uses the fullname function defined in "Creating user-defined functions" on page 620 to retrieve the names of employees:

❖ To list the names of all employees

1. Type the following:

```
SELECT fullname(emp_fname, emp_lname) AS Name
FROM employee
```

Name
Fran Whitney
Matthew Cobb
Philip Chin
Julie Jordan
...

Notes

- Default parameters can be used in calling functions. However, parameters cannot be passed to functions by name.
- Parameters are passed by value, not by reference. Even if the function changes the value of the parameter, this change is not returned to the calling environment.
- Output parameters cannot be used in user-defined functions.
- User-defined functions cannot return result sets.

Returning results from procedures

Procedures can return results in the form of a single row of data, or multiple rows. Results consisting of a single row of data can be passed back as arguments to the procedure. Results consisting of multiple rows of data are passed back as result sets. Procedures can also return a single value given in the RETURN statement.

For simple examples of how to return results from procedures, see "Introduction to procedures" on page 613. For more detailed information, see the following sections.

Returning a value using the RETURN statement

The RETURN statement returns a single integer value to the calling environment, causing an immediate exit from the procedure. The RETURN statement takes the form:

```
RETURN expression
```

The value of the supplied expression is returned to the calling environment. To save the return value in a variable, use an extension of the CALL statement:

```
CREATE VARIABLE returnval INTEGER ;
returnval = CALL myproc() ;
```

Returning results as procedure parameters

Procedures can return results to the calling environment in the parameters to the procedure.

Within a procedure, parameters and variables can be assigned values using:

- the SET statement.
- a SELECT statement with an INTO clause.

Using the SET statement

The following somewhat artificial procedure returns a value in an OUT parameter assigned using a SET statement:

```
CREATE PROCEDURE greater (   IN a INT,
                            IN b INT,
                            OUT c INT)
BEGIN
   IF a > b THEN
      SET c = a;
   ELSE
      SET c = b;
   END IF ;
END
```

Using single-row SELECT statements

Single-row queries retrieve at most one row from the database. This type of query uses a SELECT statement with an INTO clause. The INTO clause follows the select list and precedes the FROM clause. It contains a list of variables to receive the value for each select list item. There must be the same number of variables as there are select list items.

When a SELECT statement executes, the server retrieves the results of the SELECT statement and places the results in the variables. If the query results contain more than one row, the server returns an error. For queries returning more than one row, you must use cursors. For information about returning more than one row from a procedure, see "Returning result sets from procedures" on page 642.

If the query results in no rows being selected, a **row not found** warning appears.

The following procedure returns the results of a single-row SELECT statement in the procedure parameters.

❖ To return the number of orders placed by a given customer

1. Type the following:

```
CREATE PROCEDURE OrderCount (IN customer_ID INT,
                             OUT Orders INT)
BEGIN
   SELECT COUNT(DBA.sales_order.id)
      INTO Orders
   FROM DBA.customer
      KEY LEFT OUTER JOIN "DBA".sales_order
   WHERE DBA.customer.id = customer_ID;
END
```

You can test this procedure in Interactive SQL using the following statements, which show the number of orders placed by the customer with ID 102:

```
CREATE VARIABLE orders INT;
CALL OrderCount ( 102, orders );
SELECT orders;
```

Notes

- The *customer_ID* parameter is declared as an IN parameter. This parameter holds the customer ID passed in to the procedure.
- The *Orders* parameter is declared as an OUT parameter. It holds the value of the orders variable that returned to the calling environment.
- No DECLARE statement is necessary for the *Orders* variable, as it is declared in the procedure argument list.
- The SELECT statement returns a single row and places it into the variable *Orders*.

Returning result sets from procedures

Result sets allow a procedure to return more than one row of results to the calling environment.

The following procedure returns a list of customers who have placed orders, together with the total value of the orders placed. The procedure does not list customers who have not placed orders.

```
CREATE PROCEDURE ListCustomerValue ()
RESULT ("Company" CHAR(36), "Value" INT)
BEGIN
   SELECT company_name,
      CAST( sum(   sales_order_items.quantity *
                  product.unit_price)
                  AS INTEGER ) AS value
   FROM customer
      INNER JOIN sales_order
      INNER JOIN sales_order_items
      INNER JOIN product
   GROUP BY company_name
   ORDER BY value DESC;
END
```

- Type the following:

```
CALL ListCustomerValue ()
```

Company	Value
Chadwicks	8076
Overland Army Navy	8064
Martins Landing	6888
Sterling & Co.	6804
Carmel Industries	6780
...	...

Notes

- The number of variables in the RESULT list must match the number of the SELECT list items. Automatic data type conversion is carried out where possible if data types do not match.
- The RESULT clause is part of the CREATE PROCEDURE statement, and does not have a command delimiter.
- The names of the SELECT list items do not need to match those of the RESULT list.
- When testing this procedure, Interactive SQL displays only the first result set by default. You can configure Interactive SQL to display more than one result set by setting the Show multiple result sets option on the Results tab of the Options dialog.
- You can modify procedure result sets, unless they are generated from a view. The user calling the procedure requires the appropriate permissions on the underlying table to modify procedure results. This is different than the usual permissions for procedure execution, where the procedure *owner* must have permissions on the table.

  ☞ For information about modifying result sets in Interactive SQL, see "Editing table values in Interactive SQL" [*ASA Getting Started*, page 76].

Returning multiple result sets from procedures

Before Interactive SQL can return multiple result sets, you need to enable this option on the Results tab of the Options dialog. By default, this option is disabled. If you change the setting, it takes effect in newly created connections (such as new windows).

❖ To enable multiple result set functionality

1. Choose Tools ➤ Options.
2. In the resulting Options dialog, click the Results tab.
3. Select the Show Multiple Result Sets checkbox.

After you enable this option, a procedure can return more than one result set to the calling environment. If a RESULT clause is employed, the result sets must be compatible: they must have the same number of items in the SELECT lists, and the data types must all be of types that can be automatically converted to the data types listed in the RESULT list.

The following procedure lists the names of all employees, customers, and contacts listed in the database:

```
CREATE PROCEDURE ListPeople()
RESULT ( lname CHAR(36), fname CHAR(36) )
BEGIN
   SELECT emp_lname, emp_fname
   FROM employee;
   SELECT lname, fname
   FROM customer;
   SELECT last_name, first_name
   FROM contact;
END
```

Notes

- To test this procedure in Interactive SQL, enter the following statement in the SQL Statements pane:

  ```
  CALL ListPeople ()
  ```

Returning variable result sets from procedures

The RESULT clause is optional in procedures. Omitting the result clause allows you to write procedures that return different result sets, with different numbers or types of columns, depending on how they are executed.

If you do not use the variable result sets feature, you should use a RESULT clause for performance reasons.

For example, the following procedure returns two columns if the input variable is Y, but only one column otherwise:

```
CREATE PROCEDURE names( IN formal char(1))
BEGIN
   IF formal = 'y' THEN
      SELECT emp_lname, emp_fname
      FROM employee
   ELSE
      SELECT emp_fname
      FROM employee
   END IF
END
```

The use of variable result sets in procedures is subject to some limitations, depending on the interface used by the client application.

- **Embedded SQL** You must DESCRIBE the procedure call after the cursor for the result set is opened, but before any rows are returned, in order to get the proper shape of result set.

  ☞ For more information about the DESCRIBE statement, see "DESCRIBE statement [ESQL]" [*ASA SQL Reference*, page 403].

- **ODBC** Variable result set procedures can be used by ODBC applications. The Adaptive Server Anywhere ODBC driver carries out the proper description of the variable result sets.

- **Open Client applications** Open Client applications can use variable result set procedures. Adaptive Server Anywhere carries out the proper description of the variable result sets.

Using cursors in procedures and triggers

Cursors retrieve rows one at a time from a query or stored procedure with multiple rows in its result set. A cursor is a handle or an identifier for the query or procedure, and for a current position within the result set.

Cursor management overview

Managing a cursor is similar to managing a file in a programming language. The following steps manage cursors:

1. Declare a cursor for a particular SELECT statement or procedure using the DECLARE statement.

2. Open the cursor using the OPEN statement.

3. Use the FETCH statement to retrieve results one row at a time from the cursor.

4. The warning `Row Not Found` signals the end of the result set.

5. Close the cursor using the CLOSE statement.

By default, cursors are automatically closed at the end of a transaction (on COMMIT or ROLLBACK statements). Cursors are opened using the WITH HOLD clause will stay open for subsequent transactions until someone explicitly closes them.

☞ For more information on positioning cursors, see “Cursor positioning” [*ASA Programming Guide*, page 21].

Using cursors on SELECT statements in procedures

The following procedure uses a cursor on a SELECT statement. Based on the same query used in the ListCustomerValue procedure described in “Returning result sets from procedures” on page 642, it illustrates several features of the stored procedure language.

```
CREATE PROCEDURE TopCustomerValue
   (   OUT TopCompany CHAR(36),
      OUT TopValue INT )
BEGIN
   -- 1. Declare the "error not found" exception
   DECLARE err_notfound
      EXCEPTION FOR SQLSTATE '02000';
 -- 2.   Declare variables to hold
   --      each company name and its value
   DECLARE ThisName CHAR(36);
   DECLARE ThisValue INT;
```

```
  -- 3.   Declare the cursor ThisCompany
    --      for the query
    DECLARE ThisCompany CURSOR FOR
    SELECT company_name,
          CAST( sum( sales_order_items.quantity *
                product.unit_price ) AS INTEGER )
          AS value
    FROM customer
       INNER JOIN sales_order
       INNER JOIN sales_order_items
       INNER JOIN product
    GROUP BY company_name;
  -- 4. Initialize the values of TopValue
    SET TopValue = 0;
    -- 5. Open the cursor
    OPEN ThisCompany;
  -- 6. Loop over the rows of the query
    CompanyLoop:
    LOOP
       FETCH NEXT ThisCompany
          INTO ThisName, ThisValue;
       IF SQLSTATE = err_notfound THEN
          LEAVE CompanyLoop;
       END IF;
       IF ThisValue > TopValue THEN
          SET TopCompany = ThisName;
          SET TopValue = ThisValue;
       END IF;
    END LOOP CompanyLoop;
  -- 7. Close the cursor
    CLOSE ThisCompany;
END
```

Notes

The TopCustomerValue procedure has the following notable features:

- The “error not found” exception is declared. This exception signals, later in the procedure, when a loop over the results of a query completes.

  ☞ For more information about exceptions, see “Errors and warnings in procedures and triggers” on page 649.

- Two local variables ThisName and ThisValue are declared to hold the results from each row of the query.

- The cursor ThisCompany is declared. The SELECT statement produces a list of company names and the total value of the orders placed by that company.

- The value of TopValue is set to an initial value of 0, for later use in the loop.

- The ThisCompany cursor opens.

- The LOOP statement loops over each row of the query, placing each company name in turn into the variables ThisName and ThisValue. If ThisValue is greater than the current top value, TopCompany and TopValue are reset to ThisName and ThisValue.
- The cursor closes at the end of the procedure.
- You can also write this procedure without a loop by adding an ORDER BY value DESC clause to the SELECT statement. Then, only the first row of the cursor needs to be fetched.

The LOOP construct in the TopCompanyValue procedure is a standard form, exiting after the last row processes. You can rewrite this procedure in a more compact form using a FOR loop. The FOR statement combines several aspects of the above procedure into a single statement.

```
CREATE PROCEDURE TopCustomerValue2(
      OUT TopCompany CHAR(36),
      OUT TopValue INT )
BEGIN
   -- Initialize the TopValue variable
   SET TopValue = 0;
   -- Do the For Loop
   FOR CompanyFor AS ThisCompany
      CURSOR FOR
      SELECT company_name AS ThisName ,
         CAST( sum( sales_order_items.quantity *
               product.unit_price ) AS INTEGER )
         AS ThisValue
      FROM customer
         INNER JOIN sales_order
         INNER JOIN sales_order_items
         INNER JOIN product
      GROUP BY ThisName
   DO
      IF ThisValue > TopValue THEN
         SET TopCompany = ThisName;
         SET TopValue = ThisValue;
         END IF;
   END FOR;
END
```

Errors and warnings in procedures and triggers

After an application program executes a SQL statement, it can examine a **status code**. This status code (or return code) indicates whether the statement executed successfully or failed and gives the reason for the failure. You can use the same mechanism to indicate the success or failure of a CALL statement to a procedure.

Error reporting uses either the SQLCODE or SQLSTATE status descriptions. For full descriptions of SQLCODE and SQLSTATE error and warning values and their meanings, see "Database Error Messages" [*ASA Error Messages,* page 1]. Whenever a SQL statement executes, a value appears in special procedure variables called SQLSTATE and SQLCODE. That value indicates whether or not there were any unusual conditions encountered while the statement was being performed. You can check the value of SQLSTATE or SQLCODE in an IF statement following a SQL statement, and take actions depending on whether the statement succeeded or failed.

For example, the SQLSTATE variable can be used to indicate if a row is successfully fetched. The TopCustomerValue procedure presented in section "Using cursors on SELECT statements in procedures" on page 646 used the SQLSTATE test to detect that all rows of a SELECT statement had been processed.

Default error handling in procedures and triggers

This section describes how Adaptive Server Anywhere handles errors that occur during a procedure execution, if you have no error handling built in to the procedure.

☞ For different behavior, you can use exception handlers, described in "Using exception handlers in procedures and triggers" on page 654. Warnings are handled in a slightly different manner from errors: for a description, see "Default handling of warnings in procedures and triggers" on page 653.

There are two ways of handling errors without using explicit error handling:

- **Default error handling** The procedure or trigger fails and returns an error code to the calling environment.

- **ON EXCEPTION RESUME** If the ON EXCEPTION RESUME clause appears in the CREATE PROCEDURE statement, the procedure carries on executing after an error, resuming at the statement following the one causing the error.

  ☞ The precise behavior for procedures that use ON EXCEPTION

RESUME is dictated by the ON_TSQL_ERROR option setting. For more information, see "ON_TSQL_ERROR option [compatibility]" [*ASA Database Administration Guide*, page 612].

Default error handling

Generally, if a SQL statement in a procedure or trigger fails, the procedure or trigger terminates execution and control returns to the application program with an appropriate setting for the SQLSTATE and SQLCODE values. This is true even if the error occurred in a procedure or trigger invoked directly or indirectly from the first one. In the case of a trigger, the operation causing the trigger is also undone and the error is returned to the application.

The following demonstration procedures show what happens when an application calls the procedure OuterProc, and OuterProc in turn calls the procedure InnerProc, which then encounters an error.

```
CREATE PROCEDURE OuterProc()
BEGIN
   MESSAGE 'Hello from OuterProc.' TO CLIENT;
   CALL InnerProc();
   MESSAGE 'SQLSTATE set to ',
      SQLSTATE,' in OuterProc.' TO CLIENT
END
CREATE PROCEDURE InnerProc()
   BEGIN
      DECLARE column_not_found
         EXCEPTION FOR SQLSTATE '52003';
      MESSAGE 'Hello from InnerProc.' TO CLIENT;
      SIGNAL column_not_found;
   MESSAGE 'SQLSTATE set to ',
      SQLSTATE, ' in InnerProc.' TO CLIENT;
END
```

Notes

- The DECLARE statement in InnerProc declares a symbolic name for one of the predefined SQLSTATE values associated with error conditions already known to the server.
- The MESSAGE statement sends a message to the Interactive SQL Messages pane.
- The SIGNAL statement generates an error condition from within the InnerProc procedure.

The following statement executes the OuterProc procedure:

```
CALL OuterProc();
```

The Interactive SQL Messages pane displays the following:

```
Hello from OuterProc.
```

```
Hello from InnerProc.
```

None of the statements following the SIGNAL statement in InnerProc execute: InnerProc immediately passes control back to the calling environment, which in this case is the procedure OuterProc. None of the statements following the CALL statement in OuterProc execute. The error condition returns to the calling environment to be handled there. For example, Interactive SQL handles the error by displaying a message window describing the error.

The TRACEBACK function provides a list of the statements that were executing when the error occurred. You can use the TRACEBACK function from Interactive SQL by typing the following statement:

```
SELECT TRACEBACK(*)
```

Error handling with ON EXCEPTION RESUME

If the ON EXCEPTION RESUME clause appears in the CREATE PROCEDURE statement, the procedure checks the following statement when an error occurs. If the statement handles the error, then the procedure continues executing, resuming at the statement after the one causing the error. It does not return control to the calling environment when an error occurred.

☞ The behavior for procedures that use ON EXCEPTION RESUME can be modified by the ON_TSQL_ERROR option setting. For more information, see "ON_TSQL_ERROR option [compatibility]" [*ASA Database Administration Guide*, page 612].

Error-handling statements include the following:

- IF
- SELECT @variable =
- CASE
- LOOP
- LEAVE
- CONTINUE
- CALL
- EXECUTE
- SIGNAL
- RESIGNAL

- DECLARE
- SET VARIABLE

The following example illustrates how this works.

Drop the procedures

Remember to drop both the InnerProc and OuterProc procedures by entering the following commands in the SQL Statements pane before continuing with the tutorial:

```
DROP PROCEDURE OuterProc;
DROP PROCEDURE InnerProc
```

The following demonstration procedures show what happens when an application calls the procedure OuterProc; and OuterProc in turn calls the procedure InnerProc, which then encounters an error. These demonstration procedures are based on those used earlier in this section:

```
CREATE PROCEDURE OuterProc()
ON EXCEPTION RESUME
BEGIN
   DECLARE res CHAR(5);
   MESSAGE 'Hello from OuterProc.' TO CLIENT;
   CALL InnerProc();
   SELECT @res=SQLSTATE;
   IF res='52003' THEN
      MESSAGE 'SQLSTATE set to ',
         res, ' in OuterProc.' TO CLIENT;
   END IF
END;

CREATE PROCEDURE InnerProc()
ON EXCEPTION RESUME
BEGIN
   DECLARE column_not_found
      EXCEPTION FOR SQLSTATE '52003';
   MESSAGE 'Hello from InnerProc.' TO CLIENT;
   SIGNAL column_not_found;
   MESSAGE 'SQLSTATE set to ',
   SQLSTATE, ' in InnerProc.' TO CLIENT;
END
```

The following statement executes the OuterProc procedure:

```
CALL OuterProc();
```

The Interactive SQL Messages pane then displays the following:

```
Hello from OuterProc.

Hello from InnerProc.

SQLSTATE set to 52003 in OuterProc.
```

The execution path is as follows:

1. OuterProc executes and calls InnerProc.

2. In InnerProc, the SIGNAL statement signals an error.

3. The MESSAGE statement is not an error-handling statement, so control is passed back to OuterProc and the message is not displayed.

4. In OuterProc, the statement following the error assigns the SQLSTATE value to the variable named **res**. This is an error-handling statement, and so execution continues and the OuterProc message appears.

Default handling of warnings in procedures and triggers

Errors and warnings are handled differently. While the default action for errors is to set a value for the SQLSTATE and SQLCODE variables, and return control to the calling environment in the event of an error, the default action for warnings is to set the SQLSTATE and SQLCODE values and continue execution of the procedure.

Drop the procedures

Remember to drop both the InnerProc and OuterProc procedures by entering the following commands in the SQL Statements pane before continuing with the tutorial:

```
DROP PROCEDURE OuterProc;
DROP PROCEDURE InnerProc
```

The following demonstration procedures illustrate default handling of warnings. These demonstration procedures are based on those used in "Default error handling in procedures and triggers" on page 649. In this case, the SIGNAL statement generates a `row not found` condition, which is a warning rather than an error.

```
CREATE PROCEDURE OuterProc()
BEGIN
   MESSAGE 'Hello from OuterProc.' TO CLIENT;
   CALL InnerProc();
   MESSAGE 'SQLSTATE set to ',
      SQLSTATE,' in OuterProc.' TO CLIENT;
END
CREATE PROCEDURE InnerProc()
BEGIN
   DECLARE row_not_found
      EXCEPTION FOR SQLSTATE '02000';
   MESSAGE 'Hello from InnerProc.' TO CLIENT;
   SIGNAL row_not_found;
   MESSAGE 'SQLSTATE set to ',
   SQLSTATE, ' in InnerProc.' TO CLIENT;
END
```

The following statement executes the OuterProc procedure:

```
CALL OuterProc();
```

The Interactive SQL Messages pane then displays the following:

```
Hello from OuterProc.  Hello from InnerProc.  SQLSTATE
set to 02000 in InnerProc.  SQLSTATE set to 00000 in
OuterProc.
```

The procedures both continued executing after the warning was generated, with SQLSTATE set by the warning (02000).

Execution of the second MESSAGE statement in InnerProc resets the warning. Successful execution of any SQL statement resets SQLSTATE to 00000 and SQLCODE to 0. If a procedure needs to save the error status, it must do an assignment of the value immediately after execution of the statement which caused the error warning.

Using exception handlers in procedures and triggers

It is often desirable to intercept certain types of errors and handle them within a procedure or trigger, rather than pass the error back to the calling environment. This is done through the use of an **exception handler**.

You define an exception handler with the EXCEPTION part of a compound statement (see "Using compound statements" on page 634). Whenever an error occurs in the compound statement, the exception handler executes. Unlike errors, warnings do not cause exception handling code to be executed. Exception handling code also executes if an error appears in a nested compound statement or in a procedure or trigger invoked anywhere within the compound statement.

Drop the procedures

Remember to drop both the InnerProc and OuterProc procedures by entering the following commands in the SQL Statements pane before continuing with the tutorial:

```
DROP PROCEDURE OuterProc;
DROP PROCEDURE InnerProc
```

The demonstration procedures used to illustrate exception handling are based on those used in "Default error handling in procedures and triggers" on page 649. In this case, additional code handles `the column not found` error in the InnerProc procedure.

```
CREATE PROCEDURE OuterProc()
BEGIN
   MESSAGE 'Hello from OuterProc.' TO CLIENT;
   CALL InnerProc();
   MESSAGE 'SQLSTATE set to ',
      SQLSTATE,' in OuterProc.' TO CLIENT
END
CREATE PROCEDURE InnerProc()
BEGIN
    DECLARE column_not_found
    EXCEPTION FOR SQLSTATE '52003';
    MESSAGE 'Hello from InnerProc.' TO CLIENT;
  SIGNAL column_not_found;
  MESSAGE 'Line following SIGNAL.' TO CLIENT;
    EXCEPTION
        WHEN column_not_found THEN
        MESSAGE 'Column not found handling.' TO CLIENT;
        WHEN OTHERS THEN
      RESIGNAL ;
END
```

The EXCEPTION statement declares the exception handler itself. The lines following the EXCEPTION statement do not execute unless an error occurs. Each WHEN clause specifies an exception name (declared with a DECLARE statement) and the statement or statements to be executed in the event of that exception. The WHEN OTHERS THEN clause specifies the statement(s) to be executed when the exception that occurred does not appear in the preceding WHEN clauses.

In this example, the statement RESIGNAL passes the exception on to a higher-level exception handler. RESIGNAL is the default action if WHEN OTHERS THEN is not specified in an exception handler.

The following statement executes the OuterProc procedure:

```
CALL OuterProc();
```

The Interactive SQL Messages pane then displays the following:

`Hello from OuterProc. Hello from InnerProc. Column not found handling. SQLSTATE set to 00000 in OuterProc.`

Notes

- The EXCEPTION statements execute, rather than the lines following the SIGNAL statement in InnerProc.
- As the error encountered was a `column not found` error, the MESSAGE statement included to handle the error executes, and SQLSTATE resets to zero (indicating no errors).
- After the exception handling code executes, control passes back to OuterProc, which proceeds as if no error was encountered.

- You should not use ON EXCEPTION RESUME together with explicit exception handling. The exception handling code is not executed if ON EXCEPTION RESUME is included.

- If the error handling code for the `column not found` exception is simply a RESIGNAL statement, control passes back to the OuterProc procedure with SQLSTATE still set at the value 52003. This is just as if there were no error handling code in InnerProc. Since there is no error handling code in OuterProc, the procedure fails.

Exception handling and atomic compound statements

When an exception is handled inside a compound statement, the compound statement completes without an active exception and the changes before the exception are not reversed. This is true even for atomic compound statements. If an error occurs within an atomic compound statement and is explicitly handled, some but not all of the statements in the atomic compound statement are executed.

Nested compound statements and exception handlers

The code following a statement that causes an error executes only if an ON EXCEPTION RESUME clause appears in a procedure definition.

You can use nested compound statements to give you more control over which statements execute following an error and which do not.

Drop the procedures

Remember to drop both the InnerProc and OuterProc procedures by entering the following commands in the SQL Statements pane before continuing with the tutorial:

```
DROP PROCEDURE OuterProc;
DROP PROCEDURE InnerProc
```

The following demonstration procedure illustrates how nested compound statements can be used to control flow. The procedure is based on that used as an example in "Default error handling in procedures and triggers" on page 649.

```
CREATE PROCEDURE InnerProc()
BEGIN
   BEGIN
      DECLARE column_not_found
         EXCEPTION FOR SQLSTATE VALUE '52003';
         MESSAGE 'Hello from InnerProc' TO CLIENT;
         SIGNAL column_not_found;
            MESSAGE 'Line following SIGNAL' TO CLIENT
            EXCEPTION
         WHEN column_not_found THEN
            MESSAGE 'Column not found handling' TO
            CLIENT;
         WHEN OTHERS THEN
            RESIGNAL;
   END;
      MESSAGE 'Outer compound statement' TO CLIENT;
END
```

The following statement executes the InnerProc procedure:

```
CALL InnerProc();
```

The Interactive SQL Messages pane then displays the following:

```
Hello from InnerProc Column not found handling Outer
compound statement
```

When the SIGNAL statement that causes the error is encountered, control passes to the exception handler for the compound statement, and the `Column not found handling` message prints. Control then passes back to the outer compound statement and the `Outer compound statement` message prints.

If an error other than `column not found` is encountered in the inner compound statement, the exception handler executes the RESIGNAL statement. The RESIGNAL statement passes control directly back to the calling environment, and the remainder of the outer compound statement is not executed.

Using the EXECUTE IMMEDIATE statement in procedures

The EXECUTE IMMEDIATE statement allows statements to be constructed inside procedures using a combination of literal strings (in quotes) and variables.

For example, the following procedure includes an EXECUTE IMMEDIATE statement that creates a table.

```
CREATE PROCEDURE CreateTableProc(
      IN tablename char(30) )
BEGIN
   EXECUTE IMMEDIATE 'CREATE TABLE '
   || tablename
   || '(column1 INT PRIMARY KEY)'
END
```

The EXECUTE IMMEDIATE statement can be used with queries that return result sets. For example:

```
CREATE PROCEDURE DynamicResult(
   IN Columns LONG VARCHAR,
   IN TableName CHAR(128),
   IN Restriction LONG VARCHAR DEFAULT NULL)
BEGIN
    DECLARE Command LONG VARCHAR;
    SET Command = 'SELECT ' || Columns || ' FROM ' || TableName;
    IF ISNULL( Restriction,'') <> '' THEN
         SET Command = Command || ' WHERE ' || Restriction;
    END IF;
    EXECUTE IMMEDIATE Command;
END
```

The following statement calls this procedure:

```
CALL DynamicResult(
   'table_id,table_name',
   'SYSTABLE',
   'table_id <= 10')
```

table_id	table_name
1	SYSTABLE
2	SYSCOLUMN
3	SYSINDEX
...	...

In ATOMIC compound statements, you cannot use an EXECUTE

IMMEDIATE statement that causes a COMMIT, as COMMITs are not allowed in that context.

☞ For more information about the EXECUTE IMMEDIATE statement, see “EXECUTE IMMEDIATE statement [SP]” [*ASA SQL Reference*, page 429].

Transactions and savepoints in procedures and triggers

SQL statements in a procedure or trigger are part of the current transaction (see "Using Transactions and Isolation Levels" on page 99). You can call several procedures within one transaction or have several transactions in one procedure.

COMMIT and ROLLBACK are not allowed within any atomic statement (see "Atomic compound statements" on page 634). Note that triggers are fired due to an INSERT, UPDATE, or DELETE which are atomic statements. COMMIT and ROLLBACK are not allowed in a trigger or in any procedures called by a trigger.

Savepoints (see "Savepoints within transactions" on page 102) can be used within a procedure or trigger, but a ROLLBACK TO SAVEPOINT statement can never refer to a savepoint before the atomic operation started. Also, all savepoints within an atomic operation are released when the atomic operation completes.

Tips for writing procedures

This section provides some pointers for developing procedures.

Check if you need to change the command delimiter

You do not need to change the command delimiter in Interactive SQL or Sybase Central when you write procedures. However, if you create and test procedures and triggers from some other browsing tool, you may need to change the command delimiter from the semicolon to another character.

Each statement within the procedure ends with a semicolon. For some browsing applications to parse the CREATE PROCEDURE statement itself, you need the command delimiter to be something other than a semicolon.

If you are using an application that requires changing the command delimiter, a good choice is to use two semicolons as the command delimiter (;;) or a question mark (?) if the system does not permit a multicharacter delimiter.

Remember to delimit statements within your procedure

You should terminate each statement within the procedure with a semicolon. Although you can leave off semicolons for the last statement in a statement list, it is good practice to use semicolons after each statement.

The CREATE PROCEDURE statement itself contains both the RESULT specification and the compound statement that forms its body. No semicolon is needed after the BEGIN or END keywords, or after the RESULT clause.

Use fully-qualified names for tables in procedures

If a procedure has references to tables in it, you should always preface the table name with the name of the owner (creator) of the table.

When a procedure refers to a table, it uses the group memberships of the procedure creator to locate tables with no explicit owner name specified. For example, if a procedure created by user_1 references Table_B and does not specify the owner of Table_B, then either Table_B must have been created by user_1 or user_1 must be a member of a group (directly or indirectly) that is the owner of Table_B. If neither condition is met, a `table not found` message results when the procedure is called.

You can minimize the inconvenience of long fully qualified names by using a correlation name to provide a convenient name to use for the table within a statement. Correlation names are described in “FROM clause” [*ASA SQL*

Reference, page 445].

Specifying dates and times in procedures

When dates and times are sent to the database from procedures, they are sent as strings. The date part of the string is interpreted according to the current setting of the DATE_ORDER database option. As different connections may set this option to different values, some strings may be converted incorrectly to dates, or the database may not be able to convert the string to a date.

You should use the unambiguous date format *yyyy-mm-dd* or *yyyy/mm/dd* when using data strings within procedures. The server interprets these strings unambiguously as dates, regardless of the DATE_ORDER database option setting.

☞ For more information on dates and times, see “Date and time data types” [*ASA SQL Reference*, page 65].

Verifying that procedure input arguments are passed correctly

One way to verify input arguments is to display the value of the parameter in the Interactive SQL Messages pane using the MESSAGE statement. For example, the following procedure simply displays the value of the input parameter *var* :

```
CREATE PROCEDURE message_test (IN var char(40))
BEGIN
   MESSAGE var TO CLIENT;
END
```

You can also use the stored procedure debugger.

Statements allowed in batches

All SQL statements are acceptable in batches (including data definition statements such as CREATE TABLE, ALTER TABLE, and so on), with the exception of the following:

- CONNECT or DISCONNECT statement.
- ALTER PROCEDURE or ALTER FUNCTION statement.
- CREATE TRIGGER statement.
- Interactive SQL commands such as INPUT or OUTPUT.
- You cannot use host variables in batches.

The CREATE PROCEDURE statement is allowed, but must be the final statement of the batch. Therefore a batch can contain only a single CREATE PROCEDURE statement.

Using SELECT statements in batches

You can include one or more SELECT statements in a batch.

The following is a valid batch:

```
IF EXISTS(   SELECT *
            FROM SYSTABLE
            WHERE table_name='employee' )
THEN
   SELECT   emp_lname AS LastName,
            emp_fname AS FirstName
   FROM employee;
   SELECT lname, fname
   FROM customer;
   SELECT last_name, first_name
   FROM contact;
END IF
```

The alias for the result set is necessary only in the first SELECT statement, as the server uses the first SELECT statement in the batch to describe the result set.

A RESUME statement is necessary following each query to retrieve the next result set.

Calling external libraries from procedures

You can call a function in an external library from a stored procedure or user-defined function. You can call functions in a DLL under Windows operating systems, in an NLM under NetWare, and in a shared object on UNIX. You cannot call external functions on Windows CE.

This section describes how to use the external library calls in procedures.

> **Caution**
> *External libraries called from procedures share the memory of the server. If you call an external library from a procedure and the external library contains memory-handling errors, you can crash the server or corrupt your database. Ensure that you thoroughly test your libraries before deploying them on production databases.*

The API described in this section replaces an older API. Libraries written to the older API, used in versions before version 7.0, are still supported, but in new development you should use the new API.

Adaptive Server Anywhere includes a set of system procedures that make use of this capability, for example to send MAPI e-mail messages.

☞ For more information on system procedures, see "System Procedures and Functions" [*ASA SQL Reference*, page 705].

Creating procedures and functions with external calls

This section presents some examples of procedures and functions with external calls.

> **DBA authority required**
> You must have DBA authority to create procedures or functions that reference external libraries. This requirement is more strict than the RESOURCE authority required for creating other procedures or functions.

Syntax

You can create a procedure that calls a function *function_name* in DLL *library.dll* as follows:

```
CREATE PROCEDURE dll_proc ( parameter-list )
EXTERNAL NAME 'function_name@library.dll'
```

If you call an external DLL from a procedure, the procedure cannot carry out any other tasks; it just forms a wrapper around the DLL.

An analogous CREATE FUNCTION statement is as follows:

```
CREATE FUNCTION dll_func ( parameter-list )
RETURNS data-type
EXTERNAL NAME 'function_name@library.dll'
```

In these statements, *function_name* is the exported name of a function in the dynamic link library, and *library.dll* is the name of the library. The arguments in *parameter-list* must correspond in type and order to the argument expected by the library function. The library function accesses the procedure argument using an API described in "External function prototypes" on page 666.

Any value returned by the external function is in turn returned by the procedure to the calling environment.

No other statements permitted

A procedure that references an external function can include no other statements: its sole purpose is to take arguments for a function, call the function, and return any value and returned arguments from the function to the calling environment. You can use IN, INOUT, or OUT parameters in the procedure call in the same way as for other procedures: the input values get passed to the external function, and any parameters modified by the function are returned to the calling environment in OUT or INOUT parameters.

System-dependent calls

You can specify operating-system dependent calls, so that a procedure calls one function when run on one operating system, and another function (presumably analogous) on another operating system. The syntax for such calls involves prefixing the function name with the operating system name. For example:

```
CREATE PROCEDURE dll_proc ( parameter-list )
EXTERNAL NAME
'Windows95:95_fn@95_lib.dll;WindowsNT:nt_fn@nt_lib.dll'
```

The operating system identifier must be one of **WindowsNT**, **Windows95**, **UNIX**, or **NetWare**.

If the list of functions does not contain an entry for the operating system on which the server is running, but the list does contain an entry without an operating system specified, the database server calls the function in that entry.

NetWare calls have a slightly different format than the other operating systems. All symbols are globally known under NetWare, so any symbol (such as a function name) exported must be unique to all NLMs on the system. Consequently, the NLM name is not necessary in the call as long as the NLM is already loaded.

It is recommended that you always use the libray name, regardless of whether the NLM is already loaded. If the NLM is *not* already loaded, you *must* provide a library name. The file extension *.nlm* is optional.

☞ For more information about the CREATE PROCEDURE statement syntax, see "CREATE PROCEDURE statement" [*ASA SQL Reference*, page 324].

☞ For more information about the CREATE FUNCTION statement syntax, see "CREATE FUNCTION statement" [*ASA SQL Reference*, page 315].

External function prototypes

This section describes the API for functions in external libraries.

The API is defined by a header file named *extfnapi.h,* in the *h* subdirectory of your SQL Anywhere Studio installation directory. This header file handles the platform-dependent features of external function prototypes. The API supercedes a previous API for functions in external libraries.

Declaring the API version

To notify the database server that the external library is not written using the old API, provide a function as follows:

uint32 extfn_use_new_api( )

The function returns an unsigned 32-bit integer. If the return value is non-zero, the database server assumes that you are not using the old API.

If the function is not exported by the DLL, the database server assumes that the old API is in use. When using the new API, the returned value must be the API version number defined in *extfnapi.h.*

On NetWare, to notify the database server that the external procedure is written using the new API, your NLM must export either a function called extfn_use_new_api, or a function called *name*_use_new_api, where *name* is the name of the NLM. For example, an NLM named *external.nlm* would export a function external_use_new_api.

Exporting *name*_use_new_api avoids export name conflicts when more than one external NLM is in use at one time. If the NLM exports a function called *name*_use_new_api then the CREATE PROCEDURE or CREATE FUNCTION statement must contain the NLM name.

Function prototypes

The name of the function must match that referenced in the CREATE PROCEDURE or CREATE FUNCTION statement. The function declaration must be as follows:

void *function-name***(an_extfn_api ****api*, **void ****argument-handle* **)**

The function must return void, and must take as arguments a structure used to pass the arguments, and a handle to the arguments provided by the SQL procedure.

The **an_extfn_api** structure has the following form:

```
typedef struct an_extfn_api {
    short (SQL_CALLBACK *get_value)(
                void *          arg_handle,
                a_SQL_uint32    arg_num,
                an_extfn_value *value
                );
    short (SQL_CALLBACK *get_piece)(
                void *          arg_handle,
                a_SQL_uint32    arg_num,
                an_extfn_value *value,
                a_SQL_uint32    offset
                );
    short (SQL_CALLBACK *set_value)(
                void *          arg_handle,
                a_SQL_uint32    arg_num,
                an_extfn_value *value
                short          append
                );
void (SQL_CALLBACK *set_cancel)(
                void *   arg_handle,
                void *   cancel_handle
                );
} an_extfn_api;
```

The **an_extfn_value** structure has the following form:

```
typedef struct an_extfn_value {
    void *            data;
    a_SQL_uint32       piece_len;
    union {
        a_SQL_uint32   total_len;
        a_SQL_uint32   remain_len;
    } len;
    a_SQL_data_type      type;
} an_extfn_value;
```

Notes

Calling **get_value** on an OUT parameter returns the data type of the argument, and returns data as NULL.

The **get_piece** function for any given argument can only be called immediately after the **get_value** function for the same argument,

To return NULL, set **data** to NULL in **an_extfn_value**.

The **append** field of **set_value** determines whether the supplied data replaces (false) or appends to (true) the existing data. You must call **set_value** with `append=FALSE` before calling it with `append=TRUE` for the same argument. The **append** field is ignored for fixed length data types.

The header file itself contains some additional notes.

The following table shows the conditions under which the functions defined in **an_extfn_api** return false:

Function	Returns 0 when the following is true; else returns 1
get_value()	- **arg_num** is invalid; for example, **arg_num** is greater than the number of arguments in **ext_fn** - It is called before the external function call has been properly initialized
get_piece()	- **arg_num** is invalid; for example, **arg_num** does not correspond to the last **get_value**. |- The offset is greater than the total length of the value for the arg_num argument. - It is called before the external function call has been properly initialized.
set_value()	- **arg_num** is invalid; for example, **arg_num** is greater than the number of arguments in **ext_fn**. - **arg_num** argument is input only. - The type of value supplied does not match that of the **arg_num** argument. - It is called before the external function call has been properly initialized.

☞ For more information about the values you can enter in the a_sql_data_type field, see "Embedded SQL data types" [*ASA Programming Guide*, page 149].

For more information about passing parameters to external functions, see "Passing parameters to external functions" on page 669.

Implementing cancel processing

An external function that expects to be canceled must inform the database server by calling the **set_cancel** API function. You must export a special function to enable external operations to be canceled. This function must have the following form:

void an_extfn_cancel(void * *cancel_handle* **)**

If the DLL does not export this function, the database server ignores any user interrupts for functions in the DLL. In this function, *cancel_handle* is a pointer provided by the function being cancelled to the database server upon each call to the external function by the *set_cancel* API function listed in the **an_extfn_api** structure, above.

Passing parameters to external functions

Data types

The following SQL data types can be passed to an external library:

SQL data type	C type
CHAR	Character data, with a specified length
VARCHAR	Character data, with a specified length
LONG VARCHAR	Character data, with a specified length
BINARY	Binary data, with a specified length
LONG BINARY	Character data, with a specified length
TINYINT	1-byte integer
[UNSIGNED] SMALLINT	[Unsigned] 2-byte integer
[UNSIGNED] INT	[Unsigned] 4-byte integer
[UNSIGNED] BIGINT	[Unsigned] 8-byte integer
VARBINARY	Binary data, with a specified length
REAL	Single precision floating point number
DOUBLE	Double precision floating point number

You cannot use date or time data types, and you cannot use exact numeric data types.

To provide values for INOUT or OUT parameters, use the **set_value** API function. To read IN and INOUT parameters, use the **get_value** API function.

Passing NULL

You can pass NULL as a valid value for all arguments. Functions in external libraries can supply NULL as a return type for any data type.

External function return types

The following table lists the supported return types, and how they map to the return type of the SQL function or procedure.

C data type	SQL data type
void	Used for external procedures.
char *	function returning CHAR().
long	function returning INTEGER
float	function returning FLOAT
double	function returning DOUBLE.

If a function in the external library returns NULL, and the SQL external function was declared to return CHAR(), then the return value of the SQL extended function is NULL.

Hiding the contents of procedures, functions, triggers and views

In some cases, you may want to distribute an application and a database without disclosing the logic contained within procedures, functions, triggers and views. As an added security measure, you can obscure the contents of these objects using the SET HIDDEN clause of the ALTER PROCEDURE, ALTER FUNCTION, ALTER TRIGGER, and ALTER VIEW statements.

The SET HIDDEN clause scrambles the contents of the associated objects and makes them unreadable, while still allowing the objects to be used. You can also unload and reload the objects into another database.

The modification is irreversible, and for databases created using version 8.0 or higher, deletes the original text of the object. Preserving the original source for the object outside the database is required.

Debugging using the stored procedure debugger will not show the procedure definition, nor will procedure profiling display the source.

Running one of the above statements on an object that is already hidden has no effect.

To hide the text for all objects of a particular type, you can use a loop similar to the following:

```
begin
    for hide_lp as hide_cr cursor for
        select proc_name,user_name
        from SYS.SYSPROCEDURE p, SYS.SYSUSERPERM u
        where p.creator = u.user_id
        and p.creator not in (0,1,3)
    do
        message 'altering ' || proc_name;
        execute immediate 'alter procedure "' ||
            user_name || '"."' || proc_name
            || '" set hidden'
    end for
end
```

☞ For more information, see the “ALTER FUNCTION statement” [*ASA SQL Reference*, page 233], the “ALTER PROCEDURE statement” [*ASA SQL Reference*, page 236], the “ALTER TRIGGER statement” [*ASA SQL Reference*, page 258], and the “ALTER VIEW statement” [*ASA SQL Reference*, page 259].

CHAPTER 20

Debugging Logic in the Database

About this chapter

This chapter describes how to use the Sybase debugger to assist in developing SQL stored procedures, triggers, and event handlers as well as Java stored procedures.

Contents

Topic:	page
Introduction to debugging in the database	674
Tutorial: Getting started with the debugger	676
Working with breakpoints	685
Working with variables	688
Working with connections	689

Introduction to debugging in the database

You can use the debugger during the development of the following objects:

- SQL stored procedures, triggers, event handlers, and user-defined functions.
- Java stored procedures in the database.

This chapter describes how to set up and use the debugger.

Separately-licensable component

Java in the database is a separately licensable component and must be ordered before you can install it. To order this component, see the card in your SQL Anywhere Studio package or see *http://www.sybase.com/detail?id=1015780.*

Debugger features

You can carry out many tasks with the debugger, including the following:

- **Debug procedures and triggers** You can debug SQL stored procedures and triggers.
- **Debug event handlers** Event handlers are an extension of SQL stored procedures. The material in this chapter about debugging stored procedures applies equally to debugging event handlers.
- **Browse stored procedures and classes** You can browse through the source code of SQL procedures. You can also browser the source code of installed Java classes as long as the code for those classes is available on your disk.
- **Debug Java classes** You can debug Java classes that are stored in the database.
- **Trace execution** Step line by line through the code of a stored procedure or Java class running in the database. You can also look up and down the stack of functions that have been called.
- **Set breakpoints** Run the code until you hit a breakpoint, and stop at that point in the code.
- **Set break conditions** Breakpoints include lines of code, but you can also specify conditions when the code is to break. For example, you can stop at a line the tenth time it is executed, or only if a variable has a particular value. You can also stop whenever a particular exception is thrown in a Java application.

- **Inspect and modify local variables** When execution is stopped at a breakpoint, you can inspect the values of local variables and alter their value.

- **Inspect and break on expressions** When execution is stopped at a breakpoint, you can inspect the value of a wide variety of expressions.

- **Inspect and modify row variables** Row variables are the OLD and NEW values of row-level triggers. You can inspect and modify these values.

- **Execute queries** When execution is stopped at a breakpoint in a SQL procedure, you can execute queries. This permits you to look at intermediate results held in temporary tables, as well as to check values in base tables and to view the query execution plan.

Requirements for using the debugger

You need the following in order to use the debugger:

- **Permissions** In order to use the debugger, you must either have DBA authority or be granted permissions in the SA_DEBUG group. This group is added to all databases when they are created.

- **Source code for Java classes** The source code for your application must be available to the debugger. For Java classes, the source code is held on a directory on your hard disk. For stored procedures, the source code is held in the database.

- **Compilation options** To debug Java classes, they must be compiled so that they contain debugging information. For example, if you are using the Sun Microsystems JDK compiler *javac.exe*, they must be compiled using the `-g` command-line option.

Tutorial: Getting started with the debugger

This tutorial describes how to start the debugger, how to connect to a database, how to debug a simple stored procedure, and how to debug a Java class.

Lesson 1: Connect to a database and start the debugger

This tutorial shows you how to start the debugger, connect to a database, and attach to a connection for debugging. It uses the Adaptive Server Anywhere sample database.

Start the debugger

❖ To start the debugger

1. Start Sybase Central:

   Choose Start ➤ Programs ➤ SQL Anywhere 9 ➤ Sybase Central.

2. Connect to the database.

   In this tutorial, you connect to the Adaptive Server Anywhere sample database.

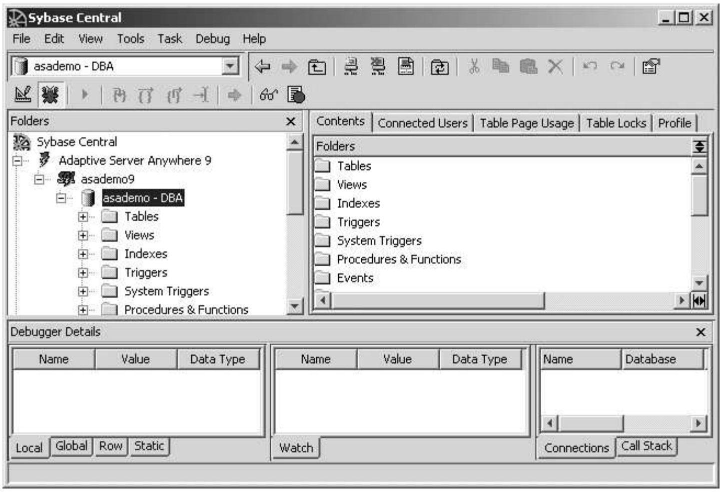
   (a) In the left pane, right click Adaptive Server Anywhere and choose Connect from the popup menu.

   The connection dialog appears.

3. Choose Debug mode.

   Sybase Central can be used in Design mode or Debug mode. When running in Debug mode, debugger breakpoints are active. Also, Sybase Central shows debugging menus and a Debugger Details pane.

   To choose Debug mode, click Task ➤ Debug. The Debugger Details pane appears at the bottom of Sybase Central and the Adaptive Server Anywhere toolbar displays a set of debugger tools.



Lesson 2: Debug a stored procedure

This tutorial describes a sample session for debugging a stored procedure. It is a continuation of "Lesson 1: Connect to a database and start the debugger" on page 676.

This tutorial illustrates how to use the debugger to identify errors in stored procedures. To set the stage, you introduce a deliberate error into the stored procedure debugger_tutorial, which is part of the sample database.

The debugger_tutorial procedure should return a result set that contains the name of the company that has placed the highest value of orders, and the value of their orders. It computes these values by looping over the result set of a query that lists companies and orders. (This result could be achieved without adding the logic into the procedure, by using a SELECT FIRST query. The procedure is used to create a convenient example.) The procedure has an intentional bug in it. In this tutorial you diagnose and fix the bug.

Run the debugger_tutorial procedure

The debugger_tutorial procedure should return a result set consisting of the top company and the value of products they have ordered. As a result of a bug, it does not return this result set. In this lesson, you run the stored procedure.

❖ To run the debugger_tutorial stored procedure

1. In the Sybase Central left pane, open the Procedures and Functions folder.

2. Execute the procedure.

   Right click the debugger_tutorial procedure and choose Execute from Interactive SQL from the popup menu.

   An Interactive SQL window opens and the following result set is displayed:

top_company	top_value
(NULL)	(NULL)

   This is clearly an incorrect result. The remainder of the tutorial diagnoses the error that produced this result.

3. Close the Interactive SQL window to clear your workspace.

Diagnose the bug

To diagnose the bug in the procedure, set breakpoints in the procedure and step through the code, watching the value of variables as the procedure is executed.

Here, you set a breakpoint at the first executable statement in the procedure.

❖ To diagnose the bug

1. Change Sybase Central to Debug mode.

   From the Task menu, choose Debug. Sybase Central displays a Debugger Details pane at the bottom of the main window.

2. Set a breakpoint at the first executable statement in the procedure.

   The statement contains the following text:

   ```
   open cur_this_cust;
   ```

   Click to the left of this line in the vertical gray bar to set a breakpoint. The breakpoint appears as a red circle.

3. Execute the procedure again.

   (a) In the left pane, right click the sp_customer_products procedure and choose Execute from Interactive SQL from the popup menu.

   (b) A message box appears, asking if you want to debug the connection from Interactive SQL. Click Yes.

Execution of the procedure stops at the breakpoint. A yellow arrow in the source code window indicates the current position, which is at the breakpoint.

4. Inspect variables.

   The Local variables window in the Debugger Details pane displays a list of variables in the procedure together with their current value and data type. The top_company, top_value, this_value, and this_company variables are all uninitialized and are therefore NULL.

5. Step through the code.

   Press F11 several times to step through the code, until you reach the following line:

   ```
   if this_value > top_value then
   ```

   As you step through the lines of the stored procedure, the value of the variables changes.

   When you are at the `if` statement, this_value is set to 3000 and top_value is still NULL.

6. Step into one more statement.

   Press F11 once more to see which branch the execution takes. The yellow arrow moves directly back to the label statement at the beginning of the loop, which contains the following text:

   ```
   customer loop: loop
   ```

   The `if` test did not return true. The test failed because a comparison of any value to NULL returns NULL. A value of NULL fails the test and the code inside the `if`...`end if` statement is not executed.

   At this point, you may realize that the problem is the fact that top_value is not initialized.

Confirm the diagnosis and fix the bug

You can test the hypothesis that the problem is the lack of initialization for top_value right in the debugger, without changing the procedure code.

❖ To test the hypothesis

1. Set a value for top_value.

   In the Local window, click the Value field of the top_value variable, and enter a value of 3000.

2. Step through the loop again.

   Press F11 to step through the instructions to the `if` statement and check the values of this_value and top_value. You may have to step through several loops until you get a value of top_value greater than 3000.

3. Disable the breakpoint and execute the procedure.

   (a) Click the breakpoint so that it turns gray (disabled).

   (b) Press F5 to complete execution of the procedure.

   The Interactive SQL window appears again. It shows the correct results.

top_company	top_value
Chadwicks	8076

   The hypothesis is confirmed. The problem is that the top_value is not initialized.

❖ To fix the bug

1. From the Task menu, choose Design to leave Debug mode.

2. Immediately after the line containing the following text

   ```
   open cur_this_cust;
   ```

   Create a new line that initializes the top_value variable:

   ```
   set top_value = 0;
   ```

3. Press CTRL+S to save the modified procedure.

4. Execute the procedure again, and confirm that Interactive SQL displays the correct results.

You have now completed the lesson. Close down Sybase Central and any open Interactive SQL windows.

Lesson 3: Debug a Java class

This lesson describes a sample session for debugging a Java class.

This lesson requires that you have the Java in the database component. Java in the database is a separately licensable component and must be ordered before you can install it. To order this component, see the card in your SQL Anywhere Studio package or see *http://www.sybase.com/detail?id=1015780*.

In this lesson, you call JDBCExamples.Query() from Interactive SQL, interrupt the execution in the debugger, and trace through the source code for this method.

The JDBCExamples.Query() method executes the following query against the sample database:

```
SELECT id, unit_price
FROM product
```

It then loops through all the rows of the result set, and returns the one with the highest unit price.

Compiling Java classes for debugging

You must compile classes with the javac `-g` option in order to debug them. The sample classes are already compiled for debugging.

Prepare the database

To work through this tutorial, you must enable the sample database to use Java, and install *JDBCExamples.class* into the sample database.

For instructions, see "Setting up the Java sample" [*ASA Programming Guide*, page 82].

☞ For information about the JDBCExamples class and its methods, see "JDBC Programming" [*ASA Programming Guide*, page 103].

Display Java source code in the debugger

The debugger looks in a set of locations for source code files (with *.java* extension). You need to add the *Samples\ASA\Java* subdirectory of your installation directory to the list of locations, so that the code for the class currently being executed in the database is available to the debugger.

❖ To display Java source code in the debugger

1. Start Sybase Central and connect to the sample database (ASA 9.0 Sample ODBC data source).

2. Choose the Sybase Central Debug task.

   Choose Task ➤ Debug.

3. Set the locations in which to look for Java source code.

   (a) From the Debug menu, choose Set Java Source Path. The Java Source Path window appears.

(b) Click Browse Folder. Navigate to the folder where your Java source code (*.java* files) is stored. To view the source code for the JDBCExamples class, browse to the *Samples\ASA\Java* subdirectory of your SQL Anywhere installation. If you installed SQL Anywhere in the default installation directory, you would navigate to the following directory:

```
C:\Program Files\Sybase\SQL Anywhere 9\Samples\ASA\Java
```

4. Display the source code for the JDBCExamples class:

(a) In the Sybase Central left pane, open the Java Objects folder.

(b) In the right pane, open the All Java Classes folder and locate the JAR file or class you wish to debug. Depending on your Sybase Central settings, you may wish to click the Creator column. This sorts the listing by creator so that classes owned by DBA appear before those owned by SYS.

(c) Double-click the JDBCExamples class.

(d) In the right pane, click the Source tab. The source code for the class is displayed.

Set a breakpoint

❖ Set a breakpoint in a Java class

1. In the source code window, page down until you see the beginning of the **Query** method. This method is near the end of the class, and starts with the following line:

```
public static int Query() {
```

2. Click the gray column on the the left of the line until it shows a red circle.

```
int max_price = 0;
```

Repeatedly clicking the indicator toggles its status.

Run the method

❖ Invoke the method from Interactive SQL

1. Start Interactive SQL. Connect to the sample database as used ID **DBA** and password **SQL**.

2. Enter the following command in Interactive SQL to invoke the method:

   ```
   SELECT JDBCExamples.Query()
   ```

   The query does not complete. Instead, execution is stopped in the debugger at the breakpoint. In Interactive SQL, the Interrupt the SQL Statement button is enabled. In the debugger Source window, the yellow arrow indicates the current line.

You can now step through source code and carry out debugging activities in the debugger.

Step through source code

This section illustrates some of the ways you can step through code in the debugger.

Following the previous section, the debugger should have stopped execution of **JDBCExamples.Query** at the first statement in the method:

Examples

Here are some example steps you can try:

1. **Step to the next line** Choose Debug ➤ Step Over, or press F10 to step to the next line in the current method. Try this two or three times.

2. **Run to the cursor** Select the following line using the mouse, and choose Debug ➤ Run To Cursor, or press Ctrl+F10 to run to that line and break:

   ```
   max_price = price;
   ```

   The yellow arrow moves to the line.

3. **Set a breakpoint and execute to it** Put the cursor at the following line (line 292) and press F9 to set a breakpoint on that line:

   ```
   return max_price;
   ```

   A red stop sign appears in the left-hand column to mark the breakpoint. Press F5 to execute to that breakpoint.

4. **Experiment** Try different methods of stepping through the code. End with F5 to complete the execution.

   The complete set of options for stepping through source code is available from the Debug menu.

When you have completed the execution, the Interactive SQL Results pane in the Results tab displays the value 24.

Inspect and modify variables

In this lesson you inspect the values of both local variables (declared in a method) and class static variables in the debugger.

Inspecting local variables You can inspect the values of local variables in a method as you step through the code, to better understand what is happening. You must have compiled the class with the javac `-g` option to do this.

❖ To inspect and modify the value of a variable

1. Set a breakpoint at the first line of the **JDBCExamples.Query** method. This line is as follows:

   ```
   int max_price = 0
   ```

2. In Interactive SQL, enter the following statement again to execute the method:

   ```
   SELECT JDBCExamples.Query()
   ```

   The query executes only as far as the breakpoint.

3. Press F10 to step to the next line. The **max_price** variable has now been declared and initialized to zero.

4. In the Local tab list, double-click the Value column entry for **max_price**, and type in 45 to change the value of **max_price** to 45.

   The value 45 is larger than any other price. Instead of returning 24, the query will now return 45 as the maximum price.

5. Press F10 repeatedly to step through the code. As you do so, the values of the variables appear in the Local tab list. Step through until the **stmt** and **result** variables have values.

6. Expand the **result** object by clicking the icon next to it, or setting the cursor on the line and pressing Enter. This displays the values of the fields in the object.

7. When you have experimented with inspecting and modifying variables, press F5 to complete the execution of the query and finish the tutorial.

Inspecting static variables In addition to local variables, you can display class-level variables (static variables) in the debugger Statics tab, and watch their values in the Watch tab. For more information, see the debugger online Help.

Working with breakpoints

This section describes how to use breakpoints to control when the debugger interrupts execution of your source code.

Setting breakpoints

A breakpoint instructs the debugger to interrupt execution at a specified line.

When you set a breakpoint, it applies to all connections. To make a breakpoint apply to a specific connection only, set a condition on the breakpoint.

❖ To set a breakpoint

1. With Sybase Central running the Debug task, display the code where you wish to set a breakpoint.

2. Click in the gray column on the left of the window, or click a line and press F9 to set the breakpoint. A red circle indicates each line with a breakpoint.

❖ To set a breakpoint (Debug menu)

1. Display the Breakpoints window.

   With Sybase Central running the Debug task, choose Debug ➤ Breakpoints.

2. In the Breakpoints window, click New Breakpoint. The New Breakpoint window is displayed.

3. Choose a Procedure name from the drop down list, and optionally enter condition and count values.

   The Condition is a SQL or Java expression that must evaluate to true for the breakpoint to interrupt execution. For example, you can set a breakpoint to apply to a connection made by a specified user, you can enter the following condition:

   ```
   CURRENT USER = 'user-name'
   ```

   The Count is a number of times the breakpoint is hit before it stops execution. A value of 0 means that the breakpoint always stops execution.

4. Click OK to set the breakpoint. The breakpoint is set on the first executable statement in the procedure.

Disabling and enabling breakpoints

You can change the status of a breakpoint from the Sybase Central right pane or from the Breakpoints window.

❖ To change the status of a breakpoint

1. Display the source code for the procedure that contains the breakpoint whose status you wish to change.
2. Click the breakpoint indicator on the left of the line you wish to edit. The status of the line switches from being an active breakpoint being a disabled breakpoint.

❖ To change the status of a breakpoint (Breakpoints window)

1. Open the Breakpoints window.
2. Edit the breakpoint.
3. Alternatively, you can delete a breakpoint by selecting the breakpoint and pressing Delete.

Editing breakpoint conditions

You can add conditions to breakpoints, to instruct the debugger to interrupt execution at that breakpoint only when a certain condition or count is satisfied.

❖ To add a condition or count to a breakpoint

1. Open the Breakpoints window.

   For a Java class, the condition must be a Java boolean expression. For procedures and triggers, it must be a SQL search condition.

Examples

In the procedure sp_contacts, you might use the breakpoint

```
contact.id = contact.old_id
```

on the line

```
DELETE FROM contact WHERE contact.id = contact.old_id
```

In the Java method JDBCExamples.Query(), you might use the breakpoint condition

```
(price < 10)
```

on the line

```
if (max.price == price) or (price == 10)
```

Working with variables

The debugger lets you view and edit the behavior of your variables while stepping through your code. The debugger provides a Debugger Details window to display the different kinds of variables used in stored procedures and Java classes. The Debugger Details windows appear at the bottom of the Sybase Central window when Sybase Central is running the Debug task.

Local variables

❖ To watch the values of your variables

1. Set a breakpoint in the procedure whose variables you wish to examine.

   ☞ For information on setting breakpoints, see "Setting breakpoints" on page 685.

2. Click the Local tab on the Variables pane of the Debugger Details.

3. Run the procedure. The variables, along with their values, appear in the Local tab.

Other variables

Global variables are defined by Adaptive Server Anywhere and hold information about the current connection, database, and other settings. They are displayed on the Globals tab of the Variables window.

☞ For a list of global variables, see "Global variables" [*ASA SQL Reference,* page 39].

Row variables are used to hold the values used in triggers. They are displayed on the Row tab of the Variables window.

☞ For more information on triggers, see "Introduction to triggers" on page 624.

Static variables are used in Java classes. They are displayed in the Statics tab.

The call stack

It is useful to examine the sequence of calls that has been made when you are debugging nested procedures or Java classes. You can view a listing of the procedures in the Call Stack tab.

❖ To display the call stack

1. Set a breakpoint in the procedure whose variables you wish to examine.

2. Run the code to the breakpoint.

   The names of the procedures appear in the Calls Stack tab. The current procedure is shown at the top of the list. The procedure that called it is immediately below, and so on.

Working with connections

The Connection window displays the connections to the database. At any time, multiple connections may be running. Some may be stopped at a breakpoint, and others may not.

The source code window displays the state for a single connection. To switch connections, double-click a connection in the Connections window.

A useful technique is to set a breakpoint so that it interrupts execution for a single user ID. You can do this by setting a breakpoint condition of the following form:

```
CURRENT USER = 'user-name'
```

The SQL special value CURRENT USER holds the user ID of the connection.

☞ For more information, see "Editing breakpoint conditions" on page 686, and "CURRENT USER special value" [*ASA SQL Reference,* page 33].

Index

Symbols

* (asterisk)
  SELECT statement 211
*=
  Transact-SQL outer joins 278
-gx option
  threads 588
=*
  Transact-SQL outer joins 278
<
  comparison operator 220
>
  comparison operator 220

A

abbreviations used in access plans 420
access plans
  abbreviations 420
  about 368
  caching of 375
  context sensitive help 430
  customizing 429
  explanation of statistics 422
  graphical plans 429
  Interactive SQL 434
  long text plans 428
  printing 429
  reading 420
  short text plans 427
  SQL functions 434
access plans caching 375
accessing remote data 557
  basic concepts 560
accessing remote data from PowerBuilder DataWindows 559
accessing tables
  index scan and sequential scan 379
actions
  CASCADE 95
  RESTRICT 95
  SET DEFAULT 95
  SET NULL 95
Adaptive Server Anywhere
  differences from other SQL dialects 474
Adaptive Server Anywhere SQL features 474
Adaptive Server architectures 443
Adaptive Server Enterprise
  compatibility 440
  compatibility in data import/export 556
  GROUP BY compatibility 258
  migrating to Adaptive Server Anywhere 548
add foreign key wizard
  using 44
adding and removing statistics 189
adding data
  about 355
  adding NULL 358
  BLOBs 360
  column data INSERT statement 358
  constraints 358
  defaults 358
  into all columns 357
  using INSERT 357
  with SELECT 359
adding new rows with SELECT 359
adding, changing, and deleting data
  about 355
administrator role
  Adaptive Server Enterprise 445
aggregate functions
  about 232
  Adaptive Server Enterprise compatibility 258
  ALL keyword 232
  data types 235
  DISTINCT keyword 235
  DISTINCT keyword and 232
  GROUP BY clause 237
  NULL 236
  order by and group by 246

outer references 233
scalar aggregates 233
vector aggregates 237
aggregates
item in access plans 426
aggregation functions
multiple levels 310
algorithms
for query execution 379
aliases
about 213
correlation names 218
ALL
keyword and aggregate functions 232
keyword and UNION clause 251
subquery tests 334, 335
ALL operator
about 334
notes 335
ALLOW_NULLS_BY_DEFAULT option
setting for Transact-SQL compatibility 451
ALTER TABLE statement
and concurrency 146
CHECK constraints 85
examples 39
foreign keys 45
primary keys 42
altering
columns 39
procedures 615
tables 38, 39
triggers 628
views 54
altering remote servers 565
always use a transaction log 161
analysis
Index Consultant 67
understanding 67
analyzing workloads
Index Consultant 63
AND
using logical operators 229
ANSI
non-ANSI joins 268
SQL/92 standard and inconsistencies 104
ANSI compliance *see* SQL standards
ANSI update constraints
in access plans 424
anti-insert
locks 132, 139
anti-semijoin
query execution algorithms 384
ANY operator
about 333
problems 333
subquery tests 333
apostrophes
character strings 225
architecture
Adaptive Server 443
arithmetic
expressions and operator precedence 216
operations 232
AS keyword
aliases 213
asademo.db file
schema 262
asajdbc server class 591
asaodbc server class 595
ascending order
ORDER BY clause 244
ASCII
format for importing and exporting 524
asejdbc server class 592
aseodbc server class 595
assigning
data types to columns 89
domains to columns 89
assumptions affecting optimization 372
asterisk (*)
SELECT statement 211
AT clause
CREATE EXISTING TABLE statement 569
atomic compound statements 634
atomic transactions 100
attributes
choosing 14
definition of 5

SQLCA.lock 107
AUTO mode
using 496
autocommit
performance 165
transactions 101
AUTOINCREMENT
default 81
negative numbers 82
signed data types 82
UltraLite applications 82
when to use 146
autoincrement
IDENTITY column 456
automatic joins
and foreign keys 474
automatic performance tuning 372
automatic translation of stored procedures 466
AUTOMATIC_TIMESTAMP option
setting for Transact-SQL compatibility 451
automation
generating unique keys 145
AvgDiskReads
estimate in access plans 423
AvgDiskReadTime
estimate in access plans 423
AvgDiskWrites
estimate in access plans 423
AvgRowCount
estimate in access plans 423
AvgRunTime
estimate in access plans 423

B

B-tree indexes
about 401
basic concepts to access remote data 560
batch operations
Interactive SQL 554
batches
about 631
control statements 631
data definition statements 631
SQL statements allowed 663
statements allowed 663
Transact-SQL overview 464
using SELECT statements 663
writing 464
BEGIN TRANSACTION statement
remote data access 581
benefits
Index Consultant recommendations 69
benefits of procedures and triggers 612
BETWEEN keyword
range queries 221
bi-directional replication 148
binary large objects
about 23
inserting 360
bitmaps 23
scanning 393
BLOBs
about 23
inserting 360
block nested loops joins
query execution algorithms 382
blocking 110, 122
deadlock 111
transactions 110
troubleshooting 111
BLOCKING option
using 110
Bloom filters
query execution algorithms 391
break conditions
setting 685
breakpoints
about 685
conditions 686
counts 686
debugging 683
disabling 686
enabling 686
setting 685
status 686
browsing
table data 41
views 56
browsing databases
and isolation levels 113
bulk loading
performance 522

bulk operations
  performance 166

C

cache
  about 176
  access plans 375
  dynamic sizing 176
  encrypted databases require larger cache 161
  initial, min and max size 177
  Java applications on UNIX 179
  monitoring size 179
  performance 161
  read-hit ratio 433
  UNIX 178
  Windows 95/98 178
  Windows NT 178
cache size
  and page size 393
  initial, min and max size 177
  Java applications on UNIX 179
  monitoring 179
  UNIX 178
  Windows 95/98 178
  Windows NT 178
CacheHits
  statistic in access plans 422
CacheRead
  statistic in access plans 422
CacheReadIndLeaf
  statistic in access plans 422
CacheReadTable
  statistic in access plans 422
caching
  access plans 375
  subqueries 418
  user-defined functions 418
call stack
  debugger 688
CALL statement
  about 611
  examples 616
  parameters 637
  syntax 633
calling external libraries from procedures 664
calling procedures 616
calling user-defined functions 621
cancel
  external functions 668
canceling request
  remote data access 588
candidate indexes
  about 64
  Index Consultant 64
capturing workloads
  Index Consultant 63, 66
cardinality
  item in access plans 425
  relationships and 7
Cartesian products 272
CASCADE action
  about 95
case sensitivity
  creating ASE-compatible databases 450
  data 453
  databases 452
  domains 452, 453
  identifiers 209, 453
  passwords 453
  remote access 587
  sort order 245
  Transact-SQL compatibility 452
  user IDs 453
CASE statement
  syntax 633
catalog
  Adaptive Server Enterprise compatibility 445
cdata directive
  using 509
changing data
  about 355
  permissions 356
  UPDATE statement 362
  updating data using more than one table 363
changing isolation levels within transactions 109
changing many-to-many relationships into entities 9
changing the isolation level 106

character data
  searching for 225
character strings
  about 225
  quotes 225
  select list using 215
character strings and quotation marks 225
character strings in query results 214
CHECK conditions
  Transact-SQL 444
CHECK constraints
  columns 85
  deleting 87
  domains 86
  modifying 87
  tables 86
check constraints
  choosing 24
  using in domains 90
check if you need to change the command delimiter
  procedures 661
check your file, table, and index fragmentation 171
checking referential integrity at commit 138
choosing column names 23
choosing constraints 24
choosing data types for columns 23
choosing isolation levels 112
classes
  remote servers 589
clauses
  about 208
  COMPUTE 460
  FOR BROWSE 460
  FOR READ ONLY 460
  FOR UPDATE 460
  GROUP BY ALL 460
  INTO 641
  ON EXCEPTION RESUME 470, 651, 655
clearing procedure profiling
  SQL 198
  Sybase Central 198
client side loading 522
CLOSE statement
  procedures 646
clustered indexes
  Index Consultant recommendations 68, 70
  using 59
colons separate join strategies 427
column attributes
  AUTOINCREMENT 146
  generating default values 146
  NEWID 145
column CHECK constraints from domains 86
column statistics
  about 369
  updating 371
columns
  allowing NULL values 23
  altering 39
  assigning data types and domains 89
  constraints 24
  data types 23
  defaults 79
  GROUP BY clause 237
  IDENTITY 456
  naming 23
  properties 23
  select list 212
  select statements 212
  timestamp 454
command delimiter
  setting 661
command files
  building 553
  overview 553
  SQL Statements pane 553
commands
  loading in Interactive SQL 554
  saving in Interactive SQL 554
commas
  in star joins 282
  table expression lists 272
  when joining table expressions 295
COMMIT statement
  compound statements 634
  procedures and triggers 660
  verify referential integrity 138
COMMMIT statement

remote data access 581
common estimates used in the plan 423
common statistics used in the plan 422
common table expressions
about 305
common applications 310
datatypes in recursive 320
exploring hierarchical data structures 315
least distance problems 322
multiple aggregation levels 310
parts explosion problems 317
restrictions on recursive 315
storing constant sets 312
where permitted 308
comparison operators
NULL values 227
subqueries 346
symbols 220
comparison test
subqueries 332
comparisons
NULL values 227
trailing blanks 220
compatibility
Adaptive Server Enterprise 440
case sensitivity 452
GROUP BY clause 258
import/export with Adaptive Server Enterprise 556
non-ANSI joins 268
outputting nulls 527
servers and databases 443
setting options for Transact-SQL compatibility 451
compatibility of joins 462
complete passthrough of the statement
remote data access 584
completing transactions 101
compliance with SQL standards *see* SQL standards
composite indexes
about 397
effect of column order 398
hash values 402
compound statements
atomic 634
declarations 634
using 634
compressed B-tree indexes
about 402
compression
performance 166
COMPUTE clause
CREATE TABLE 46
unsupported 460
computed columns
creating 46
indexes 61
INSERT statements 47
limitations 48
making queries using functions sargable 405
recalculation 48
triggers 47
UPDATE statements 47
computing values in the SELECT list 215
concatenating strings
NULL 228
conceptual data modeling
about 3
conceptual database models
definition of 5
concurrency 102
about 104, 145
and data definition statements 146
benefits of 102
consistency 104
how locking works 131
improving 114
improving and indexes 143
improving using indexes 115
inconsistencies 104
ISO SQL/92 standard 104
performance 102
primary keys 145
replication 148
types of locks 132
concurrent transactions
blocking 110, 122
conditions
connecting with logical operators 229
configuration notes for JDBC classes 591
configuring

the Sybase Central Performance Monitor 190
configuring databases for Transact-SQL compatibility 449
configuring the Sybase Central Performance Monitor 190
conflicts
  cyclical blocking 111
  locking 110
  transaction blocking 110, 122
conflicts between locks 134
conformance with SQL standards *see* SQL standards
connecting
  starting a database without connecting 35
connecting conditions with logical operators 229
CONNECTION_PROPERTY function
  about 187
connections
  debugger 689
  debugging 676
  remote 581
connectivity problems
  remote data access 587
consistency
  about 100
  assuring using locks 131
  correctness and scheduling 112
  dirty reads 104, 134
  dirty reads tutorial 116
  during transactions 104
  effects of unserializable schedules 113
  example of non-repeatable read 120
  ISO SQL/92 standard 104
  isolation levels 104
  phantom rows 104, 123, 135, 142
  practical locking implications 126
  repeatable reads 104, 119, 135
  two-phase locking 140
  versus isolation levels 105, 123, 126, 142
  versus typical transactions 113
consolidated databases
  setting 33
constant expression defaults 83
constraints 87
  CHECK constraints 86
  columns and tables 24
  introduction 77
  unique constraints 87
contiguous storage of rows 392
control statements
  list 633
conventions
  documentation xii
conversion errors during import 527
conversion of outer joins to inner joins 414
converting subqueries in the WHERE clause to joins 345
copying
  data with INSERT 359
  database objects in Sybase Central 73
  procedures 616
  tables 48
  views 52
copying database objects in Sybase Central 73
copying databases
  replicating data and concurrency 148
correlated subqueries
  about 339, 345
  outer references 340
correlation names
  about 293
  in self-joins 281
  in star joins 282
  table names 218
cost model
  about 369
  Index Consultant use of 67
cost-based optimization 368
costs
  Index Consultant recommendations 69
COUNT function
  about 235
  NULL 236
CREATE DATABASE statement
  Adaptive Server Enterprise 443
  using 29, 30
create database wizard
  creating Transact-SQL compatible

databases 449
using 28
CREATE DEFAULT statement
unsupported 444
CREATE DOMAIN statement
Transact-SQL compatibility 444
using 89
CREATE EXISTING TABLE statement
using 571
CREATE FUNCTION statement
about 620
CREATE INDEX statement
and concurrency 146
CREATE PROCEDURE statement
examples 613
parameters 636
CREATE RULE statement
unsupported 444
CREATE SERVER statement
JDBC and Adaptive Server Enterprise 592
ODBC and Adaptive Server Enterprise 596
remote servers 592
CREATE TABLE statement
about 37
and concurrency 146
foreign keys 45
primary keys 42
proxy tables 571
Transact-SQL 458
CREATE TRIGGER statement
about 625
CREATE VIEW statement
WITH CHECK OPTION clause 52
creating
column defaults 79
data types 89, 90
database for Windows CE 28
database from SQL 29, 30
database from the command line 29
domains 89, 90
indexes 60
procedures 613
procedures and functions with external calls 664
remote procedures 613
tables 37
triggers 625
user-defined functions 620
views 50
creating a database 27
creating a proxy table with the CREATE TABLE statement 571
creating a Transact-SQL-compatible database 449
creating compatible tables 458
creating databases
Sybase Central 28
creating external logins 567
creating proxy tables in SQL 571
creating proxy tables in Sybase Central 570
creating remote procedures 578
creating remote servers 562
cross joins 272
cross products 272
current date and time defaults 80
cursor instability 105
cursor management
overview 646
cursors
and LOOP statement 646
in procedures 646
instability 105
on SELECT statements 646
procedures and triggers 646
stability 105
updating in joins 268
customizing graphical plans 429
cyclical blocking conflict 111

D

data
adding, changing, and deleting 355
case sensitivity 453
consistency 104
exporting 532
exporting as XML 482
formats for importing and exporting 524
importing 524, 529
importing and exporting 522
integrity and correctness 112

invalid 76
permissions required to modify data 356
searching 58
viewing 41
data consistency
assuring using locks 131
correctness 112
dirty reads 104, 134
dirty reads tutorial 116
ISO SQL/92 standard 104
phantom rows 104, 123, 135, 142
practical locking implications 126
repeatable reads 104, 119, 135
two-phase locking 140
data definition
concurrency 145
data definition language
about 26
data definition statements
and concurrency 146
data entry
and isolation levels 113
data formats
for importing and exporting 524
data integrity
about 76
checking 95
column constraints 24
column defaults 79
constraints 78, 85
effects of unserializable schedules on 113
enforcing 92
information in the system tables 97
losing 94
tools 77
data migration wizard
about 548
using 548
data model normalization 15
data modeling
about 3
data modification statements
about 356
data organization
physical 392
data sources
external servers 594
data types
aggregate functions 235
assigning columns 89
choosing 23
creating 89, 90
deleting 91
EXCEPT operation 251
INTERSECT operation 251
remote procedures 579
SQL and C 669
timestamp 454
UNION operation 251
user-defined 89
database administrator
roles 446
database design concepts 5
database files
fragmentation 171, 193
growing 541
growing after deletes 541
performance 163
database objects
copying in Sybase Central 73
editing properties 32
database options
Index Consultant 70
setting for Transact-SQL compatibility 451
database pages
Index Consultant recommendations 68
database procedures
viewing profiling data 197
database statistics
about 191
database threads
blocked 111
databases
case sensitivity 450, 452
creating 27
creating for Windows CE 28
creating from SQL 29, 30
creating from Sybase Central 28
creating from the command line 29
deleting 30
design concepts 5

designing 3
disconnecting from databases 31
displaying system objects 34
displaying system tables 48
erasing 30
erasing from the command line 30
exporting 536
file compatibility 27
importing 529
importing XML 483
initializing 27
initializing from SQL 29, 30
initializing from Sybase Central 28
installing jConnect metadata support 35
migrating to Adaptive Server Anywhere 548
normalizing 15
rebuilding 543
reloading 543
setting a consolidated database 33
setting options 32
starting without connecting 35
storing XML 481
Transact-SQL compatibility 449
transaction log 27
unloading 536
unloading and reloading 539, 543–545
upgrading database file format 541
verifying design 21
viewing and editing properties 32
working with 27
working with objects 25
DataSet
using to export relational data as XML 482
using to import XML 488
datatypes
in recursive subqueries 320
DataWindows
remote data access 559
dates
entry rules 225
procedures and triggers 662
searching for 225
DB2 remote data access 597
db2odbc server class 597
DB_PROPERTY function
about 187
dBASE format for importing and exporting 524
dberase utility 30
using 30
dbinit utility
using 29
dbisql utility
rebuilding databases 540
dbo user ID
Adaptive Server Enterprise 445
dbspaces
managing 444
dbunload utility 540
exporting data 532
DDL
about 26
deadlocks
about 110
reasons for 111
transaction blocking 111
debugger
about 674
connecting 676
debugging Java classes 680
debugging stored procedures 677
displaying source code 681
examining variables 688
getting started 676
requirements 675
starting 676
tutorial 676
working with breakpoints 685
working with connections 689
debugger features 674
debugger utility
features 674
debugger_tutorial procedure
about 677
debugging
about 673
breakpoints 683
compiling classes 681
features 674
introduction 674
Java 680

local variables 684
permissions 675
requirements 675
stored procedures 677
tutorial 677, 680
debugging logic in the database 673
decision support
and isolation levels 113
declarations in compound statements 634
DECLARE statement
compound statements 634
procedures 646, 650
declaring parameters for procedures 636
default error handling in procedures and triggers 649
default handling of warnings in procedures and triggers 653
defaults
AUTOINCREMENT 81
column 79
constant expressions 83
creating 79
creating in Sybase Central 80
current date and time 80
INSERT statement and 358
introduction 77
NEWID 82
NULL 83
string and number 83
Transact-SQL 444
user ID 81
using in domains 90
with transactions and locks 146
defragmenting
about 193
all tables in a database 194
hard disk 193
individual tables in a database 195
delaying referential integrity checks 138
DELETE statement
locking during 139
using 365
deleting
column defaults 80
data types 91
database files 30
domains 91
indexes 62
procedures 617
tables 41
triggers 629
user-defined data types 91
views 55
deleting all rows from a table 366
deleting and deleting CHECK constraints 87
deleting data
about 355
DELETE statement 365
TRUNCATE TABLE statement 366
deleting remote servers 564
delimit statements within your procedure 661
depth
item in access plans 425
derived tables
in joins 287
in key joins 301
in natural joins 290
in outer joins 278
using in the FROM clause 218
descending order
ORDER BY clause 244
design details pane
about 34
design process 11
designing databases
about 3
concepts 5
procedure 11
designing the database table properties 23
designing your database 3
deterministic functions
defined 418
devices
managing 444
difference between FALSE and UNKNOWN 228
differences from other SQL dialects 473
directed graphs 322
direction
item in access plans 425
dirty reads 104, 134
tutorial 116

versus isolation levels 105
disabling breakpoints 686
enabling 686
disabling procedure profiling
SQL 198
Sybase Central 198
DISCONNECT statement
using 31
disconnecting
from databases 31
other users from a database 31
discovery of exploitable conditions 415
disk access cost model
about 369
disk allocation for inserted rows 392
disk space
reclaiming 541
DISK statements
unsupported 444
DiskRead
statistic in access plans 422
DiskReadIndInt
statistic in access plans 422
DiskReadIndLeaf
statistic in access plans 422
DiskReadTable
statistic in access plans 422
DiskWrite
statistic in access plans 422
displaying system objects in a database 34
displaying system tables 48
DISTINCT clause
SELECT statement 217
unnecessary distinct elimination 408
distinct elimination
about 408
DISTINCT keyword
aggregate functions 232, 235
distinct list
item in access plans 426
DLL
calling from procedures 664
external procedure calls 665
DML
about 356
documentation
conventions xii
SQL Anywhere Studio x
documents
inserting 360
domain creation wizard
using 89
domains
assigning columns 89
case sensitivity 453
CHECK constraints 86
creating 89, 90
deleting 91
examples of uses 89
using 89
double quotes
character strings 225
DROP CONNECTION statement
using 31
DROP DATABASE statement
Adaptive Server Enterprise 443
using 30
DROP statement
and concurrency 146
DROP TABLE statement
example 41
DROP TRIGGER statement
about 629
DROP VIEW statement
example 55
dropping
domains 91
indexes 62
procedures 617
tables 41
triggers 629
views 55
dropping connections
remote data access 588
dropping external logins 568
dropping remote procedures 579
DUMP DATABASE statement
unsupported 443
DUMP TRANSACTION statement
unsupported 443
duplicate correlation names in joins (star joins) 282
duplicate elimination
query execution algorithms 386

duplicate results
  eliminating 217
duplicate rows
  removing with UNION 251
dynamic cache sizing
  about 176
  about UNIX 178
  about Windows 178

E

early release of locks 113, 141
  an exception 142
editing
  properties of database objects 32
  table data 41
editing breakpoint conditions 686
effects of
  transaction scheduling 113
  unserializable transaction scheduling 113
efficiency
  improving and locks 115
  improving using indexes 143
element directive
  using 506
eliminating duplicate query results 217
elimination of unnecessary case translation 416
enabling breakpoints 686
enabling procedure profiling
  SQL 197
  Sybase Central 197
encryption
  cache size 161
  hiding objects 670
ending transactions 101
enforcing column uniqueness 400
enforcing entity and referential integrity 92
enforcing referential integrity 93
ensuring compatible object names 453
ensuring data integrity 75
entities
  about 5
  attributes 5
  choosing 11
  definition of 5
  forcing integrity 92
entity integrity 474
  breached by client application 92
  introduction 78
entity-relationship diagrams
  about 5
  reading 8
equals operator
  comparison operator 220
equijoins
  about 270
erase database wizard
  using 30
erase utility
  using 30
erasing databases 30
error handling
  ON EXCEPTION RESUME 651
  procedures and triggers 649
error handling in Transact-SQL procedures 469
errors
  conversion 527
  procedures and triggers 649
  Transact-SQL 469, 470
errors and warnings in procedures and triggers 649
EstCpuTime
  estimate in access plans 423
EstDiskReads
  estimate in access plans 423
EstDiskReadTime
  estimate in access plans 423
EstDiskWrites
  estimate in access plans 423
estimated leaf pages
  item in access plans 425
estimated pages
  item in access plans 424
estimated row size
  item in access plans 424
estimated rows
  item in access plans 424
EstRowCount
  estimate in access plans 423
EstRunTime
  estimate in access plans 423

events
viewing individual profiling information 201
viewing summary profiling data 200
examining variables
debugger 688
examples
dirty reads 116
implications of locking 126
non-repeatable read 120
non-repeatable reads 119
phantom locks 126
phantom rows 123
Excel and remote access 602
EXCEPT operation
combining queries 251
NULL 254
rules 252
using 252
exception handlers
nested compound statements 656
procedures and triggers 654
exceptions
declaring 650
exclusive locks 132
exclusive versus shared locks 133
EXECUTE IMMEDIATE statement
procedures 658
executing triggers 627
existence test
about 338
negation of 339
EXISTS operator 338
EXISTS predicates
rewriting subqueries as 374
explicit join conditions 264
explicit join conditions (the ON phrase) 269
EXPLICIT mode
syntax 500
using 499
using the cdata directive 509
using the element directive 506
using the hide directive 507
using the xml directive 508
writing queries 502
explode
query execution algorithms 391
export tools 532
exporting
Adaptive Server Enterprise compatibility 556
file formats 524
introduction 524
NULL values 527
query results 534
schema 542
tables 537
exporting data
about 522
schema 542
tools 532
exporting databases
using 536
exporting relational data as XML 482
exporting relational data as XML from Interactive SQL 482
exporting relational data as XML using the DataSet object 482
exporting tables
schema 542
expression SQL
item in access plans 426
expressions
NULL values 228
external calls
creating procedures and functions 664
external functions
canceling 668
passing parameters 669
prototypes 666
return types 670
external loading 522
external logins
about 567
creating 567
dropping 568
external servers
ODBC 594
extract database wizard
about 547
extracting
databases for SQL Remote 547

F

FALSE conditions
and NULL 228
features not supported for remote data 587
Federal Information Processing Standard Publication compliance *see* SQL standards
feedback
documentation xvi
providing xvi
FETCH statement
procedures 646
fetchtst 195
file formats
for importing and exporting 524
rebuilding databases 541
file fragmentation
about 193
file types
for importing and exporting 524
files
fragmentation 171
performance 163
filter and pre-filter 390
filters
query execution algorithms 390
finishing transactions 101
FIPS compliance *see* SQL standards
FIRST clause
about 245
FIXED format for importing and exporting 524
FOR BROWSE clause
unsupported 460
FOR clause
obtaining query results as XML 491
using FOR XML AUTO 496
using FOR XML EXPLICIT 499
using FOR XML RAW 494
FOR READ ONLY clause
ignored 460
FOR statement
syntax 633
FOR UPDATE clause
unsupported 460
FOR XML AUTO
using 496
FOR XML clause
BINARY data type 491
EXPLICIT mode syntax 500
IMAGE data type 491
LONG BINARY data type 491
obtaining query results as XML 491
restrictions 491
usage 491
using AUTO mode 496
using EXPLICIT mode 499
using RAW mode 494
VARBINARY data type 491
FOR XML EXPLICIT
syntax 500
using 499
using the cdata directive 509
using the element directive 506
using the hide directive 507
using the xml directive 508
FOR XML RAW
using 494
foreign keys
and integrity 474
creating 44, 45
deleting 44
displaying in Sybase Central 44
in key joins 292
managing 43
mandatory/optional 93
modifying 45
performance 182
referential integrity 94
role name 293
formats
for importing and exporting 524
FORWARD TO statement 577
FoxPro
format for importing and exporting 524
remote data access 604
fragmentation
about 193
file 193
indexes 195
of files, tables, and indexes 171
tables 193
FROM clause
derived tables in 218

explanation of joins 264
introduction 218
stored procedures in 218
full compares
about 396
statistic in access plans 422
full outer joins
about 274
FullCompare
statistic in access plans 422
functions
caching 418
deterministic 418
external 664
idempotent 418
TRACEBACK 650
tsequal 455
user-defined 620
viewing individual profiling information 201
viewing summary profiling data 200

G

general guidelines for writing portable SQL 458
general problems with queries
remote data access 588
generated join conditions 264
generated joins and the ON phrase 269
generating
physical data model 19
generating unique keys 145
global autoincrement
compared to GUIDs and UUIDs 82
global temporary tables 72
global variables
debugger 688
go
batch statement delimiter 631
GRANT statement
and concurrency 146
Transact-SQL 447
graph type
configuring the Performance Monitor 190
graphical plan
description 430
graphical plan with statistics
about 429
Interactive SQL 434
SQL functions 434
viewing 431
graphical plans
about 429
context sensitive help 430
customizing 429
Interactive SQL 434
predicate 433
printing 429
SQL functions 434
graphing
using the Performance Monitor 188
greater than
comparison operator 220
range specification 221
greater than or equal to
comparison operator 220
GROUP BY ALL clause
unsupported 460
GROUP BY clause
about 237
Adaptive Server Enterprise compatibility 258
aggregate functions 237
execution 238
order by and 246
SQL standard compliance 258
SQL/92 standard 258
WHERE clause 240
group by list
item in access plans 426
group by with multiple columns 240
group reads
tables 393
grouping algorithms
query execution algorithms 387
GROUPING function
NULL 249
ROLLUP operation 249
groups
Adaptive Server Enterprise 446
GUIDs
compared to global autoincrement 82
default column value 82

generating 145

H

hash anti-semijoin
  query execution algorithms 384
hash B-tree indexes
  about 401
hash distinct
  query execution algorithms 386
hash group by
  query execution algorithms 388
hash joins
  query execution algorithms 383, 384
hash maps
  query execution algorithms 391
hash not exists
  query execution algorithms 384
hash semijoin
  query execution algorithms 384
hash values
  indexes 401
HAVING clause
  GROUP BY and 242
  logical operators 243
  performance 405
  selecting groups of data 242
  subqueries 330
  with and without aggregates 242
hide directive
  using 507
hierarchical data structures 315, 317
histograms
  about 369
  updating 371
HOLDLOCK keyword
  Transact-SQL 461
how data can become invalid 76
how database contents change 77
how joins work 263
how locking is implemented 142
how locking works 131
how NULL affects Transact-SQL outer joins 280
how queries with group by are executed 238
how subqueries work 345
how the optimizer works 369

I

I/O
  scanning bitmaps 393
IBM DB2
  migrating to Adaptive Server Anywhere 548
  remote data access to DB2 597
icons
  used in manuals xiv
idempotent functions
  defined 418
identifiers
  case sensitivity 453
  qualifying 209
  uniqueness 453
  using in domains 90
identifying entities and relationships 11
IDENTITY column 456
  retrieving values 456
if a client application breaches entity integrity 92
if a client application breaches referential integrity 94
IF statement
  syntax 633
images
  inserting 360
implementation of locking 142
implementing recommendations
  Index Consultant 70
import tools 528
import wizard
  about 528
  using 529
importing
  Adaptive Server Enterprise compatibility 556
  databases 529
  file formats 524
  introduction 524
  non-matching table structures 525
  NULL values 525
  tools 528
  using temporary tables 72
importing and exporting data 521
importing data
  about 522

conversion errors 527
DEFAULTS option 526
from other databases 529
interactively 529
LOAD TABLE statement 530
performance 522
proxy tables 529
temporary tables 525, 526
tools 528
importing XML documents as relational data 483
importing XML using OPENXML 483
importing XML using the DataSet object 488
improving concurrency at isolation levels 2 and 3 114
improving index performance 396
improving performance 161
IN conditions
subqueries 336
IN keyword
matching lists 222
IN list
algorithm 381
item in access plans 426
optimization 412
IN parameters
defined 636
inconsistencies
avoiding using locks 131
dirty reads 104, 134
dirty reads tutorial 116
effects of unserializable schedules 113
example of non-repeatable read 120
ISO SQL/92 standard 104
phantom rows 104, 123, 135, 142
practical locking implications 126
inconsistencies non-repeatable reads 104, 119, 135
increase the cache size 161
IndAdd
statistic in access plans 422
Index Consultant
about 65
assessing recommendations 69
connection state 70
implementing recommendations 70
introduction 58, 156
recommendations 68
server state 70
starting 65
stopping 65
understanding 63, 66
workloads 63, 66
index creation wizard
using 60
index fragmentation 195
index scans
about 379
index selectivity
about 396
indexed distinct
query execution algorithms 387
indexed group by
query execution algorithms 388
indexes
about 395
assistance 156
B-tree 401
benefits 63
benefits and locking 115
can usually be found to satisfy a predicate 373
candidate 64
clustered 59
composite 397, 402
compressed B-tree 402
correlations between 70
costs 63
creating 60
deleting 62
effect of column order 398
fan-out and page sizes 402
fragmentation 195
frequently-searched columns 58
hash B-tree 401
hash values 401
HAVING clause performance 405
improving concurrency 143
Index Consultant 58, 63, 65
inspecting 71
leaf pages 397
optimization and 395
performance 162

predicate analysis 405
recommended page sizes 402
sargable predicates 405
structure 397
temporary tables 396
Transact-SQL 453
types of index 401
understanding the Index Consultant 66
unused 69
validating 61
virtual 64
when to use 58
WHERE clause performance 405
working with 58
indexes in the system tables 71
indexes:
computed columns 61
IndLookup
statistic in access plans 422
initial cache size 177
initialization utility
using 29
inner and outer joins 274
inner joins
about 274
INOUT parameters
defined 636
INPUT statement
about 528
using 529
inputting
import tools 528
importing data 524, 529
importing databases 529
importing tables 530
INSERT statement
about 357, 528
locking during 136
SELECT 357
using 529
inserting data
adding NULL 358
BLOBs 360
column data INSERT statement 358
constraints 358
defaults 358
into all columns 357
using INSERT 357
with SELECT 359
inserting documents and images 360
inserting values into all columns of a row 357
inserting values into specific columns 358
installing
jConnect metadata support 35
instest 195
integrity
about 76
checking 95
column defaults 79
constraints 78, 85
enforcing 92
information in the system tables 97
losing 94
tools 77
using triggers to maintain 78
integrity constraints belong in the database 76
integrity rules in the system tables 97
Interactive SQL
batch operations 554
command delimiter 661
command files 553
exporting query results 534
exporting relational data as XML 482
loading commands 554
rebuilding databases 540
running scripts 554
saving commands 554
Interactive SQL import wizard
about 528
interference between transactions 110, 122
interleaving transactions 112
internal loading 522
internal operations
remote data access 583
interrupt
Run menu 685
INTERSECT operation
combining queries 251
NULL 254
rules 252
using 252

INTO clause
using 641
invalid data 76
invocations
statistic in access plans 422
IS NULL keyword 228
ISNULL function
about 228
ISO compliance *see* SQL standards
ISO SQL/92 standard
concurrency 104
typical inconsistencies and 104
isolation level 0
example 116
SELECT statement locking 134
isolation level 1
example 119
SELECT statement locking 135
isolation level 2
example 123, 126
SELECT statement locking 135
isolation level 3
example 125
SELECT statement locking 135
isolation levels
about 104
changing within a transaction 109
choosing 112
choosing types of locking tutorial 122
implementation at level 0 134
implementation at level 1 135
implementation at level 2 135
implementation at level 3 135
improving concurrency at levels 2 and 3 114
ODBC 107
setting 106
tutorials 116
typical transactions for each 113
versus typical inconsistencies 105, 123, 126, 142
versus typical transactions 113
viewing 109
isolation levels and consistency 104

J

Java
about debugging 674
debugging 680
Java debugger
debugging Java classes 680
debugging stored procedures 677
displaying source code 681
requirements 675
starting 676
tutorial 676
jConnect metadata support
installing 35
JDBC-based server classes 591
join algorithms
about 381
join compatible data types 268
join conditions
types 270
join elimination rewrite optimization 411
join operators
Transact-SQL 462
joining more than two tables 267
joining remote tables 574
joining tables from multiple local databases 576
joining two tables 266
joins
about 264
automatic 474
Cartesian product 272
commas 272
conversion of outer joins to inner joins 414
converting subqueries into 341
converting subqueries to joins 345
cross join 272
data type conversion 268
default is KEY JOIN 265
derived tables 287
duplicate correlation names 282
equijoins 270
FROM clause 264
how an inner join is computed 266
in delete, update and insert statements 268
inner 274
inner and outer 274
join conditions 264

join elimination rewrite optimization 411
joined tables 265
key 474
key joins 292
natural 474
natural joins 288
nesting 267
non-ANSI joins 268
null-supplying tables 274
of more than two tables 267
of table expressions 267
of tables in different databases 576
of two tables 266
ON phrase 269
outer 274
preserved tables 274
query execution algorithms 381
remote tables 574
search conditions 270
self-joins 281
star joins 282
Transact-SQL 462
Transact-SQL outer, null values and 280
Transact-SQL outer, restrictions on 279
Transact-SQL outer, views and 280
updating cursors 268
WHERE clause 270

K

key joins
about 292
if more than one foreign key 293
of lists and table expressions that do not contain commas 299
of table expression lists 297
of table expressions 295
of table expressions that do not contain commas 296
of views and derived tables 301
rules 303
the ON phrase 269
with an ON phrase 292
key type
item in access plans 425
keys
assigning 16
performance 182
keywords
HOLDLOCK 461
NOHOLDLOCK 461
remote servers 587

L

laptop computers
and transactions 148
leaf pages 397
least distance problems 322
LEAVE statement
syntax 633
left outer joins
about 274
less than
comparison operator 220
range specification 221
less than or equal to
comparison operator 220
levels of isolation
about 104
changing 106
changing within a transaction 109
setting default 106
LIKE conditions
LIKE optimizations 413
LIKE operator
wildcards 224
LIKE optimizations 413
limiting rows
FIRST clause 245
TOP clause 245
limiting the memory used by the cache 177
line breaks
SQL 209
listing remote server capabilities 566
listing the columns on a remote table 572
listing the remote tables on a server 566
literal values
NULL 228
LOAD DATABASE statement
unsupported 443
LOAD TABLE statement
about 528

using 530
LOAD TRANSACTION statement
unsupported 443
loading
commands in Interactive SQL 554
local temporary tables 72
local variables
debugger 688
locked tables
item in access plans 424
locking
reducing through indexes 400
locking during deletes 139
locking during inserts 136
locking during queries 134
locking during updates 138
locks
about 131
anti-insert 132, 139
blocking 110, 122
choosing isolation levels tutorial 122
conflict handling 110, 122
conflicting types 134
deadlock 111
early release of 113, 141, 142
exclusive 132
implementation at level 0 134
implementation at level 1 135
implementation at level 2 135
implementation at level 3 135
inconsistencies versus typical isolation levels 105, 142
insert 132
isolation levels 104
nonexclusive 132
objects that can be locked 131
orphans and referential integrity 137
phantom rows versus isolation levels 123, 126
procedure for deletes 139
procedure for inserts 136
procedure for updates 138
query execution algorithms 391
read 132, 140
reducing the impact through indexes 115
shared versus exclusive 133
transaction blocking and deadlock 110
two-phase locking 140
types of 132
typical transactions versus isolation levels 113
uses 133
viewing in Sybase Central 131
write 132
logging SQL statements 34
logical operators
connecting conditions 229
HAVING clauses 243
logs
rollback log 103
long plans
about 428
Interactive SQL 434
SQL functions 434
LONG VARCHAR data type
storing XML 481
LOOP statement
in procedures 646
syntax 633
losing referential integrity 94
LOTUS file format
format for importing and exporting 524
Lotus Notes
passwords 605
remote data access 604

M

maintenance
performance 161
managing
transactions 581
managing foreign keys 43
managing primary keys 42
mandatory
foreign keys 93
mandatory relationships 8
many-to-many relationships
definition of 7
resolving 19, 21
master database
unsupported 443
matching character strings in the WHERE clause 222

materializing result sets
query processing 185
MAX function
rewrite optimization 412
maximum cache size 177
merge joins
query execution algorithms 385
merge sort
query execution algorithms 389
MESSAGE statement
procedures 650
metadata support
installing for jConnect 35
Microsoft Access
migrating to Adaptive Server Anywhere 548
remote data access 603
Microsoft Excel
remote data access 602
Microsoft FoxPro
remote data access 604
Microsoft SQL Server and remote access 600
Microsoft SQL Server databases
migrating to Adaptive Server Anywhere 548
migrating databases
about 548
MIN function
rewrite optimization 412
minimal administration work
optimizer 372
minimizing downtime during rebuilding 545
minimum cache size 177
modifying
CHECK constraints 87
column defaults 80
views 54
modifying and deleting CHECK constraints 87
modifying and deleting column defaults 80
monitor
configuring 190
opening the Sybase Central Performance Monitor 189
Performance Monitor overview 188
monitoring and improving performance 153
monitoring cache size 179
monitoring database performance 187
monitoring database statistics from Sybase Central 188
monitoring database statistics from Windows Performance Monitor 190
monitoring performance
abbreviations used in access plans 420
reading access plans 420
tools to measure queries 195
monitoring query performance 195
more than one transaction at once 102
msodbc server class 600
multiple databases
joins 576
multiple transactions
concurrency 102

N

name spaces
indexes 453
triggers 453
naming and nesting savepoints 103
natural joins
about 288
of table expressions 289
of views and derived tables 290
with an ON phrase 289
nested block join and sorted block 382
nested block joins
query execution algorithms 382
nested compound statements and exception handlers 656
nested loops joins
query execution algorithms 381
nested loops semijoin
query execution algorithms 382
nested subqueries
about 343
nesting
derived tables in joins 287
in joins 267
in outer joins 276

nesting and naming savepoints 103
NetWare
 external functions 666
 external procedure calls 665
NEWID
 when to use 145
NEWID function
 default column value 82
newsgroups
 technical support xvi
NLM
 calling from procedures 664
 external functions 666
 external procedure calls 665
NOHOLDLOCK keyword
 ignored 461
non-ANSI joins 268
non-dirty reads
 tutorial 116
non-repeatable reads
 about 104
 example 120
 isolation levels 105, 142
 tutorial 119
nonexclusive locks 132
normal forms
 first normal form 17
 normalizing database designs 15
 second normal form 18
 third normal form 18
normalization
 about 15
 performance benefits 162
normalize your table structure 162
NOT
 using logical operators 229
not equal to
 comparison operator 220
not greater than
 comparison operator 220
NOT keyword
 search conditions 221
not less than
 comparison operator 220
Notes and remote access 604
NULL
 about 226
 aggregate functions 236
 allowing in columns 23
 column default 451
 column definition 228
 comparing 227
 default 83
 default parameters 227
 DISTINCT clause 217
 EXCEPT operation 254
 INTERSECT operation 254
 output 527
 properties 228
 ROLLUP operation 249
 set operators 254
 sort order 245
 Transact-SQL compatibility 458
 Transact-SQL outer joins 280
 UNION operation 254
null-supplying tables
 in outer joins 274

O

objects
 hiding 670
objects that can be locked 131
obtaining database statistics from a client application 187
obtaining query results as XML 490
occasionally connected users
 replicating data and concurrency 148
ODBC
 applications 107
 applications, and locking 107
 external servers 594
ODBC server classes 594, 602
odbcfet 195
OLAP
 ROLLUP operation 247
 subtotal rows 247
ON clause
 joins 269
ON EXCEPTION RESUME clause
 about 651
 not with exception handling 655
 stored procedures 649
 Transact-SQL 470
ON phrase

joins 269
one-to-many relationships
definition of 7
resolving 19
one-to-one relationships
definition of 7
resolving 19
online analytical processing
ROLLUP operation 247
OPEN statement
procedures 646
opening the Sybase Central Performance Monitor 189
OPENXML function
using 483
operators
arithmetic 216
connecting conditions 229
NOT keyword 221
precedence 216
optimization
cost based 368
reading access plans 420
using indexes 143
optimization for minimum or maximum functions 412
optimization goal
in access plans 424
optimization of queries
about 368
assumptions 372
reading access plans 420
rewriting subqueries as EXISTS predicates 374
steps in 377
optimize for first rows or for entire result set 373
optimizer
about 368, 369
assumptions 372
predicate analysis 405
role of 368
semantic subquery transformations 404
semantic transformations 407
optimizer estimates
about 369
optional foreign keys 93
optional relationships 8
options
BLOCKING 110
DEFAULTS 526
ISOLATION_LEVEL 106
setting database options 32
OR
using logical operators 229
Oracle and remote access 599
Oracle databases
migrating to Adaptive Server Anywhere 548
oraodbc server class 599
ORDER BY and GROUP BY 246
ORDER BY clause
GROUP BY 246
limiting results 245
performance 184
sorting query results 244
order-by
item in access plans 427
ordered distinct
query execution algorithms 387
ordered group by
query execution algorithms 388
ordering of transactions 112
organization
of data, physical 392
organizing query results into groups 237
orphan and referential integrity 137
other uses for indexes 400
OUT parameters
defined 636
outer joins
about 274
and join conditions 276
complex 276
in Transact-SQL 278
of views and derived tables 278
restrictions 279
star join example 285
Transact-SQL 462
Transact-SQL, restrictions on 279
Transact-SQL, views and 280
outer references
about 340
aggregate functions 233

HAVING clause 330
output redirection 534
OUTPUT statement 534
about 532
using to export data as XML 482
outputting
export tools 532
exporting data 524
exporting databases 536
exporting query results 534
exporting tables 537
outputting nulls 527

P

page map
item in access plans 424
page maps
scanning 393
page size
about 393
and indexes 394
disk allocation for inserted rows 392
performance 170
page sizes
and indexes 402
pages
disk allocation for inserted rows 392
parentheses
in arithmetic statements 216
UNION operators 251
partial index scan
about 400
partial passthrough of the statement
remote data access 585
particular concurrency issues 145
parts explosion problems 317
passing parameters to external functions 669
passing parameters to functions 638
passing parameters to procedures 637
passwords
case sensitivity 453
Lotus Notes 605
performance
about 161
autocommit 165
automatic tuning 372
bulk loading 522
bulk operations 166
cache 161
cache read-hit ratio 433
comparing optimizer estimates and actual statistics 431
compression 166
database design 162
estimate source 432
file fragmentation 171, 193
file management 163
improving 58, 59
improving versus locks 115
index fragmentation 195
indexes 58, 162
keys 182
measuring query speed 195
monitoring 187
monitoring in Windows 190
page size 170
predicate analysis 405
reading access plans 420
recommended page sizes 402
reducing requests 167
runtime actuals and estimates 432
scattered reads 171
selectivity 432
statistics in Windows Performance Monitor 190
table and page size 393
table fragmentation 193
tips 161
transaction log 161
WITH EXPRESS CHECK 166
work tables 185
performance considerations for moving data 522
Performance Monitor
adding and removing statistics 189
configuring 190
opening in Sybase Central 189
overview 188
running multiple copies 191
setting the interval time 190
starting 191
Sybase Central 188
Windows 190

PerformanceFetch 195
PerformanceInsert 195
PerformanceTraceTime 195
PerformanceTransaction 195
permissions
- Adaptive Server Enterprise 446
- data modification 356
- debugging 675
- procedure result sets 642
- procedures calling external functions 664
- triggers 629
- user-defined functions 623

permissions for data modification 356
phantom
- rows 104, 135, 142

phantom locks 126
phantom rows
- tutorial 123
- versus isolation levels 105, 126, 142

physical data model
- generating 19

physical data organization 392
place different files on different devices 163
plans
- abbreviations used in 420
- caching of 375
- context sensitive help 430
- customizing 429
- graphical plans 429
- Interactive SQL 434
- long text plans 428
- printing 429
- reading 420
- short text plans 427
- SQL functions 434

plus operator
- NULL values 228

portable computers
- replicating databases 148

portable SQL 458
PowerBuilder
- remote data access 559

practical locking implications tutorial 126
predicate analysis
- about 405

predicate pushdown into grouped or unioned views 410
predicates
- about 405
- item in access plans 426
- performance 405
- reading in access plans 433

prefix columns
- ROLLUP operation 247

prefixes
- ROLLUP operation 247
- subtotal rows 247

PREPARE statement
- remote data access 581

preserved tables
- in outer joins 274

primary keys
- and integrity 474
- AUTOINCREMENT 81
- concurrency 145
- creating 42
- entity integrity 92
- generation 145
- managing 42
- modifying 42
- performance 182
- using NEWID to create UUIDs 82

primary keys enforce entity integrity 92
procedure creation wizard
- about 613
- using 613

procedure language
- overview 463

procedure profiling
- clearing in Sybase Central 198
- clearing with SQL 198
- disabling in Sybase Central 198
- disabling with SQL 198
- enabling in Sybase Central 197
- enabling with SQL 197
- events 200, 201
- information for individual procedures 201, 203
- resetting in Sybase Central 198
- resetting with SQL 198
- stored procedures and functions 200, 201

summary data 199
summary of procedures 202
triggers 200, 202
viewing data in Interactive SQL 202
viewing data in Sybase Central 197, 199

procedures
about 609
adding remote procedures 578
altering 615
benefits of 612
calling 616
command delimiter 661
copying 616
creating 613
cursors 646
dates 662
default error handling 649
deleting 617
deleting remote procedures 579
error handling 469, 470, 649
exception handlers 654
EXECUTE IMMEDIATE statement 658
external functions 664
multiple result sets from 643
overview 611
parameters 636, 637
permissions for result sets 642
result sets 618, 642
return values 469
returning results 640
returning results from 617
savepoints 660
security 612
SQL statements allowed 636
structure 636
table names 661
times 662
tips for writing 661
Transact-SQL 466
Transact-SQL overview 463
translation 466
using 613
using cursors in 646
using in the FROM clause 218
variable result sets from 644
verifying input 662
warnings 653

profiling database procedures 197

profiling information
events 201
stored procedures and functions 201
triggers 202

program variables
in common table expression 310

properties
setting all database object properties 32

properties of NULL 228

property
definition of 5

PROPERTY function
about 187

property sheets 32

protocols
two-phase locking 141

prototypes
external functions 666

proxy table creation wizard
using 570

proxy tables
about 560, 569
creating 560, 570, 571
location 569

publications
data replication and concurrency 148

Q

qualifications
about 219

qualified names
database objects 209

quantified comparison test 347
subqueries 333

queries
about 208
access plans 420
common table expressions 305
optimization 368, 369
selecting data from a table 207
set operations 251
Transact-SQL 459

queries blocked on themselves
remote data access 588

query execution algorithms 379
  abbreviations used in access plans 420
  anti-semijoin 384
  block nested loops joins 382
  Bloom filters 391
  duplicate elimination 386
  explode 391
  filter and pre-filter 390
  grouping algorithms 387
  hash anti-semijoin 384
  hash distinct 386
  hash group by 388
  hash joins 383, 384
  hash not exists 384
  hash semijoin 384
  IN list 381
  index scans 379
  indexed distinct 387
  indexed group by 388
  joins 381
  locks 391
  merge joins 385
  merge sort 389
  nested block joins 382
  nested loops joins 381
  nested loops semijoin 382
  ordered distinct 387
  ordered group by 388
  row limits 391
  semijoin 381, 382, 384
  sequential table scans 380
  single group by 388
  sorted block joins 382
  sorting and unions 389
  union all 389
query normalization
  remote data access 583
query optimization and execution 367
query parsing
  remote data access 583
query performance
  reading access plans 420
query preprocessing
  remote data access 583
query results
  exporting 534
quotation marks
  Adaptive Server Enterprise 225
  character strings 225
QUOTED_IDENTIFIER option
  about 225
  setting for Transact-SQL compatibility 451

R

RAISERROR statement
  ON EXCEPTION RESUME 470
  Transact-SQL 470
range queries 221
RAW mode
  using 494
read locks 132, 140
reading access plans 420
reading entity-relationship diagrams 8
reading the access plan
  key statistics 431
rebuild file formats 541
rebuild tools 540
rebuilding 543
  databases 543
  minimizing downtime 545
  purpose 541
  replicating databases 544
  tools 540
rebuilding databases
  about 539
recommendations
  Index Consultant 68
recommended page sizes 402
recursive queries
  restrictions 315
recursive subqueries
  about 305
  datatype declarations in 320
  least distance problems 322
  multiple aggregation levels 310
  parts explosion problems 317
recursive tables
  algorithm 381
redirecting
  output to files 534
reduce the number of requests between client and server 167
reducing the impact of locking 115

references
displaying references from other tables 44
referential integrity 474
about 76
actions 94
breached by client application 94
checking 95
column defaults 79
constraints 78, 85
enforcing 92
information in the system tables 97
introduction 78
losing 94
orphans 137
tools 77
verification at commit 138
referential integrity actions
implemented by system triggers 95
reflexive relationships 8
relationships
about 6
cardinality of 7
changing to an entity 9
choosing 11
definition of 5
mandatory versus optional 8
many-to-many 7
one-to-many 7
one-to-one 7
reflexive 8
resolving 19
roles 7
relative benefit
Index Consultant recommendations 68
reloading
databases 543
reloading databases
about 539
remember to delimit statements within your procedure 661
remote data
location 569
remote data access
about 557
case sensitivity 587
connection names 588
internal operations 583
introduction 558
passthrough mode 577
performance limitations 558
PowerBuilder DataWindows 559
remote servers 562
SQL Remote unsupported 587
troubleshooting 587
unsupported features 587
remote databases
replication 148
remote procedure calls
about 578
remote procedure creation wizard
using 578, 613
remote procedures
adding 578
calls 578
creating 613
data types 579
deleting 579
remote server creation wizard
using 563
remote servers
about 562
altering 565
classes 589, 590
creating 562
deleting 564
external logins 567
listing properties 566
transaction management 581
remote table mappings 560
remote tables
about 560
accessing 557
listing 566
listing columns 572
remote transaction management overview 581
renaming columns in query results 213
repeatable reads 104, 119, 135
replication
concurrency 148
concurrency issues 145
rebuilding databases 539, 544
replication and concurrency 148

requests
reducing number of 167
requests tab
Index Consultant recommendations 69
requirements for using the debugger 675
reserved words
remote servers 587
resetting procedure profiling
SQL 198
Sybase Central 198
RESIGNAL statement
about 655
resolving
relationships 19
RESTRICT action
about 95
restrictions
remote data access 587
restrictions on transaction management 581
result sets
limiting the number of rows 245
multiple 643
permissions 642
procedures 618, 642
Transact-SQL 467
variable 644
retrieving the first few rows of a query 245
RETURN statement
about 640
return types
external functions 670
return values
procedures 469
returning a value using the RETURN statement 640
returning multiple result sets from procedures 643
returning procedure results in parameters 617
returning procedure results in result sets 618
returning result sets from procedures 642
returning result sets from Transact-SQL procedures 467
returning results as procedure parameters 640
returning results from procedures 640
returning variable result sets from procedures 644
REVOKE statement
and concurrency 146
Transact-SQL 447
rewrite optimization
about 407
rewriting subqueries as EXISTS predicates 374
right outer joins
about 274
role names
about 293
role of the optimizer 368
roles
Adaptive Server Enterprise 445
definition of 7
rollback logs
savepoints 103
ROLLBACK statement
compound statements 634
procedures and triggers 660
triggers 464
rolling back transactions 101
ROLLUP operation
about 247
NULL 249
subtotal rows 247
understanding GROUP BY 239
ROLLUP operation: example 247
row limit count
item in access plans 427
row limits
query execution algorithms 391
rows
copying with INSERT 360
deleting 393
selecting 219
RowsReturned
statistic in access plans 422
rules
Transact-SQL 444
rules describing the operation of key joins 303
running
command files 553

SQL scripts 553, 554
RunTime
statistic in access plans 422

S

SA_DEBUG group
debugger 675
sa_migrate system procedure
about 548
using 549
sa_migrate_create_fks system procedure
using 550
sa_migrate_create_remote_fks_list system procedure
using 550
sa_migrate_create_remote_table_list system procedure
using 550
sa_migrate_create_tables system procedure
using 550
sa_migrate_data system procedure
using 550
sa_migrate_drop_proxy_tables system procedure
using 550
sa_pause_workload_capture procedure
pausing the Index Consultant 65
sa_stop_index_consultant procedure
stopping the Index Consultant 65
sa_stop_workload_capture procedure
stopping the Index Consultant 65
sample database
schema for asademo.db 262
sargable predicates
about 405
savepoints
nesting and naming 103
procedures and triggers 660
within transactions 102
saving
commands in Interactive SQL 554
saving transaction results 101
scalar aggregates 233
scattered reads
performance 171
schedules
effects of serializability 113
effects of unserializable 113
serializable 112
serializable versus early release of locks 142
two-phase locking 140
scheduling of transactions 112
schema
exporting 542
scripts
running in Interactive SQL 554
security
hiding objects 670
procedures 612
select list
about 211
aliases 213
calculated columns 215
EXCEPT statements 251
in access plans 424
INTERSECT statements 251
UNION operation 252
UNION statements 251
SELECT statement
about 208
aliases 213
character data 225
column headings 213
column order 212
cursors 646
INSERT from 357
INTO clause 641
keys and query access 182
specifying rows 219
strings in display 214
Transact-SQL 459
variables 461
selecting all columns from a table 211
selecting specific columns from a table 212
selectivity
item in access plans 425
reading in access plans 433
selectivity estimates
reading in access plans 433
using a partial index scan 400
self-joins 281

SELF_RECURSION option
Adaptive Server Enterprise 464
semantic query transformations 404
semantic transformations
about 407
semicolon
command delimiter 661
semijoin
query execution algorithms 381, 382, 384
sending native statements to remote servers 577
separate primary and foreign key indexes 183
sequential scans
about 380
disk allocation and performance 392
sequential table scans
about 380
disk allocation and performance 392
serializable schedules
about 112
effect of 113
two-phase locking 140
versus early release of locks 142
server capabilities
remote data access 583
server classes
about 560
asajdbc 591
asaodbc 595
asejdbc 592
aseodbc 595
db2odbc 597
defining 560
msodbc 600
ODBC 594, 602
oraodbc 599
server classes for remote data access 589
server side loading 522
server state
Index Consultant 70
servers
graphing with the Performance Monitor 188
starting a database without connecting 35
servers and databases
compatibility 443
SET clause
UPDATE statement 362
SET DEFAULT action
about 95
set membership test 350
=ANY 336
negation of 336
SET NULL action
about 95
set operations
about 251
NULL 254
rules 252
SET OPTION statement
Transact-SQL 451
setting breakpoints
debugger 685
setting database options 32
setting options for Transact-SQL compatibility 451
setting properties for database objects 32
setting the isolation level 106
setting the isolation level from an ODBC-enabled application 107
shared objects
calling from procedures 664
shared versus exclusive locks 133
short plans
about 427
Interactive SQL 434
SQL functions 434
SIGNAL statement
procedures 650
Transact-SQL 470
single group by
query execution algorithms 388
sort order
ORDER BY clause 244
sorted block joins
query execution algorithms 382
sorting
query execution algorithms 389
with an index 184
sorting and unions 389
sorting query results 184

source code window
  setting breakpoints 685
sp_addgroup system procedure
  Transact-SQL 447
sp_addlogin system procedure
  support 443
  Transact-SQL 447
sp_adduser system procedure
  Transact-SQL 447
sp_bindefault procedure
  Transact-SQL 444
sp_bindrule procedure
  Transact-SQL 444
sp_changegroup system procedure
  Transact-SQL 447
sp_dboption system procedure
  Transact-SQL 451
sp_dropgroup system procedure
  Transact-SQL 447
sp_droplogin system procedure
  Transact-SQL 447
sp_dropuser system procedure
  Transact-SQL 447
special IDENTITY column 456
special Transact-SQL timestamp column and data type 454
specialized joins 281
specifying a consolidated database 33
specifying dates and times in procedures 662
specifying proxy table locations 569
SQL
  differences from other SQL dialects 474
  entering 209
SQL 3 compliance *see* SQL standards
SQL 92 compliance *see* SQL standards
SQL 99 compliance *see* SQL standards
SQL Anywhere Studio
  documentation x
SQL queries 209
SQL Remote
  remote data access 587
  replicating and concurrent transactions 148
SQL Server and remote access 600
SQL standards 3
  compliance 473
  GROUP BY clause 258
  non-ANSI joins 268
SQL statements
  logging in Sybase Central 34
  writing compatible SQL statements 458
SQL statements allowed in procedures and triggers 636
SQL statements for implementing integrity constraints 78
SQL-3 compliance *see* SQL standards
SQL-92 compliance *see* SQL standards
SQL-99 compliance *see* SQL standards
SQL/3 compliance *see* SQL standards
SQL/92 compliance *see* SQL standards
SQL/99 compliance *see* SQL standards
SQL/XML
  about 490
SQL3 compliance *see* SQL standards
SQL_TXN_ISOLATION 108
SQL_TXN_READ_COMMITTED
  isolation level 107
SQL_TXN_READ_UNCOMMITTED
  isolation level 107
SQL_TXN_REPEATABLE_READ
  isolation level 107
SQL_TXT_SERIALIZABLE
  isolation level 107
SQLCA.lock
  selecting isolation levels 107
  versus isolation levels 105
SQLCODE variable
  introduction 649
SQLSetConnectOption 108
SQLSTATE variable
  introduction 649
standard output
  redirecting to files 534
standards *see* SQL standards
standards and compatibility *see* SQL standards
star joins 282
starting
  Index Consultant 65
starting a database without connecting 35
statement-level triggers 463

statements
  CALL 611, 616, 633, 637
  CASE 633
  CLOSE 646
  COMMIT 634, 660
  compound 634
  CREATE DATABASE 443
  CREATE DEFAULT 444
  CREATE DOMAIN 444
  CREATE PROCEDURE 613, 636
  CREATE RULE 444
  CREATE TABLE 458
  CREATE TRIGGER 625
  DECLARE 634, 646, 650
  DISK 444
  DROP DATABASE 443
  DUMP DATABASE 443
  DUMP TRANSACTION 443
  EXECUTE IMMEDIATE 658
  FETCH 646
  FOR 633
  GRANT 447
  IF 633
  LEAVE 633
  LOAD DATABASE 443
  LOAD TRANSACTION 443
  logging 34
  LOOP 633, 646
  MESSAGE 650
  OPEN 646
  optimization 368
  OUTPUT 534
  RAISERROR 470
  RETURN 640
  REVOKE 447
  ROLLBACK 464, 660
  SELECT 459, 461, 641
  SIGNAL 470, 650
  WHILE 633
statements allowed in batches 663
statistics
  access plans 420, 422
  adding to the Performance Monitor 189
  available 191
  column statistics 369
  displaying 191
  monitoring 187
  performance 190
  removing to the Performance Monitor 189
  updating column statistics 371
statistics are present and correct 373
steps in optimization 377
stored procedure language
  overview 463
stored procedures
  common table expressions in 310
  debugging 677
  Transact-SQL stored procedure overview 463
  using in the FROM clause 218
  viewing individual profiling information 201
  viewing profiling data 197
  viewing summary profiling data 200
storing values
  in common table expressions 312
storing XML documents in relational databases 481
string and number defaults 83
strings
  matching 222
  quotation marks 225
structure of procedures and triggers 636
subqueries
  about 327, 328
  ALL test 334
  ANY operator 333
  ANY test 333
  caching of 418
  comparison operators 346
  comparison test 331, 332
  converting to joins 341, 345
  correlated 340, 345
  existence test 331, 338
  GROUP BY 330
  HAVING clause 330
  IN keyword 222
  nested 343
  optimizer internals 345
  outer references 330
  quantified comparison test 331, 333
  rewriting as EXISTS predicates 374
  rewriting as joins 341

row group selection 330
row selection 329
set membership test 331, 336
types of operators 331
WHERE clause 329, 345
subqueries and joins 341
subqueries in the HAVING clause 330
subquery and function caching 418
subquery comparison test 332
subquery set membership test
about 336
subquery tests 331
subquery transformations during optimization 404
subquery unnesting 408
subscriptions
data replication and concurrency 148
substituting a value for NULL 228
subtotal rows
construction 247
definition 247
ROLLUP operation 247
subtransactions
and savepoints 102
procedures and triggers 660
summarizing query results using aggregate functions 232
summarizing, grouping and sorting query results 231
summary information
ROLLUP operation 247
summary profiling data
events 200
stored procedures and functions 200
triggers 200
summary rows
ROLLUP operation 247
summary values 237
about 232
support
newsgroups xvi
swap space
database cache 178
Sybase Central
altering tables 39
and column defaults 80
column constraints 87
copying database objects 73
copying tables 48
creating databases 28
creating indexes 60
creating tables 37
deleting databases 30
deleting tables 41
displaying system objects 34
displaying system tables 48
dropping views 55
erasing databases 30
installing jConnect metadata support 35
logging SQL statements 34
managing foreign keys 44
managing primary keys 42
modifying views 55
rebuilding databases 540
setting a consolidated database 33
setting database options 32
starting a database without connecting 35
translating procedures 466
validating indexes 61
Sybase Central Performance Monitor 188
symbols
string comparisons 223
syntax-independent optimization 368
SYSCOLSTAT
updating column statistics 371
SYSCOLUMNS view
conflicting name 450
SYSINDEX table
index information 71
SYSINDEXES view
conflicting name 450
index information 71
SYSIXCOL table
index information 71
sysservers system table
remote servers 562
SYSTABLE system table
view information 56
system administrator
Adaptive Server Enterprise 445
system catalog

Adaptive Server Enterprise compatibility 445
system functions
tsequal 455
system objects 34
displaying 48
system security officer
Adaptive Server Enterprise 445
system tables
Adaptive Server Enterprise compatibility 445
and indexes 71
displaying 48
information about referential integrity 97
owner 445
Transact-SQL name conflicts 450
views 56
system triggers
implementing referential integrity actions 95
system views
and indexes 71
information about referential integrity 97
SYSVIEWS view
view information 56

T

table and page sizes 393
table expressions
how they are joined 267
in key joins 295
syntax 264
table fragmentation
about 193
table names
fully qualified in procedures 661
identifying 209
procedures and triggers 661
table scans
about 380
disk allocation and performance 392
table size
about 393
table structures for import 525
tables
adding keys to 42, 44, 45
altering 38, 39
bitmaps 393
browsing data 41
column names 23
constraints 24
copying 48
copying rows 360
correlation names 218
creating 37
creating proxy tables in SQL 571
creating proxy tables in Sybase Central 570
defragmenting all tables in a database 194
defragmenting individual tables in a database 195
deleting 41
displaying primary keys in Sybase Central 42
displaying references from other tables 44
dropping 41
editing data 41
exporting 537
fragmentation 193
group reads 393
importing 530
listing remote 566
managing foreign keys 43–45
managing primary keys 42
managing table constraints 87
naming in queries 218
properties 23
proxy 569
remote access 560
structure 38
system tables 48
Transact-SQL 458
work tables 185
working with 37
technical support
newsgroups xvi
temporary files
work tables 163
temporary tables
about 72

importing data 525, 526
indexes 396
local and global 72
Transact-SQL 459
work tables in query processing 185
testing
database design 15, 21
testing a column for NULL 227
testing set membership with IN conditions 336
text plans
reading access plans 427
theorems
two-phase locking 141
threads
deadlock when none available 111
times
procedures and triggers 662
TIMESTAMP data type
Transact-SQL 454
tips
performance 161
tips for writing procedures 661
tools
rebuilding databases 540
TOP clause
about 245
top performance tips 161
total benefits
Index Consultant recommendations 69
total cost benefit
Index Consultant recommendations 69
TRACEBACK function 650
trailing blanks
comparisons 220
creating databases 450
Transact-SQL 450
Transact-SQL
about 440
batches 464
creating databases 449
IDENTITY column 456
joins 462
NULL 458
outer join limitations 279
outer joins 278
overview 440
procedures 463
result sets 467
timestamp column 454
trailing blanks 450
triggers 463
variables 468
writing compatible SQL statements 458
writing portable SQL 458
Transact-SQL batch overview 464
Transact-SQL compatibility 439
databases 452
setting database options 451
Transact-SQL procedure language overview 463
Transact-SQL stored procedure overview 463
Transact-SQL trigger overview 463
transaction blocking
about 110
transaction log
performance 161
role in data replication 149
transaction management
and remote data 581
transaction processing
effects of scheduling 113
performance 102
scheduling 112
serializable scheduling 112
transaction log based replication 149
two-phase locking 140
transaction scheduling
effects of 113
transactions
about 100
blocking 110, 111, 122
completing 101
concurrency 102
data modification 356
deadlock 111
interference between 110, 122
managing 581
more than one at once 102
procedures and triggers 660
remote data access 581
replicating concurrent 148

savepoints 102
starting 101
sub-transactions and savepoints 102
using 101
transactions and data modification 356
transactions and isolation levels 99
transactions and savepoints in procedures and triggers 660
transactions processing
blocking 110, 122
transformations
rewrite optimization 407
trantest 195
trigger creation wizard
using 625
triggers
about 609
altering 628
benefits of 612
command delimiter 661
creating 625
cursors 646
dates 662
deleting 629
error handling 649
exception handlers 654
executing 627
execution permissions 629
overview 611
recursion 464
ROLBACK statement 464
savepoints 660
SQL statements allowed in 636
statement-level 463
structure 636
times 662
Transact-SQL 453, 463
using 624
viewing individual profiling information 202
viewing summary profiling data 200
warnings 653
troubleshooting
ANY operator 333
deadlocks 111
debugging classes 681
performance 161
remote data access 587
TRUNCATE TABLE statement
about 366
try using Adaptive Server Anywhere’s compression features 166
tsequal function 455
turn off autocommit mode 165
tutorials
dirty reads 116
implications of locking 126
isolation levels 116
non-repeatable reads 119
phantom locks 126
phantom rows 123
two-phase locking 140
two-phase locking theorem 141
types of explicit join conditions 270
types of index 401
types of locks 132
types of semantic transformations 407
typical transactions at various isolation levels 113
typical types of inconsistencies 104

U

uncorrelated subqueries
about 345
underlying assumptions
optimizer 372
understanding complex outer joins 276
understanding group by 238
union all
query execution algorithms 389
UNION operation
combining queries 251
NULL 254
rules 252
unions
query execution algorithms 389
unique keys
generating and concurrency 145
unique results
limiting 217
uniqueness
enforcing with an index 400
UNKNOWN
and NULL 228

unknown values. about 226
unload database wizard
about 541
using 536
UNLOAD statement
about 532
UNLOAD TABLE statement
about 532
unloading and reloading
databases 543–545
unloading databases
about 539
using 536
unnecessary distinct elimination 408
unserializable transaction scheduling
effects of 113
unused indexes
Index Consultant recommendations 69
UPDATE statement
locking during 138
using 362
updates tab
Index Consultant recommendations 69
updating column statistics 371
upgrade database wizard
installing jConnect metadata support 35
upgrading databases 541
use and appropriate page size 170
use bulk operations methods 166
use fully-qualified names for tables in procedures 661
use indexes effectively 162
use of work tables in query processing 185
use the WITH EXPRESS CHECK option when validating tables 166
user IDs
Adaptive Server Enterprise 446
case sensitivity 453
default 81
user-defined data types 89
CHECK constraints 86
creating 89, 90
deleting 91
user-defined functions
about 620
caching 418
calling 621
creating 620
dropping 622
execution permissions 623
external functions 664
parameters 638
users
occasionally connected 148
uses for locks 133
using aggregate functions with distinct 235
using CHECK constraints on columns 85
using CHECK constraints on tables 86
using column defaults 79
using comparison operators in the WHERE clause 220
using compound statements 634
using count (*) 235
using cursors in procedures and triggers 646
using cursors on SELECT statements in procedures 646
using domains 89
using exception handlers in procedures and triggers 654
using FOR XML AUTO 496
using FOR XML EXPLICIT 499
using FOR XML RAW 494
using foreign keys to improve query performance 182
using group by with aggregate functions 237
using joins in delete, update, and insert statements 268
using keys to improve query performance 182
using lists in the WHERE clause 222
USING parameter value in the CREATE SERVER statement 592
using primary keys to improve query performance 182
using procedures, triggers, and batches 609
using ranges (between and not between) in the WHERE clause 221
using remote procedure calls 578

using SELECT statements in batches 663
using subqueries 327
using subqueries in the WHERE clause 329
using Sybase Central to translate stored procedures 466
using table and column constraints 85
using the cache to improve performance 176
using the EXECUTE IMMEDIATE statement in procedures 658
using the RAISERROR statement in procedures 470
using the WHERE clause for join conditions 270
using the WITH CHECK OPTION clause 52
using transaction and isolation levels 99
using transactions 101
using views 52
using views with Transact-SQL outer joins 280
using XML in the database 479
UUIDs
compared to global autoincrement 82
default column value 82
generating 145

V

validating
indexes 61
validating tables
WITH EXPRESS CHECK 166
validation
column constraints 24
ValuePtr parameter
about 107
variables
assigning 461
debugging 684
local 461
SELECT statement 461
SET statement 461
Transact-SQL 468
vector aggregates 237
verifying
database design 21
verifying that procedure input arguments are passed correctly 662
view creation wizard
using 51
viewing
table data 41
view data 56
viewing procedure profiling data
Sybase Central 199
viewing procedure profiling information in Interactive SQL 202
viewing profiling information for a specific procedure in Interactive SQL 203
viewing the isolation level 109
views
browsing data 56
check option 52
common table expressions 305
copying 52
creating 50
deleting 55
FROM clause 218
in key joins 301
in natural joins 290
in outer joins 278
modifying 54
SYSCOLUMNS 450
SYSINDEXES 450
updating 52
using 52
working with 50
views in the system tables 56
virtual indexes
about 64
Index Consultant 64
Index Consultant analysis step 67
virtual memory
a scarce resource 374

W

waiting
to access locked rows 122
to verify referential integrity 138
waiting to access locked rows
deadlock 110
warnings

procedures and triggers 653
Watcom-SQL
about 440
writing compatible SQL statements 458
when to create an index 395
when to use indexes 58
WHERE clause
about 219
compared to HAVING 242
GROUP BY clause 240
joins 270
NULL values 227
performance 184, 405
string comparisons 223
subqueries 329
UPDATE statement 363
where you can use aggregate functions 233
WHILE statement
syntax 633
wildcards
LIKE operator 224
string comparisons 223
Windows CE
creating databases 28
Windows Performance Monitor
about 190
WITH CHECK OPTION clause
about 52
WITH clause 305
optimizer algorithm 381
WITH EXPRESS CHECK
performance 166
wizards
add foreign key 44
create database 28
data migration 548
domain creation 89
erase database 30
import 528
index creation 60
procedure creation 613
proxy table creation 570
remote procedure creation 578, 613
remote server creation 563
trigger creation 625
upgrade database 35
view creation 51
work tables
about 185
performance tips 163
query processing 185
working with breakpoints 685
working with column defaults in Sybase Central 80
working with database objects 25
working with databases 27
working with external logins 567
working with indexes 58
working with proxy tables 569
working with remote servers 562
working with table and column constraints in Sybase Central 87
working with tables 37
working with views 50
workload capture
pausing 65
stopping 65
workloads
analyzing 63
capturing 63, 66
defined 63
Index Consultant 63
understanding 66
write locks 132
writing an EXPLICIT mode query 502
writing compatible queries 459
writing compatible SQL statements 458

X

XML
defined 480
exporting data as from Interactive SQL 482
exporting data as using the DataSet object 482
exporting relational data as 482
format 524
importing as relational data 483
importing using the DataSet object 488
obtaining query results as XML 491
storing in relational databases 481
using FOR XML AUTO 496

using FOR XML EXPLICIT 499
using FOR XML RAW 494
using in Adaptive Server Anywhere databases 479
XML and Adaptive Server Anywhere 480
XML data type
using 481
xml directive
using 508
XMLAGG function
using 510
XMLCONCAT function
using 511
XMLELEMENT function
using 512
XMLFOREST function
using 514
XMLGEN function
using 515