

GIS Investigations: Earth Science

to Accompany ArcGIS Version 9.x

Data Detectives: Where's the Water?

Student Activities

Michelle K. Hall
Science Education Solutions, Inc.

Anne K. Huth
Science Education Solutions, Inc.

C. Scott Walker
Harvard University

Larry P. Kendall
Science Education Solutions, Inc.

© 2008 Thomson Delmar Learning, a part of the Thomson Corporation.
Thomson, the Star logo and Delmar Learning are trademarks used herein under license.

For more information contact Thomson Delmar Learning,
5 Maxwell Drive, Clifton Park, NY 12065.

Printed in the United States of America
1 2 3 4 5 XXX 11 10 09 08 07

Or find us on the World Wide Web at <http://www.delmarlearning.com>

ALL RIGHTS RESERVED. No part of this work covered by the copyright hereon may be reproduced or used in any form or by any means—graphic, electronic, or mechanical, including photocopying, recording, taping, Web distribution or information storage and retrieval systems—without written permission of the publisher.

For permission to use material from this text or product, submit a request online at <http://www.thomsonrights.com>
Any additional questions about permissions can be submitted by email to thomsonrights@thomson.com

Library of Congress Cataloging-in-Publication Data on file for ISBN-10: 1-4180-6597-8 and ISBN-13: 978-1-4180-6597-3

Acknowledgments

Series Authors

Michelle K. Hall
Anne K. Huth
Jennifer A. Weeks
C. Scott Walker
Larry P. Kendall

Programmers

Jeff S. Jenness
Christian J. Schaller

Media Developers

Christian J. Schaller
Ted Stude

Technical Reviewers

Margaret Chernosky
Lydia Fox
Kathleen Friedman
Robert Kolvoord
Carla McAuliffe
Anne Ortiz
Alan Sills
Jessica Walker

Scientific Reviewers

Robert Butler
Peter Kresan
David Smith
Terry Wallace
Joseph Watkins

Technical Advisors

Tom Garrison
Cheryl Greengrove
Miles Logsdon
David Smith
Jim Washburne
Douglas Yarger

Proofreader

James Kevin

Data Providers

Robert Diaz
Virginia Institute of Marine Science
Don Pool
USGS Tucson Field Office
Pima County Department
of Transportation
Technical Services
Division
Nancy Rabelais
*Louisiana University
Marine Consortium*
Christopher Scotese
The Paleomap Project

Field Testers

Tekla Cook
Jo Dodds
Christine Donovan
Lillian Fox
Joshua Hall
Alan Kelley
Robert Kolvoord
Kathy Krucker
Kathy Likos
Daniel Montoya
Stephen Murray
Anthony Ochiuzzi
Graciela Rendon-Coke
Richard Spitzer
Anne Thames
Steven Uyeda
Margaret Wilch

Assistants

Tammy Baldwin
Christine Hallman
Sara McNamara
Marie Renwald
Megan Sayles

The authors would also like to thank the many scientists who took the time to learn about this project and share critical research data and expertise, and to the agencies and individuals that have given us permission to include their outstanding illustrations and photos.



Michelle K. Hall, Director
Science Education Solutions, Inc.
Los Alamos Research Park
4200 West Jemez Drive
Synergy Center Suite 301
Los Alamos NM 87544-2587
saguaro@scieds.com



Table of contents

Introduction

Getting started	i
Important notice for ArcGIS 9.2 users	i
Required software	i
Software and data preparation	i
Using ArcMap	iii
The ArcMap user interface	v
Basic operations	v
Troubleshooting and support options	viii
Working with large numbers	xii
Estimating percent area	xiii
Philosophy & design	xv
Philosophy	xv
Instructional design: The 5-E Learning Cycle	xvi
Learning science with a GIS	xvi
Module overview	xviii
Key concepts	xviii
Unit descriptions	xviii
National Science Education Standards	xxi
NSES cross-reference chart	xxii
ArcMap Quick Reference Sheet	xxiii

Investigations

Unit 1 - Where in the World?	1
Warm-up 1.1 — Global water sources	3
Investigation 1.2 — Measuring global water	7
Reading 1.3 — Utilizing global water reservoirs	17
Investigation 1.4 — What if the ice sheets melted?	23
Wrap-up 1.5 — Comparing major reservoirs	35
Unit 2 - The Renewable Resource	39
Warm-up 2.1 — Too little, too much	41
Investigation 2.2 — Global precipitation patterns	55
Reading 2.3 — Moving air and water	63

Investigation 2.4A—U.S. precipitation patterns	71
Investigation 2.4B—U.S. precipitation patterns	79
Investigation 2.5—Surface water flow	85
Wrap-up 2.6—The local water picture	93
Unit 3 - Using Water	99
Warm-up 3.1—Water in your world.....	101
Investigation 3.2A—Water for many uses	103
Investigation 3.2B—Water for many uses	109
Reading 3.3—Water at work	115
Investigation 3.4—Feeding a nation	121
Wrap-up 3.5—Meeting the challenge	129
Unit 4 - Water for a Desert City	131
Warm-up 4.1—Living in a desert	133
Investigation 4.2A—Water in the balance	137
Investigation 4.2B—Water in the balance	147
Reading 4.3—The Tucson Basin aquifer	151
Investigation 4.4—Groundwater issues	155
Investigation 4.5—Conserving water	163
Wrap-up 4.6—The voice of conservation	171

Getting started

Important notice for ArcGIS version 9.2 users

Mac OS X compatibility

At this time, ArcGIS 9.x is not compatible with any version of the Macintosh operating system. Users may get satisfactory, but slow, performance running ArcGIS under Virtual PC software on a Macintosh computer, but this is neither recommended nor supported.

What is the difference between ArcGIS, ArcView, and ArcMap?

For all practical purposes, you can think of these as three different names for the same geographic information system software.

Technically, ArcGIS is a family of related tools for managing geographic information systems on a variety of scales, ranging from Web servers to handheld devices.

One of these tools is a package for use on desktop computers, called ArcView. The ArcGIS 9.x desktop software package consists of three components, each interacting with geographic data in a unique way:

- ArcCatalog — management
- ArcMap — viewing and analysis
- ArcToolbox — modifying data

In these materials, you will only be using the ArcMap component of ArcGIS 9.x.

The *Data Detectives* series requires ArcGIS version 9.x software from ESRI, Inc. ArcGIS software is not included in the package, and must be licensed separately. These materials are NOT compatible with any version of ArcView GIS 1.x, 2.x, or 3.x, or ArcGIS 8.x. For more information on licensing options, go to

<http://www.esri.com/industries/university/index.html>

All *Data Detectives* modules have been tested on ArcGIS version 9.2 and have been found to work properly. However, many data frames and most of the data layers do not have a defined projection or coordinate system. This may cause problems if you attempt to use the *Data Detectives* datasets in student- or teacher-customized data frames that have an established projection. In this case, we recommend that you set the geographic datasets to WGS84 world coordinate system. Other projections and coordinate systems used in the *Data Detectives* series include UTM Zone 18 (New York City Case study in *Tropical Cyclones*), UTM Zone 12 (*Where's the Water?*), and Arizona State Plane – Central (*Where's the Water?*). Projection files for all the datasets in each activity will be posted to

www.scieds.com/saguaro

Required software

In addition to ArcGIS 9.x, these materials require the following software. Most are available as free downloads from their respective publishers.

- Saguaro Tools for ArcGIS 9.x
- Web browser (Internet Explorer, Netscape, Opera, Mozilla, etc.)
- Windows Media Player
- Google Earth (free version)
- Adobe Reader

Software and data preparation

Minimum system requirements

Your computer must meet the following minimum requirements to use these materials:

- 1 GHz or faster Intel-compatible CPU



- Windows 2000 or Windows XP (home or professional edition)
- 512 MB total RAM (more is better)
- CD-ROM drive (for installing data sets)
- Up to 840 MB of free space on hard drive for data (depending on module(s) used)

Preparation checklist

To prepare computers for using the *Data Detectives* ArcGIS 9.x series, complete the following checklist. Sources for downloading free helper software are provided.

- Install ArcGIS 9.x software according to the publisher's instructions.
- Download and install Google Earth (free version) according to the publisher's instructions (<http://earth.google.com/download-earth.html>).
- Download and install Adobe Reader according to the publisher's instructions (<http://www.adobe.com/products/acrobat/readstep2.html>).
- Install the SAGUARO Tools from the *Data Detectives* CD-ROM (see instructions below).
- Copy the module data to local hard drives or server (see instructions below).

Using more than one module?

The software requirements for all modules in the *Data Detectives* 9.x series are identical. If you are using more than one module in the series, you only need to install the applications once.

Each module does, however, have unique datasets that must be copied to a server or local hard drives.

Installing the SAGUARO Tools

The SAGUARO Tools are a set of custom ArcMap tools used in the *Data Detectives* modules. Copy the **SAGUARO Tools** folder from the *Data Detectives* CD-ROM to the hard drive. You only need to install the SAGUARO Tools once — all versions posted with the modules are identical.

The SAGUARO Tools folder contains an installer application (**SAGUARO_Install.exe**) and instructions for installation (**ST_readme.rtf**).

Copying data to your local hard drive or server

Copy the folders listed in the table on the following page to your computer's hard drive or to a shared server. If you are not using all of the units in the module, you may wish to only copy the data folders you are interested in using. Be sure to copy the entire unit folder and its contents, and do not change the name of any file or folder. The permissions for the unit folder and its contents should already be set to Read Only to prevent accidental alteration.



Data Detectives module name	Folders to copy
Dynamic Earth	ddde_unit_1 through ddde_unit_5
Tropical Cyclones	ddtc_unit_1 through ddtc_unit_4
Where's the Water?	ddww_unit_1 through ddww_unit_4
The Ocean Environment	ddoe_unit_1 through ddoe_unit_4

Monitor resolution

The modules were designed for use with a monitor resolution of at least 1024 by 768 pixels and highest (32-bit) color quality. Consult your computer lab or network administrator about setting monitor resolution, if necessary.

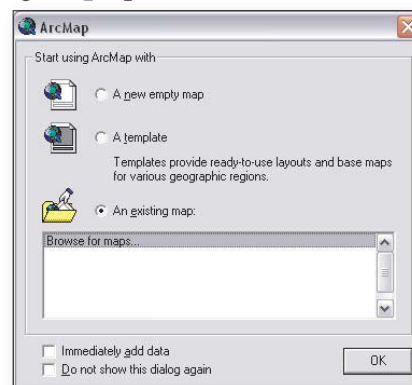
Problems?

Help with common installation and use problems can be found in the **Troubleshooting and support options** section of this introduction.

Using ArcMap

Launching ArcMap and opening project files

- To launch the ArcMap application, click the Start button on the Windows Taskbar and choose **All Programs > ArcGIS > ArcMap** (ArcMap).
- If you see the ArcMap dialog box, choose **Browse for file** under the **An existing map** option.



- Choose **File > Open**.
- Navigate to the appropriate unit folder installed on your local hard drive or server and open it.
- Locate the specified ArcMap document file and open it. (The .mxd file extension may or may not be visible, depending on how the computer has been set up.)

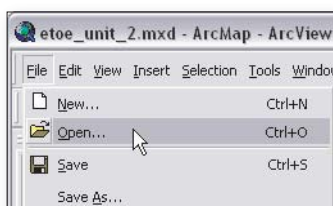
ArcMap shortcuts

In addition to the Start menu, an ArcMap shortcut may have been placed on the desktop or taskbar for your convenience.

Why doesn't the ArcMap startup dialog box appear?



If someone has checked the **Do not show this dialog again** checkbox, it will no longer appear each time you launch ArcMap.

“File > Open...” means...



Visual cues

Visual cues are used to make the investigation directions easier to follow.

- Text preceded by a computer symbol  is an instruction — something to do on the computer.
- Names of tools or buttons are capitalized and are followed by a picture of that item as it appears on screen — for example, the Identify tool .
- The > symbol between boldface words or phrases in text indicates a menu choice. Thus, **File > Open...** means “pull down the File menu and choose Open...”

Sidebars contain important information!

The page sidebars contain useful information such as definitions, explanations, illustrations, examples, reminders, warnings, tips, and hints. If you are not sure what to do, look for help in the sidebar first.

Closing map files

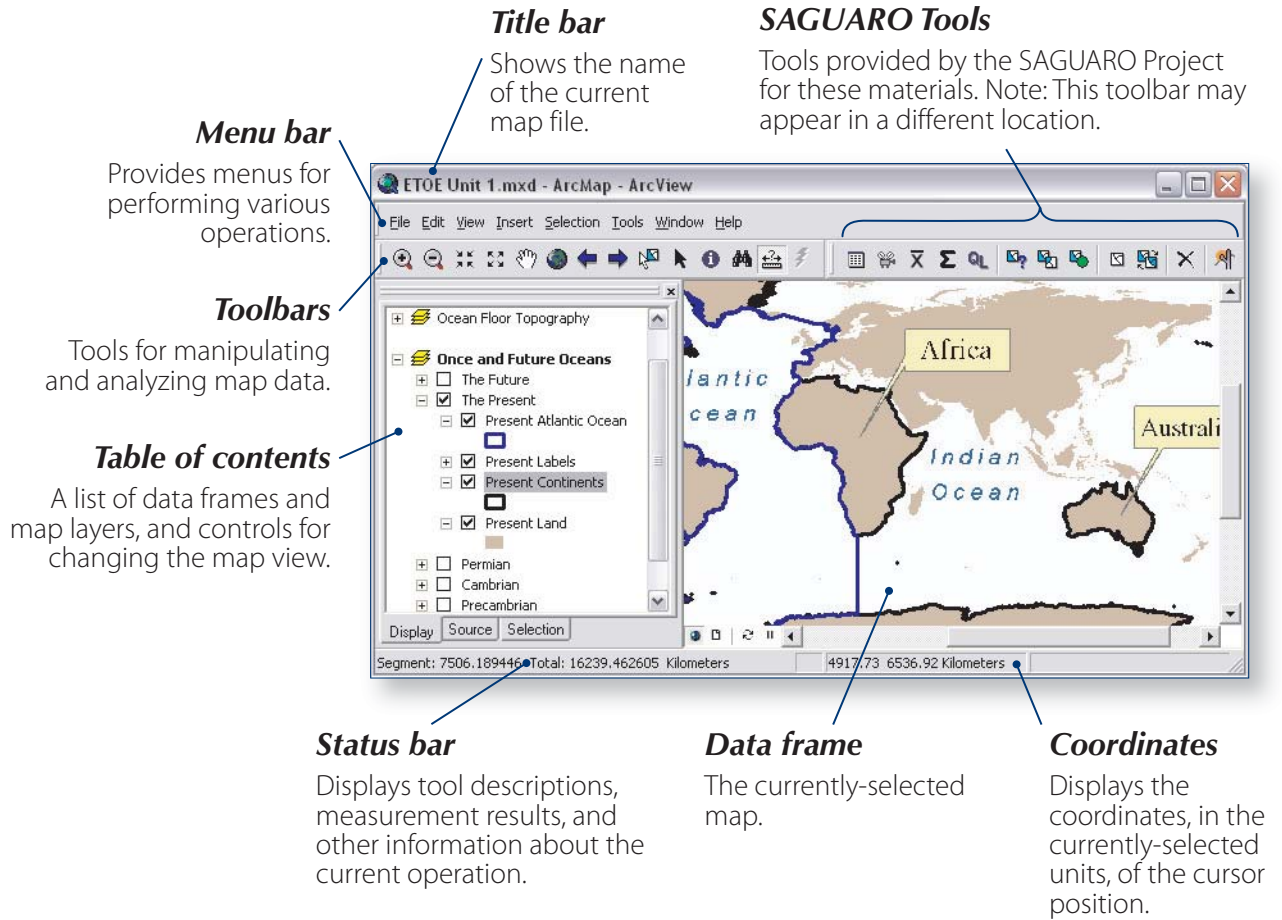
When you have completed an investigation or must stop for some reason, choose **File > Exit** and click **No** when asked if you want to save your changes.

What if I click “Yes”?

Don't worry if you click **Yes** when you close a map file. The files have been locked to prevent you from accidentally modifying them.



The ArcMap user interface



Basic operations

Activating a data frame

To activate a data frame, right-click its name and choose Activate from the pop-up menu. The title of the activated data frame is highlighted bold.

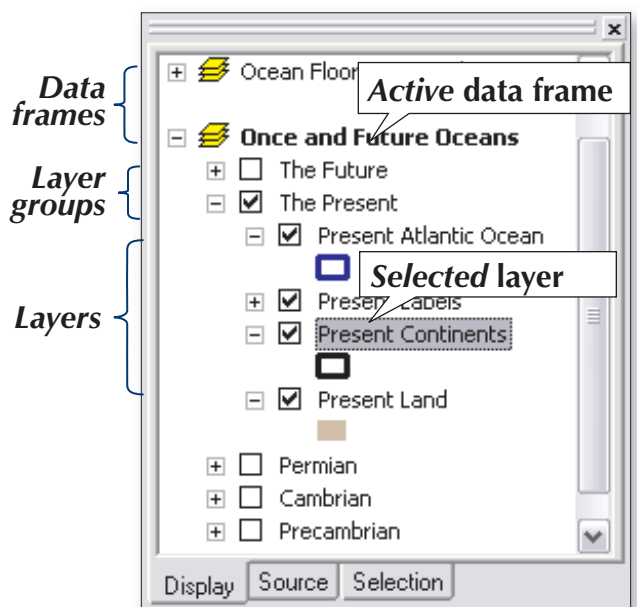
Expanding and collapsing data frames

To expand a data frame and show its layers, click the expand box **+**. To collapse a data frame and hide its layers, click the collapse box **-**.

Selecting layers or layer groups

To select a layer or layer group, click the layer or layer group name. Selected layers or layer groups are highlighted. To select multiple layers or layer groups, hold down the control key while clicking additional names.

Table of contents



Expanding and collapsing layers or layer groups

To expand a layer or layer group, click the expand box . To collapse a layer or layer group, click the collapse box .

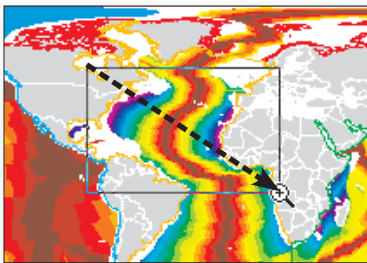
Turning layers or layer groups on and off

To turn a layer or layer group on, check the box in front of its name. To turn a layer or layer group off, uncheck the box in front of its name. If a layer is turned on but is not visible, it may be hidden behind another layer. Try turning off the layers *above* that layer in the Table of Contents.





Zooming

Zooming

The most efficient way to zoom in on a specific area is to drag a box around the area using the Zoom In tool. Drag diagonally from one corner of the area to the opposite corner, then release the button.

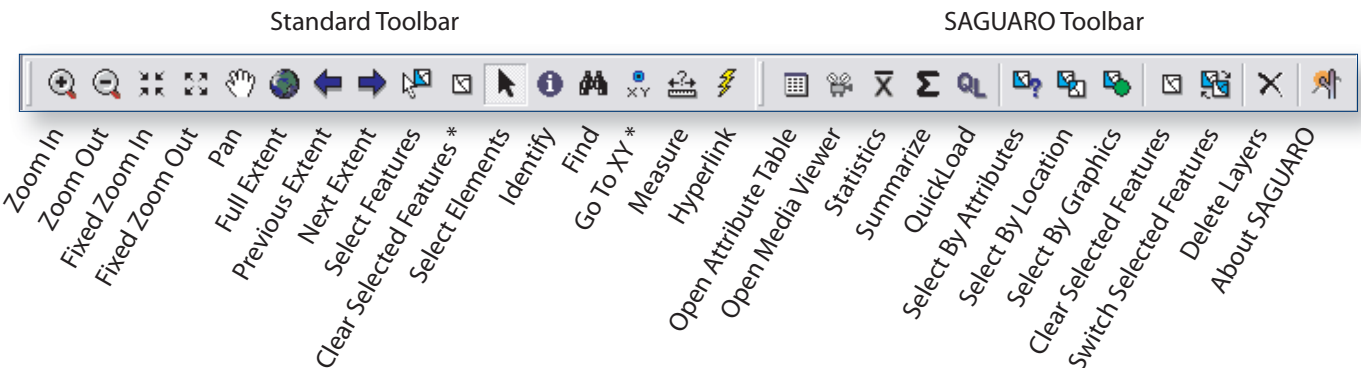


ArcMap has tools for zooming — enlarging and reducing areas of the map — that work like the tools you have used in other applications.

- To zoom in on an area, click and drag diagonally with the Zoom In tool  to outline the area on the map. When you release the button, the area you selected will rescale to fill the data frame window.
- To zoom out, click anywhere on the map with the Zoom Out tool .
- If you zoom in or out so far that you do not know where you are, undo previous zooms by clicking the Previous Extent button .
- To view the entire data frame, click the Full Extent button .

ArcMap 9.x tools

The tools and buttons of the standard ArcMap toolbar and the SAGUARO toolbar are labeled below. Tools marked with an asterisk (*) do not appear on the standard toolbar in ArcMap 9.0 or 9.1. The location and orientation of each toolbar can be changed by the user. The SAGUARO toolbar must be installed according to the instructions in the Instructor's Guide.



Opening ArcMap files (.mxd)

At the beginning of each investigation, there is an instruction like this:

 Launch ArcMap, and locate and open the **ddww_unit_1.mxd** file.

To do this, follow these steps:

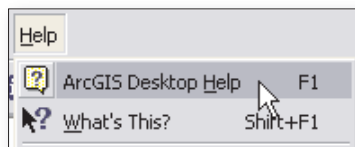
1. Click the Windows Start menu and choose **All Programs > ArcGIS > ArcMap**.
2. Choose **File > Open...** and navigate to where the ArcMap document file (also called the *map file*) is located. It should be in a folder named with the module abbreviation and unit number, such as **ddww_unit_1**. If you need help, your teacher can tell you where to find this file.

ArcMap document files end with an **.mxd** file extension. Depending on how your computer was set up, some file extensions may not be visible. In that case, the file will be named **ddww_unit_1**.

Troubleshooting and support options

ArcGIS help

This module provides all of the directions you need to complete the investigations using ArcGIS 9.x. If you have other questions about the capabilities of ArcGIS, choose **Help > ArcGIS Desktop Help**.



SAGUARO Tools

Problem

“The instructions say to click a tool or button that isn’t there.”

Solution

Right-click on any of the empty toolbars in the ArcMap interface and choose **Saguaro Tools** from the toolbar menu. If you don’t see Saguaro Tools on the toolbar menu, you must install the SAGUARO Tools for ArcGIS 9.x, according to the instructions provided with the installer application.

Media viewer and hyperlinks

Problem

“When I click the Media Viewer button and try to open an image (.jpg) or movie (.wmv) file, nothing happens or I get a message telling me that an application can’t be found.”

Solution

First, make sure a current version of the Windows Media Viewer application is installed, then set the file type associations for .jpg and .wmv files to open using Windows Media Viewer.

Problem

“When I turn on and activate a layer, the hyperlinks do not work or the image files cannot be found.”

Solution

If the hyperlinks are not working properly when the appropriate layer is on and active, then the **ArcGIS Desktop 9.1 Service Pack 2** probably needs to be installed. For download and installation instructions for this service pack, visit the ESRI Support Center at

<http://support.esri.com/index.cfm?fa=downloads.patchesServicePacks.viewPatch&PID=43&MetalID=1162>

Or, you can simply visit

support.esri.com



Use the search string “ArcGIS Desktop 9.1 Service Pack” to find Service Pack 2. Installing this service pack should fix any instability within ArcMap, as well as any problems using hyperlinks.

General

Problem

“At the beginning of an investigation, it tells me to locate and open the [filename].mxd file. Where is it?”

Solution

Your instructor or lab supervisor can tell you where to find the .mxd file for the investigation, assuming that it has been copied to your computer's hard drive or to a shared drive.

Problem

“Why doesn't the ArcMap startup dialog box appear when I launch ArcMap?”


Solution

If someone has checked the **Do not show this dialog again** checkbox, it will no longer appear each time you launch ArcMap. To restore this behavior, launch ArcMap, choose Tools > Options and click the General tab. Check the **Show setup dialog** option and click **OK**. The setup dialog will appear the next time you launch ArcMap.

Problem

“When I open a data frame, sometimes the map does not finish drawing on the screen, leaving it either incomplete or totally blank.”

Solution

This occurs sometimes under both ArcGIS versions 9.1 and 9.2. To remedy this, you can click the Refresh View button  at the bottom of the map screen, and the map should redraw properly.

Problem

“When I turn a layer on or off in the Table of Contents, the data frame view doesn't change.” Or “When I do some operation, nothing appears to happen.”

Solution

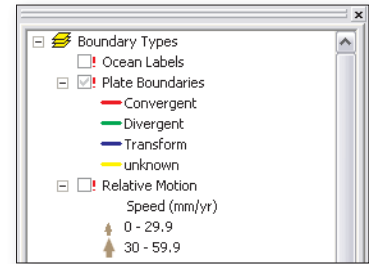
You probably have the wrong data frame activated in the Table of Contents. Right-click the name of the data frame you are using in the Table of Contents and choose **Activate**. (Shortcut: Alt-click items in the Table of Contents to activate them.)

Problem

“When I open an .mxd file, one or more of the layers in the Table of Contents have a red exclamation point after them, and the data frame does not show all of the layers.”


Solution(s)

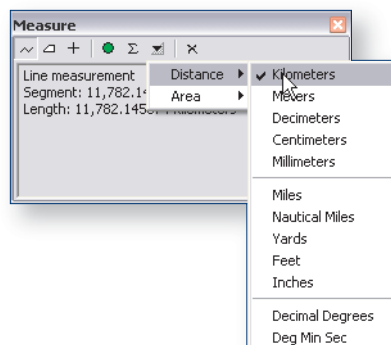
Someone may have moved, renamed, or deleted the data files associated with the .mxd file. The best solution is to reinstall the unit folder. If this is not possible, check to be sure that the files are there and have not been moved or renamed. Then, you can reassociate a layer in the Table of Contents with its data file by turning on the layer and using the Set Data Source dialog box that opens to browse to the correct file. If there are multiple “lost” files, a single restored association may restore all of them.

***Differences between ArcMap 9.1 and ArcMap 9.2***

There are minor differences between the user interface of ArcMap versions 9.1 and 9.2. While these differences do not affect the outcomes of the *Data Detectives* investigations, instructors may need to point out minor changes to a few procedures.

Measure tool

- In ArcMap 9.1, measurements made with the Measure tool  appear in the left side of the Status Bar (at the bottom of the window).
- In ArcMap 9.2, a Measure window appears when you click the Measure tool. Before measuring, choose the desired distance units from the **Choose Units** menu. By using appropriate units, students may be able to skip tedious conversion calculations in some investigations.



Students may also find the **Snap to Features (on/off)** option on the Measure window toolbar useful. When it is turned on, measurement vertices automatically snap to the nearest map feature.

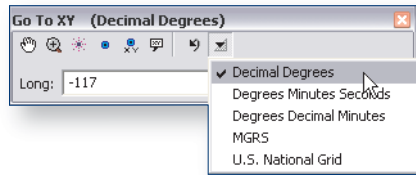




Window names

The names of some windows have been simplified in ArcMap 9.2. For example, the **Identify Results** window in ArcMap 9.1 is simply named **Identify** in ArcMap 9.2.

Toolbar buttons

Two buttons on the standard toolbar of ArcMap 9.2 do not appear on the ArcMap 9.1 toolbar.



- The Clear Selected Features button  clears any features highlighted by a selection operation. It is identical to the Clear Selected Features button on the SAGUARO toolbar.
- The Go To XY button  allows users to enter coordinates in any of several coordinate systems to center the display at that location. Click the **Units** menu to enter coordinates in the desired system. The current units are shown in parentheses on the window title bar.

Windows Vista compatibility

Question

“I use Microsoft’s Windows Vista. Will ArcGIS 9 work in this environment?”

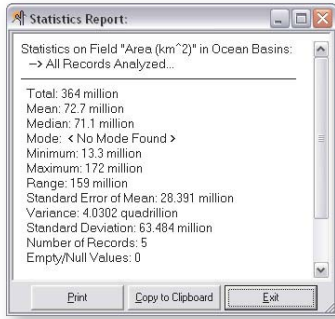
Answer

According to ESRI’s Web site at the time of this publication:

“ArcGIS 9.2 products are not currently supported on the Microsoft Windows Vista release. ESRI is committed to supporting ArcGIS on the Windows Vista operating system and will be adding support for Windows Vista in future service packs (after ArcGIS 9.2 Service Pack 2) and future releases.

“ArcGIS 9.1 and earlier is not supported on the Microsoft Windows Vista operating system and there are no plans to support ArcGIS 9.1 and earlier on this operating system in the future.”

However, the ESRI Web site also mentions, with regard to Vista compatibility, that “ArcGIS works with Vista but there are some issues with the License Manager”, and that “The License Manager does not function properly. It is possible to manually start LM from a command prompt.”



Working with large numbers

Some of the numbers you will work with in these investigations are quite large. When talking about the amount of water in the ocean or the energy of an earthquake or hurricane, you routinely use values in the billions or even trillions. Where possible, ArcGIS has been modified to make these very large and very small numbers easier to read. For example, in the Statistics Report window shown at left, the total area is given as 364 million, rather than 363958342077361 square kilometers.

Occasionally, you will need to convert millions to billions or thousands, or vice versa. For example, to convert the **Mean** value in the window at left from millions to billions, move the decimal point three places to the *left*. To go from millions to thousands, move the decimal three places to the *right*.

$$72700 \text{ thousand} = 72.7 \text{ million} = 0.0727 \text{ billion}$$

Rounding examples

For example, if your number is

319,740,562.85

To round to the nearest ten million:

- Find the ten millions digit (1).
- Look at the number to its right (9). Because it is between 5 and 9, add one to the ten millions digit to make it 2.
- Change the whole numbers to the right of the ten millions digit to zeros and drop the decimal point and everything to its right. The result is **320,000,000**.

Rounding to the nearest...

- ...million (1,000,000) = **320,000,000**
(adding 1 to 319 gives 320)
- ...hundred thousand (100,000) = **319,700,000**
- ...ten thousand (10,000) = **319,740,000**
- ...thousand (1,000) = **319,741,000**
- ...hundred (100) = **319,740,600**
- ...ten (10) = **319,740,560**
- ...one (1) = **319,740,563**
- ...tenth (0.1) = **319,740,562.9**

To round to the nearest 0.1 million:

- Find the 0.1 millions digit (7). This is also called the hundred thousands digit.
- Look at the number to its right (4). Because it is between 0 and 4, do not add one to the 0.1 millions digit.
- Insert the decimal point in the proper location. The result is **319.7 million**.

Rounding

Most of these numbers are approximations, so it does not make sense to be overly precise when you are calculating or recording them. Look at the number written below, and the place value of each of the digits. Face it—when you are talking about nearly 149 billion of something, who cares about hundred-thousandths, or even tens of millions?

hundred billions
 ten billions
 billions
 hundred millions
 ten millions
 millions
 hundred thousands
 ten thousands
 thousands
 hundreds
 tens
 ones
 tenths
 hundredths
 thousandths
 ten-thousandths
 hundred-thousandths

148,753,982,067.95249

Throughout these investigations, you will be asked to round answers to a particular value and number of decimal places, such as “Round your answer to the nearest 0.1 million.” Rounding numbers is simple, if you follow these steps. Examples are shown at the left.

- Look only at the numeral to the right of the place value you are rounding to. For example, when rounding to the nearest thousand, look only at the numeral in the hundreds place.
- If the numeral to the right is 0-4, do not change the number you are rounding to. If the number to the right is 5-9, add one to the number you are rounding to.
- Change whole numerals to the right of the place you are rounding to into zeros, and omit all unused decimal places.
- For any number less than 1, include a zero to the left of the decimal point. (Instead of *.79 billion*, write *0.79 billion*.)



Rounding decimal fractions

Rounding decimals works the same way, except that you are rounding to tenths, hundredths, thousandths, and so on. Do not add zeros to the right of the decimal point. In other words, rounding 2.587 to the nearest tenth is 2.6, *not* 2.600.

Estimating percent area

You will occasionally be asked to estimate the percent area covered by land, ocean, or some other feature. This is a difficult skill for some people to master, but can be learned with practice.

Cloud cover exercise

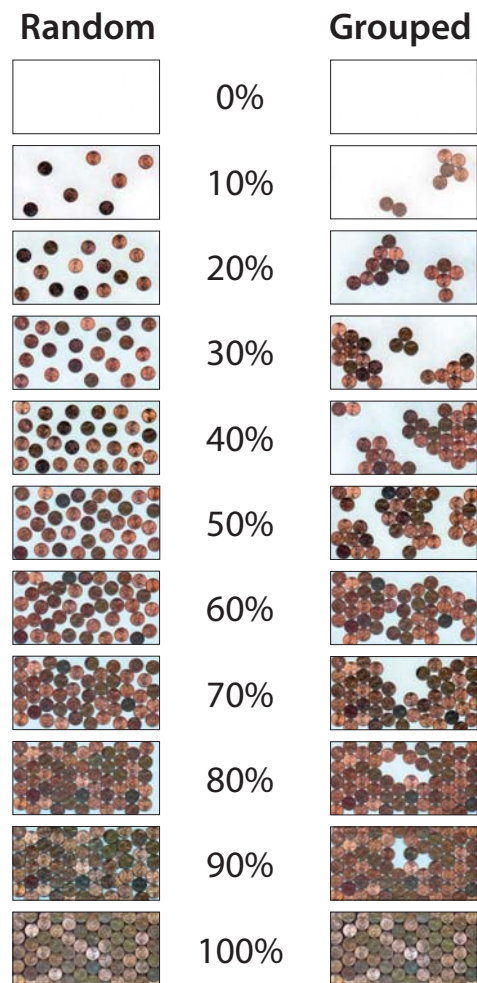
Here is a simple activity that demonstrates the confusing nature of cover estimates.

- Take two full sheets of blue paper and one of white paper. The blue paper represents sky, and the white paper represents clouds.
- Cut the white sheet in half. Tear or cut the first half of the white sheet into large pieces and glue them onto one of the blue sheets without overlapping.
- Repeat the step above with the other half of the white sheet and the other blue sheet. This time, cut or tear the white sheet into small chunks before gluing them on.

In both cases, the cloud cover is 50 percent. Half of the blue sky is covered by white clouds, but the sheet covered by large clouds appears more open than the sheet covered by small clouds.

Comparing to standards

One method of estimating coverage is to compare to visual standards. When estimating coverage you need to consider how the features are arranged.

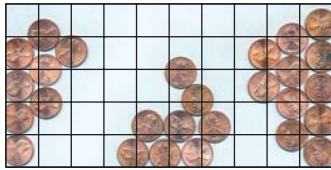


Gridding

Another approach to estimating coverage is to divide the area up into a grid, either mentally or physically, and determine the number of grid squares that are at least half-covered. To find the percent coverage, calculate the ratio of covered squares to total squares and multiply by 100.

In the example at left, approximately 20 of the 50 squares are at least half covered.

$$20/50 \times 100 = 40\% \text{ coverage}$$



Philosophy & design

Philosophy

Thinking scientifically

An Earth scientist makes a living by observing and measuring nature. Whether recording and analyzing earthquakes or measuring subtle changes in sea surface temperature over many decades, a successful Earth scientist relies heavily on his or her ability to recognize patterns. Patterns in space and time are the keys to many of the great discoveries about how Earth works. The investigations in this series are designed to help you develop your ability to recognize and interpret nature's fundamental patterns by exploring recent scientific data using a computer and geographic information system (GIS) software.

Most of these patterns are presented through maps, which are among scientists' most important tools. Maps allow you to visually explore spatial relationships between phenomena such as surface winds and ocean currents; natural features such as continents and ocean basins; and human features such as countries and cities. Behind each map layer is a table containing an extensive database of information about each feature in that layer. By carefully analyzing these data, you can identify patterns in the data that are difficult to discover through visual examination alone.

Planning to learn

Each unit of the series leads you through a well-tested learning process that builds upon your existing knowledge. Each unit begins with a warm-up exercise designed to stimulate your thinking about the major concepts presented in the unit and the key questions that motivate and guide scientific research. It will help you frame your own questions about the topic—questions that you may be able to answer for yourself as you learn more in later investigations.

In the first investigation, you will explore maps and data looking for patterns. As you examine these patterns, you should ask yourself questions such as:

- Where do they occur? (or not occur?)
- Why does this pattern occur here and not elsewhere?
- What might cause this pattern?
- What else is spatially associated with this phenomenon?
- Do these things usually occur together in the same places?
- How has this pattern changed spatially through time?

What is a GIS?

GIS provides tools for organizing, manipulating, analyzing, and visualizing information about the world using digital maps and databases.



5-E Learning Cycle

Engage (Warm-up)

This stage is designed to help you understand the learning task and make connections to past and present learning experiences. It should stimulate your interest and prompt you to ask your own questions about the topic.

Explore (Investigation)

Here you investigate key concepts by exploring scientific, geographic, and economic data sets. You begin identifying patterns in the data and connecting them to Earth processes. This further stimulates curiosity and new questions develop. You may diverge from the written investigation to explore your own questions, continually building on your knowledge base. Through this process of questioning and exploration, you begin to formulate your understanding of basic concepts.

Explain (Reading)

This stage introduces you more formally to the lesson's scientific and geographic concepts. You should gain a better understanding of major concepts, acquire important terminology, and verify answers to questions or problems posed earlier. In addition, more abstract concepts not easily explored in earlier activities are introduced and explained.

Elaborate (Investigation)

Here you will expand on what you have learned and apply your newfound knowledge to different situations. You will test ideas more thoroughly and explore deeper relationships.

Evaluate (Wrap-up)

At the end of each unit, you will use your understanding of key concepts to propose explanations and solutions to local or regional problems.

A brief reading provides key background information about scientific principles and concepts, and should help you begin to answer the questions raised earlier.

Finally, in one or more additional investigations, you apply your new knowledge to solve a particular problem. This helps you measure your understanding of the material and apply the concepts you have learned to a new location or situation.

GIS made easier

The purpose of these investigations is not simply to learn how to use GIS, but to use one as a tool to explore and learn about natural processes and features and how they relate to humans and human activities. For this reason, all of the data have been assembled into ready-to-use projects, and complex operations have been eliminated or simplified. Although it is helpful for you to have basic computer skills, you do not need experience with ArcGIS software to complete the investigations. The ArcMap user interface has been modified to simplify complex and repetitive processes. Directions for each task are provided in the text, so you will learn to use the tool as you explore with it. The investigations barely scratch the surface of the data that have been provided, and we encourage you to explore the data on your own.

Instructional design: The 5-E Learning Cycle

This series was designed using the 5-E Learning Cycle model, which promotes inquiry and exploration as a process for learning science. The Learning Cycle, originally credited to Karplus and Thier (*The Science Teacher*, 1967) and later modified by Roger Bybee for the Biological Sciences Curriculum Study (BSCS) project, proposes that learning something new or understanding something familiar in greater depth involves making sense of both prior experience and firsthand knowledge gained from new explorations. The 5-E model divides learning experiences into five stages: Engage, Explore, Explain, Elaborate, and Evaluate. Each stage builds on the previous stages as you construct new understanding and develop new skills.

Learning science with a GIS

Geographic Information Systems (GIS) provide an ideal vehicle for learning topics in Earth and environmental sciences and helping you develop scientific problem-solving skills. Formerly limited to professionals with access to high-end computer workstations, today GIS is accessible to many, and is being used by students from elementary through graduate school. GIS has a number of advantages over traditional materials when used as an instructional tool. These include:

- **Data visualization**—GIS-based investigations allow you to identify and characterize relationships by manipulating



multiple visual representations of data, including dynamic and customizable maps, tables, charts, and animations.

- **Data analysis**—Analytical tools enable you to quantify relationships within and among spatial data sets using database functions, statistical analyses, and spatial overlay operations.
- **Multimedia integration**—Other forms of digital information, including animations, video, audio, and digital stills, can be woven into GIS activities, greatly enriching and extending your learning experience.
- **Technology literacy and transferable skills**—The use of GIS promotes technology literacy and provides you with skills transferable to your own research, other course work, and the workplace.

GIS-based instructional materials have the potential to enhance your learning by reinforcing concepts through discovery and by improving problem solving, visualization, and computational skills.

Module overview

In this module, students will examine the movement of water through the hydrologic cycle with an emphasis on factors controlling precipitation, surface flow, and groundwater recharge, and the importance of wise water management.

Module objectives

In this module, students will

- identify questions regarding the use and management of global water resources.
- use technology and mathematics to improve their investigations of water resources.
- formulate and revise explanations for precipitation and water flow patterns using logic and evidence.
- identify local, regional and global challenges of managing water resources.

Learning objectives

Unit 1 objectives

In this unit, students will

- Understand the distribution of global water resources and the movement of water through the hydrologic cycle.
- Estimate the volume of water contained in the three largest water reservoirs.
- Explore technologies used to extract water resources.
- Relate how climatic changes would alter the distribution of water and impact the global population.

Key concepts

Where's the Water? emphasizes six basic concepts.

- Water on Earth exists in several large global reservoirs and moves among these reservoirs through various processes collectively called the hydrologic cycle.
- Freshwater comprises a very small percentage of Earth's water supply, and much of this freshwater is not easily accessible.
- Wind, weather fronts, convection, and topography determine where precipitation occurs.
- Topography and other characteristics of the land surface determine how surface water moves.
- Human-related and environmental factors influence our ability to utilize water resources.
- Wise water management is crucial for sustaining the current and future global population.

Unit descriptions

This module contains four units that introduce students to the hydrologic cycle, patterns of water use and precipitation, and various water resources issues around the world and in the United States.

Unit 1 – Where in the World?

• **Warm-up 1.1 – Global water sources**

Students identify global water reservoirs and predict the relative size and accessibility of each reservoir. Students also consider how these reservoirs are used and the challenges of maintaining a safe water supply in their community.

• **Investigation 1.2 – Measuring global water**

Students examine ocean bathymetry and estimate the volume of water held in three important water reservoirs: oceans, ice sheets, and the atmosphere.

• **Reading 1.3 – Utilizing global water reservoirs**

Students are provided with a more complete understanding of



the hydrologic cycle and an explanation of the technology used to obtain freshwater from oceans, ice sheets, and the atmosphere.

- **Investigation 1.4 – What if the ice sheets melted?**

Students examine the potential effects of global warming on world population. They visualize how a change in sea level resulting from the melting of polar ice sheets would impact densely populated coastal areas and croplands.

- **Wrap-up 1.5 – Comparing major reservoirs**

Students discuss the advantages and disadvantages of obtaining and using water from oceans, ice sheets, and the atmosphere. They also use Internet resources to identify countries that could extract drinking water from these reservoirs.

Unit 2 – The Renewable Resource

Unit 2 objectives

In this unit, students will

- Examine how the movement of water through the hydrologic cycle generates weather that impacts society.
- Explore patterns of precipitation and surface flow at various scales.
- Discover how topography, winds, fronts, and convection influence precipitation.
- Identify factors driving local precipitation.

- **Warm-up 2.1 – Too little, too much**

Students read historical accounts of severe droughts and floods in the U.S. and examine statistics detailing monetary losses that illustrate the economic, ecological, and sociological effects of too little or too much precipitation.

- **Investigation 2.2 – Global precipitation patterns**

Students examine patterns of global precipitation and the role it plays in the formation of two important biomes—deserts and rainforests.

- **Reading 2.3 – Moving air and water**

Students are given an in-depth explanation of how winds influence the formation of precipitation and how topography influences the movement of runoff.

- **Investigations 2.4A and 2.4B – U.S. precipitation patterns**

Students investigate how wind and topography influence precipitation. They compare average seasonal paths of the jet stream to precipitation trends, and use graphs to examine the relationship between topography and precipitation.

- **Investigation 2.5 – Surface water flow**

Students examine the influence of aspect on surface water flow in different regions of the U.S. They compare the mean precipitation and annual discharge in important U.S. watersheds in disparate climates, and calculate evapotranspiration and infiltration to determine how these processes affect runoff.

- **Wrap-up 2.6 – The local water picture**

Students use Internet weather resources to determine how uplift triggered by topography, weather fronts, winds, and convection have contributed to recent precipitation events in the U.S.

Unit 3 objectives

In this unit, students will

- Understand how water is used in different economic sectors.
- Investigate patterns in water use and consumption, and relate them to precipitation patterns.
- Analyze agricultural practices in the U.S. in the context of water resource management.
- Identify local and regional challenges in water management and formulate potential solutions to these problems.

Unit 4 objectives

In this unit, students will

- Identify challenges regarding the use and management of water resources in arid environments.
- Understand the characteristics of an aquifer and the physical and societal effects of groundwater removal.
- Conduct studies of groundwater use, aquifer recharge, and the physical and economic impacts of groundwater withdrawal.
- Examine potential conservation strategies and develop a plan to address future water needs.

Unit 3 – Using Water

- **Warm-up 3.1 – Water in your world**

Students contemplate the role of water in their everyday life by categorizing the ways in which water is used in their home and their community.

- **Investigations 3.2A and 3.2B – Water for many uses**

Students investigate water use and consumption patterns by major economic sectors in the U.S., and examine relationships between these patterns and precipitation.

- **Reading 3.3 – Water at work**

Students read about water use in the domestic, commercial, industrial, agricultural, mining, and power sectors and are introduced to issues regarding conservation and sustainability of our water resources.

- **Investigation 3.4 – Feeding a nation**

Students examine patterns in precipitation and agricultural products and practices in the U.S. They explore relationships between where crops are grown, irrigation use, surface water availability, and location of large groundwater aquifers. Finally, they estimate the amount of water in the High Plains Aquifer, and calculate the number of years until its water supply is depleted at the current withdrawal rate.

- **Wrap-up 3.5 – Meeting the challenge**

In this open-ended investigation, students use information learned in previous activities to discuss regional and local issues of water quality and quantity. Students evaluate how these issues affect them personally, and formulate recommendations to address local and regional challenges.

Unit 4 – Water for a Desert City

- **Warm-up 4.1 – Living in a desert**

Students are introduced to the challenges of managing water resources in desert communities, focusing specifically on Tucson, Arizona, a city in the Sonoran Desert of the southwestern U.S.

- **Investigations 4.2A and 4.2B – Water in the balance**

Students investigate precipitation, stream discharge, and aquifer recharge of the Tucson area. They examine the interaction between precipitation, population growth, and water use, and how this relationship influences the amount of water withdrawn and recharged to the aquifer.

- **Reading 4.3 – The Tucson Basin aquifer**

Students learn about the composition and structure of aquifers. They are introduced to potential physical and economic consequences of groundwater withdrawal.



- ***Investigation 4.4 – Groundwater issues***

Students examine current and predicted environmental and economic consequences of excessive groundwater withdrawal from the Tucson Basin aquifer.

- ***Investigation 4.5 – Conserving water***

Students investigate the amount of water used in daily activities, the cost of water, and the feasibility of harvesting rainwater to meet some of Tucson's water needs.

- ***Wrap-up 4.6 – The voice of conservation***

In this open-ended investigation, students use knowledge gained in previous activities to develop a conservation plan that addresses various aspects of Tucson's water-supply problem.

National Science Education Standards

The *Data Detectives* series is correlated to the National Science Education Standards (NSES), as set forth by the National Research Council. The cross-reference chart on the following page shows the standards for grades 9-12 that are either directly or indirectly addressed by each lesson and each unit.

Additional documents correlating these materials with national standards in geography and mathematics may be available from the *Data Detectives* Web site at www.scieds.com/saguaro.

NSES cross-reference chart, grades 9-12

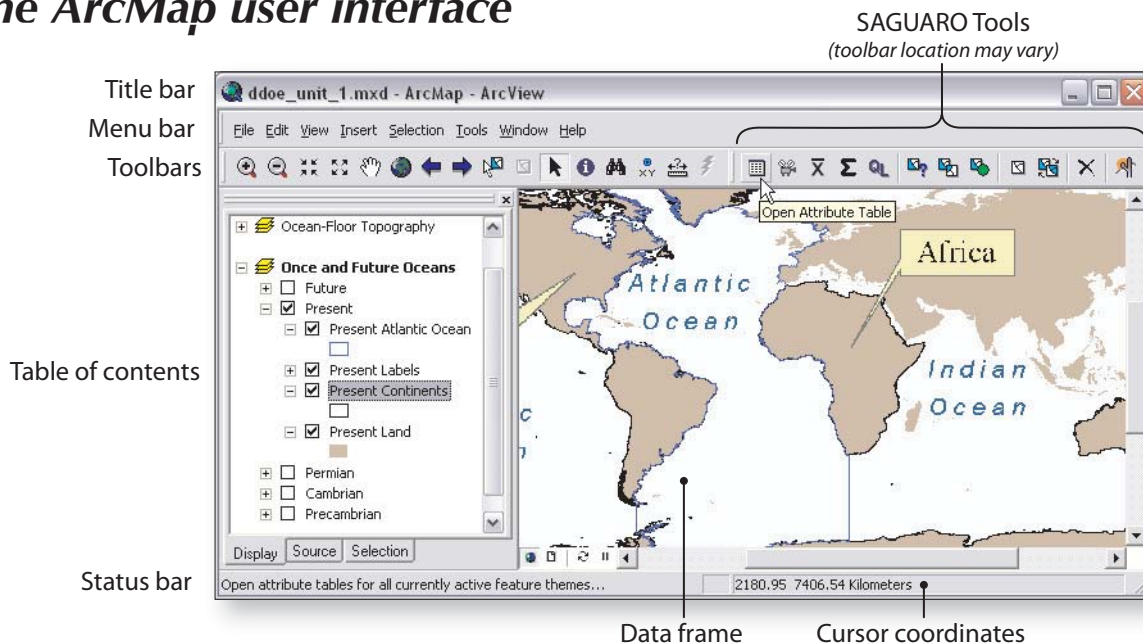
Content Standards	Unit 1 Where in the World?					Unit 2 The Renewable Resource						Unit 3 Using Water					Unit 4 Water for a Desert City					
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5	4.6
Unifying Concepts and Processes																						
Systems, order, and organization	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X
Evidence, models, and explanation	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X
Constancy, change, and measurement	X	X	X	X		X	X		X	X	X		X		X		X	X		X	X	
Evolution and equilibrium		X	X	X											X		X	X	X	X		
Form and function	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Science as Inquiry																						
Abilities necessary to do scientific inquiry		X		X	X		X		X	X	X		X		X	X		X		X	X	X
Understanding about scientific inquiry		X		X	X		X		X	X	X		X		X	X	X	X		X		X
Earth and Space Science																						
Energy in the Earth system		X	X	X	X	X	X	X	X	X	X		X									
Geochemical cycles	.	X	X	X	X	.	X	X	X	X	X	.	.	.	X	.	X	X	X	X	X	X
Origin and evolution of the Earth system			X																			
Origin and evolution of the universe																						
Physical Science																						
Structure of atoms																						
Structure and properties of matter																						
Chemical reactions																						
Motions and forces																						
Conservation of energy and increase in disorder																						
Interactions of energy and matter																						
Science and Technology																						
Abilities of technological design		X	X	X			.	.	.	.		.		.	.		.		.	.	X	
Understandings about science and technology		.	X	X			.	.	X	X		X	X	X		X	X		X	X	X	X
Science in Personal and Social Perspectives																						
Personal and community health	X		X		X	X								X								
Population growth														X			X	X		X	X	X
Natural resources	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Environmental quality	X		X		X	X				X		X			X	X						
Natural and human-induced hazards	X		X	X	X	X				X		X	X	X	X	X	X	X	X	X	X	X
Science and technology in local, national, and global challenges	X	X	X	X	X	X				X				X	X	X	X	X	X	X	X	X
History and Nature of Science																						
Science as a human endeavor	X	X	X	X	X	X	.	X	X	.	.	.	.	X	X	X	X	.	.	X	X	X
Nature of scientific knowledge	.	X	X	X	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.
Historical perspectives	.	.	X	.	.	X	.	.	X	.	.		.	X	X	.	X	X	X	X	X	.

X = standard is directly addressed **.** = underlying concept throughout unit



ArcMap Quick Reference Sheet

The ArcMap user interface



To see the name of a tool...

Position the cursor over the tool on the toolbar and wait until the yellow tool tip box appears. Tools are also described in the Status Bar.

To activate a data frame...

Right-click its name and choose **Activate** from the pop-up menu. The title of the activated data frame is highlighted bold.

To expand or collapse a data frame...

Click the expand box or the collapse box in front of the layer or data frame name.

To select a layer or layer group...

Click the layer or layer group name to highlight it. To select multiple layers or layer groups, hold down the control key while clicking additional names.

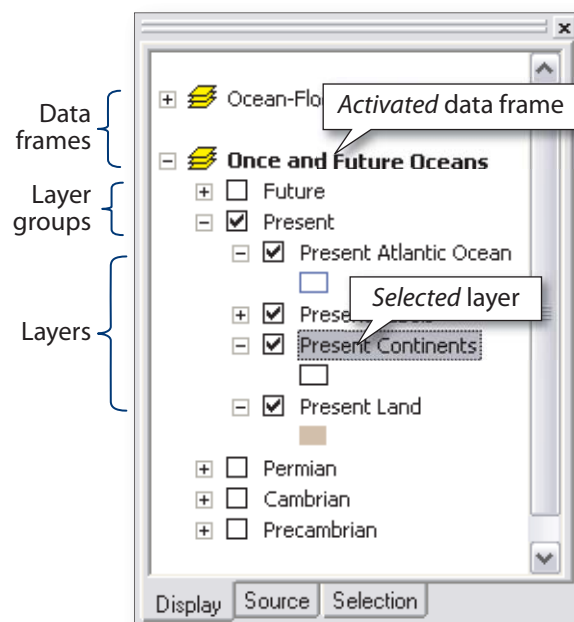
To expand or collapse a layer or layer group...

Click the expand box or the collapse box in front of the layer or layer group name.

To turn a layer or layer group on or off...

Check or uncheck the box in front of the layer or layer group name. If a layer is on but is not visible, it may be hidden behind another layer. Try turning off layers above that layer.

Table of contents

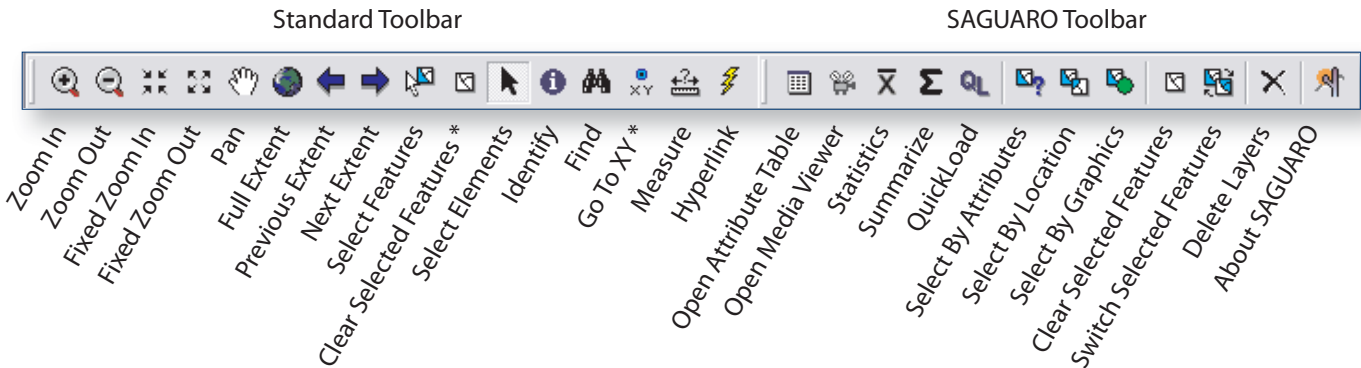


Data Detectives: Where's the Water?

Introduction

ArcMap 9.x tools

The tools and buttons of the standard ArcMap toolbar and the SAGUARO toolbar are labeled below. Tools marked with an asterisk (*) do not appear on the standard toolbar in ArcMap 9.0 or 9.1. The location and orientation of each toolbar can be changed by the user. The SAGUARO toolbar must be installed according to the instructions in the Instructor's Guide.



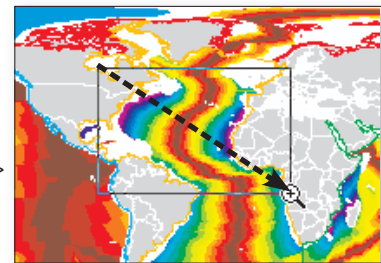
Opening ArcMap files (.mxd)

At the beginning of each investigation, there is an instruction like this:

 Launch ArcMap, and locate and open the **ddww_unit_1.mxd** file.

To do this, follow these steps:

1. Click the Windows Start menu and choose **All Programs > ArcGIS > ArcMap**.
2. Choose **File > Open...** and navigate to where the ArcMap document file (also called the *map file*) is located. It should be in a folder named with the module abbreviation and unit number, such as **ddww_unit_1**. If you need help, your teacher can tell you where to find this file.







ArcMap document files end with an .mxd file extension. Depending on how your computer was set up, some file extensions may not be visible. In that case, the file will be named **ddww_unit_1**.

If your teacher gives you different directions for opening the map files, follow those directions instead!

Zooming

ArcMap has tools for zooming — enlarging and reducing areas of the map — that work like the tools you have used in other applications.

- To zoom in on an area, click and drag diagonally with the Zoom In tool  to outline the area on the map. When you release the button, the area you selected will rescale to fill the data frame window.
- To zoom out, click anywhere on the map with the Zoom Out tool .
- If you zoom in or out so far that you do not know where you are, undo previous zooms by clicking the Previous Extent button .
- To view the entire data frame, click the Full Extent button .



