

“On using a Geographic Information System to Store, Retrieve and Disseminate Water Resources Data”

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ABSTRACT

Geographic Information Systems (GIS) can be used for a variety of applications, the most popular being spatial analysis. Another excellent use of GIS is database management, or simply put “record keeping”. Santa Barbara County Water Agency (SBCWA), a division of the Santa Barbara County Public Works Department (SBCPWD), is an agency with tasks of water planning, water conservation and efficiency. SBCWA concerns itself with both quantity and quality issues related to the surface and ground waters in Santa Barbara County, California, USA.

In response to the need to effectively store and quickly retrieve information and data about the water resources of the area, as well as graphically display, correlate and analyze, and disseminate to co-workers within the Public Works Department, other County departments, colleagues, researchers and contractors working with Santa Barbara County, SBCWA has developed a comprehensive GIS database system that effectively gathers water databases of enormous sizes, raster imagery, general information and data into an electronic format. This comprehensive “electronic format” GIS database essentially replaces several file cabinets of paper files, making the process of retrieving and disseminating data much more efficient and thus cost effective.



INTRODUCTION

Santa Barbara County Public Works Department (SBCPWD) is responsible for roadway infrastructure, solid waste disposal and recycling, surveying, flood control, and water resources planning in the unincorporated areas within Santa Barbara County, California, USA. In order to provide adequate services in these areas to the citizens of the community the Public Works Department is utilizing GIS in many aspects of daily tasks as well as long-term objectives. A few examples of this are:

- The Road and Transportation divisions use GIS to track roadway maintenance activities
- The Solid Waste division uses GIS to map landfill locations against groundwater basins
- The Surveyor uses GIS to perform spatial analysis on its record and property deed drawings
- The Flood Control division uses GIS to track channel and stream maintenance activities
- The Water Agency division uses GIS to store, retrieve and disseminate records of groundwater level, stream flow, rainfall and water quality

This paper will focus on the last point: *Using a Geographic Information System to Store, Retrieve and Disseminate Water Resources Data*. We will explore how to acquire, create and manage an efficient database, how to effectively display and use data in both *ArcMap* and *ArcView*, and how to quickly disseminate the information to colleagues or co-workers whom need the data to perform some type of hydrological analysis.

HYDROLOGICAL DATASETS

Santa Barbara County Water Agency (SBCWA) concerns itself with both quantity and quality issues related to the surface and ground waters in Santa Barbara County, California, USA. The datasets we will focus on are groundwater level and quality, stream flow quantity and quality, and rainfall depth. Groundwater information is used to calculate groundwater basin storage and analyze water quality trends. Stream flow information is used to calculate watershed runoff and groundwater basin loading. Rainfall information is used to calculate groundwater basin recharge and establish rainfall-runoff relationships.

Groundwater Level

Groundwater level information is currently generated from around 275 dedicated observation wells and piezometers throughout County, and adjacent areas that drain into the County. In addition, historical records exist on approximately another 720 sites that were once observation sites, or have some information to offer from when the well was drilled. SBCWA currently has around 127,000 records of “depth to water” readings in its groundwater level database, making efficient database design imperative.

Groundwater Water Quality

At around 25 sites in the County water samples are taken by the United States Geological Survey (USGS) in conjunction with SBCWA and chemical constituents are analyzed (United States Geological Survey, 2003). Since around 25 constituents are analyzed from each sample (75 for a few sites examining pesticides (organic chemical constituents)), this database can become problematical if not properly designed. In addition to the 25 active monitoring sites there are records from another approximate 75 sites.

Stream Flow

At around 30 sites in the County stream flow measurements are made by the United States Geological Survey (USGS) in conjunction with SBCWA and local water districts. In addition to the 30 active sites there are records from approximately another 100 historical sites. These sites produce both “daily average hydrographs” and “peak flows”. Daily average hydrographs are used in water resources planning to analyze the amount of water passing a particular point in a stream or river. In constructing a daily average hydrograph, continuous raw data is condensed into a “daily average”. The SBCWA database contains approximately 650,000 “daily average” records making efficient database design imperative. Peak flows are used primarily for flood control work and are representative of a seasonal high flow or unusual high flow. Using an annual or partial peak flow series one can perform *frequency exceedence* to calculate the expectation or frequency of receiving a certain magnitude flow that may impact a particular watercourse (Chow, 1988).

Stream Flow Water Quality

At 10 of the 30 stream flow sites water samples are taken and analyzed for chemical constituents. Since around 25 constituents are analyzed from each sample this database can become problematical if not properly designed. In addition to the 10 active sites there are records on another approximate 50 sites.

Rainfall Depth

The Flood Control Division currently maintains a precipitation database that contains records back to the 1800's. This 164,000 record database is a compilation of rainfall records collected by the Flood Control Division, the National Oceanic and Atmospheric Association (NOAA), and local cooperators. It consists of daily rainfall depths, otherwise called “non-recording” rainfall data, and depth-duration-frequency data from “recording” or “continuous” rain gages.

DATABASE DESIGN

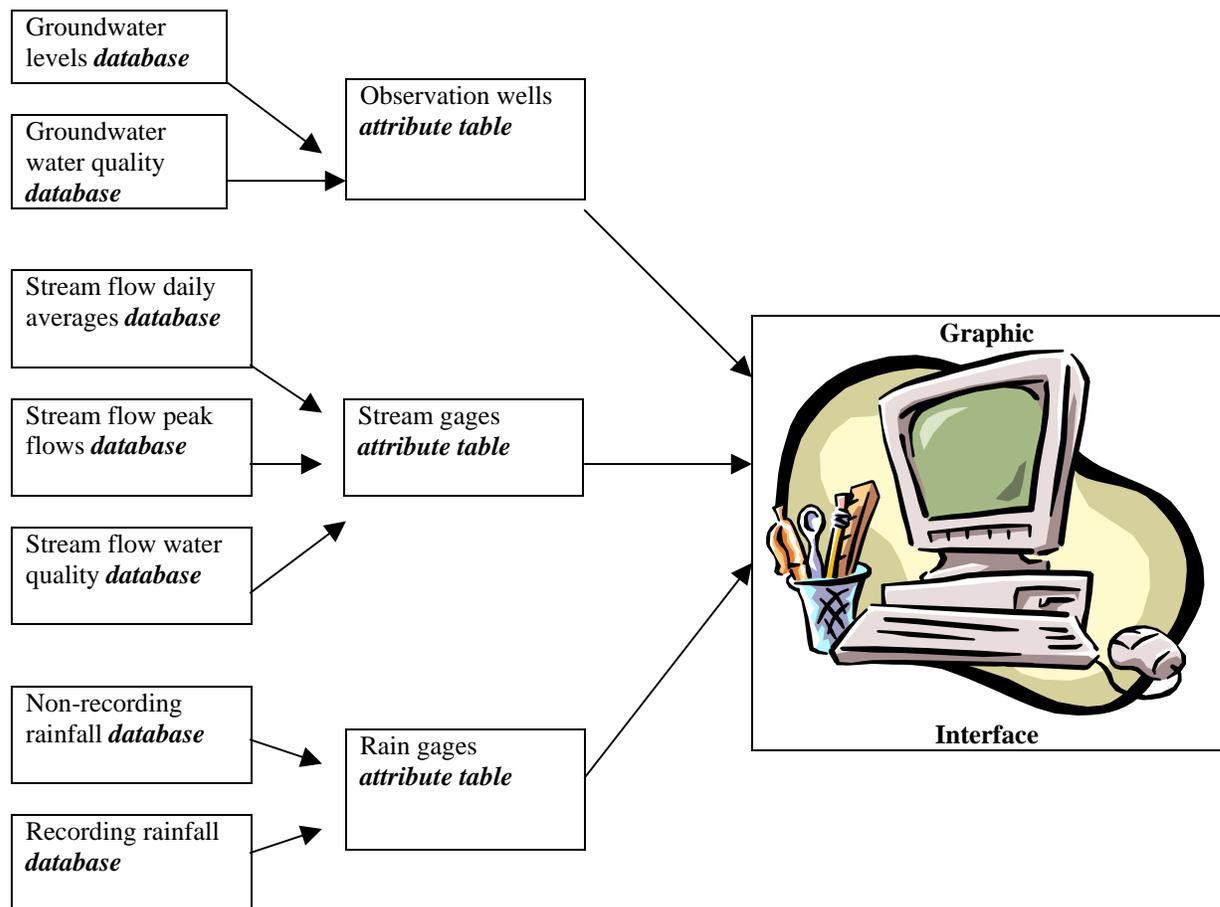
A critical aspect of the evolution of any GIS system is database design. Database structure must be thoroughly planned before embarking on data acquisition and entry as changes to your database design become more difficult as your database grows. The designer must decide how to properly organize the database. When working with databases of enormous record or file size computer efficiency and file loading time must be taken into account.

Santa Barbara County Water Agency builds its databases by the following rules:

- Separate databases as much as possible and create as individual files
- Create attribute files that contain only pertinent information on identifying and plotting datasets
- Maintain databases in separate files that are relational to the attribute file
- Keep the file sizes as small as possible for ease of loading and data storage

Keeping databases separate

SBCWA has structured its GIS development according to the following diagram:



Three attribute tables: observation wells, stream gages and rain gages control and affect the display of data. **From these three attribute files seven separate databases can be related to and controlled, one for each type of hydrologic data.**

Creating attribute files that contain only pertinent information on identifying and plotting datasets

The attribute files or tables should not contain any information other than what is needed to identify and plot the station or record. The tables should not contain any record data as that should be kept in a separate data table that can be related. The graphic below displays the attribute table design for the observation wells database.

FID	Shape	REP	STATE_WELL	WELL_ID	LAT	DE	LON	DEC	LSD	LOCALITY
0	Point	1	11M/29W-35A1	35A1	34.93500	-120.52417	123			
1	Point	2	11M/29W-33G1	33G1	34.93056	-120.56667	80			Division St @ RR King
2	Point	3	11M/29W-33C4	33C4	34.93611	-120.56372	80			
3	Point	4	11M/29W-28M1	28M1	35.00333	-120.57389	77			E of Guadalupe dunes
4	Point	5	11M/29W-25F3	25F3	35.00368	-120.51806	130			Division @ Santa Road
5	Point	6	11M/29W-20E1	20E1	35.01861	-120.58222	49			Oso Place Lake Road
6	Point	7	11M/34W-34J2	34J2	34.98638	-120.43472	290			
7	Point	8	11M/34W-30Q1	30Q1	34.99722	-120.49583	148			SE of Nipano mesa Rd
8	Point	9	11M/34W-29R1	29R1	34.99944	-120.475	164			
9	Point	10	10M/36W-14H1	14H1	34.95111	-120.63778	160			
10	Point	11	10M/36W-12P1	12P1	34.95667	-120.62806	28			E of Guadalupe dunes
11	Point	12	10M/36W-12K3	12K3	34.95111	-120.62361	30			
12	Point	13	10M/36W-12K2	12K2	34.95111	-120.62361	30			
13	Point	14	10M/36W-14H1	14H1	34.97806	-120.62893	128			
14	Point	15	10M/29W-25J2	25J2	34.90167	-120.52639	112			Field E of Hwy 1
15	Point	16	10M/29W-29M1	29M1	34.91584	-120.52270	110			
16	Point	17	10M/29W-24Q1	24Q1	34.93722	-120.51333	162			Ex BMW headst well
17	Point	18	10M/29W-24B1	24B1	34.93089	-120.51444	144			SW Jct Ray & Brown rd
18	Point	19	10M/29W-23M2	23M2	34.92089	-120.54020	125			S of Brown Road
19	Point	20	10M/29W-21B1	21B1	34.93917	-120.56894	94			Mahoney Blue Farm
20	Point	21	10M/29W-18F2	18F2	34.94972	-120.60596	49			SW from Guadalupe
21	Point	22	10M/29W-18F1	18F1	34.94972	-120.60596	49			
22	Point	23	10M/29W-14P1	14P1	34.94000	-120.53883	118			N of Brown Road
23	Point	24	10M/29W-14L1	14L1	34.94417	-120.53639	102			
24	Point	25	10M/29W-12M1	12M1	34.96167	-120.51344	138			
25	Point	26	10M/29W-11E4	11E4	34.96333	-120.53861	122			Silva Farm N of Hwy 166
26	Point	27	10M/29W-11E2	11E2	34.96278	-120.53861	122			
27	Point	28	10M/29W-9M5	9M5	34.95528	-120.57333	87			
28	Point	29	10M/29W-9M4	9M4	34.95594	-120.57361	87			

Note that only station ID (here STATE_WELL), plotting coordinates, and some ancillary information are present here in the attribute table. This philosophy optimizes attribute table efficiency.

Maintain databases in concise separate files that are relational to the attribute file

By keeping your databases separate but relational you will be able to handle record databases and raster imagery of enormous size in an efficient manner. Just as with the design of the attribute table the data tables should contain only necessary information. In the example below, which is from the groundwater levels database, note that only information pertinent to the individual record is present.

```

"State_well_id", "Date", "Year", "Month", "Day", "Data", "Code"
"4N/25W-19F1", "80", 1956, 0, 0, 50.00, "R"
"4N/25W-19F1", "80", 1958, 0, 0, 60.00, "R"
"4N/25W-19F1", "80", 1949, 5, 23, 75.00, "R"
"4N/25W-19F1", "80", 1949, 12, 12, 83.58,
"4N/25W-19H1", "120", 1948, 2, 20, 91.00,
"4N/25W-19H1", "120", 1949, 5, 24, 108.68,
"4N/25W-19H1", "120", 1949, 12, 12, 112.14,
"4N/25W-19H1", "120", 1950, 11, 23, 111.05,
"4N/25W-19H1", "120", 1956, 4, 17, 97.02,
"4N/25W-19H1", "120", 1972, 5, 18, 70.84,
"4N/25W-19H1", "120", 1977, 9, 28, 97.32,
"4N/25W-19H1", "120", 1977, 10, 17, 98.50,
"4N/25W-19H1", "120", 1977, 11, 16, 100.40,
"4N/25W-19H1", "120", 1977, 12, 19, 101.85,
"4N/25W-19H1", "120", 1978, 1, 25, 98.70,
"4N/25W-19H1", "120", 1978, 2, 16, 98.25,
"4N/25W-19H1", "120", 1978, 3, 16, 94.82,
"4N/25W-19H1", "120", 1978, 4, 17, 93.06,
"4N/25W-19J5", "25", 1999, 12, 20, 34.23, "R"
"4N/25W-19J5", "25", 2000, 1, 20, 34.80, "R"

```

The previous example displays a comma delimited text file with only the needed seven fields: State well ID, wellhead datum, year, month, day of measurement, measurement, and code. Code in this database refers to one of the intricacies of measuring groundwater: if a nearby well is pumping or has recently been pumped it can affect the measurement and thus it needs to be noted. The state well ID is the field that is also in the attribute table that we will relate to allowing us to select records displayed from the attribute table but also cross-selecting them in the database. Note that “datum” (the field labeled LSD (land surface datum)) is also in the attribute file and thus is duplicated and could be removed from the data table saving file size and file time loading. In this case the designer elected to keep it in the main database as it helps to quickly relate the “depth to water” measurements to a “water surface elevation” by utilizing the wellhead elevation or datum.

Keep the file sizes as small as possible for ease of loading and data storage

SBCWA prefers the use of comma delimited text files as they are the purist form of a data file without any hidden or un-needed characters that increase database size. Text files are compatible for linking to relational files with *ArcView 3.x*, which the SBCWA system was designed around. However, *ArcMap 8.x* is currently not compatible with text files, so you must convert your text (.txt, .csv) files to *database* (.dbf) files at a considerable gain of file size, sometimes as much as 20x. If your database is large, such as the 127,000 record groundwater levels database, you may have an issue with file size upon converting text files to *database* files or in making *database* files. Since *Microsoft Excel* will only handle around 65,000 rows, it may not be suitable this type of file manipulation. *Microsoft Access* can handle an unlimited amount of rows, and it will export *database* (.dbf) files. Our 5 megabyte groundwater levels text file format database turned into 100 megabytes upon converting it to a *database* format. However, by manually manipulating each field in *Access* before exporting to *database* format, we were able to get our groundwater levels file size down to 15 megabytes (Liddell, 2004).

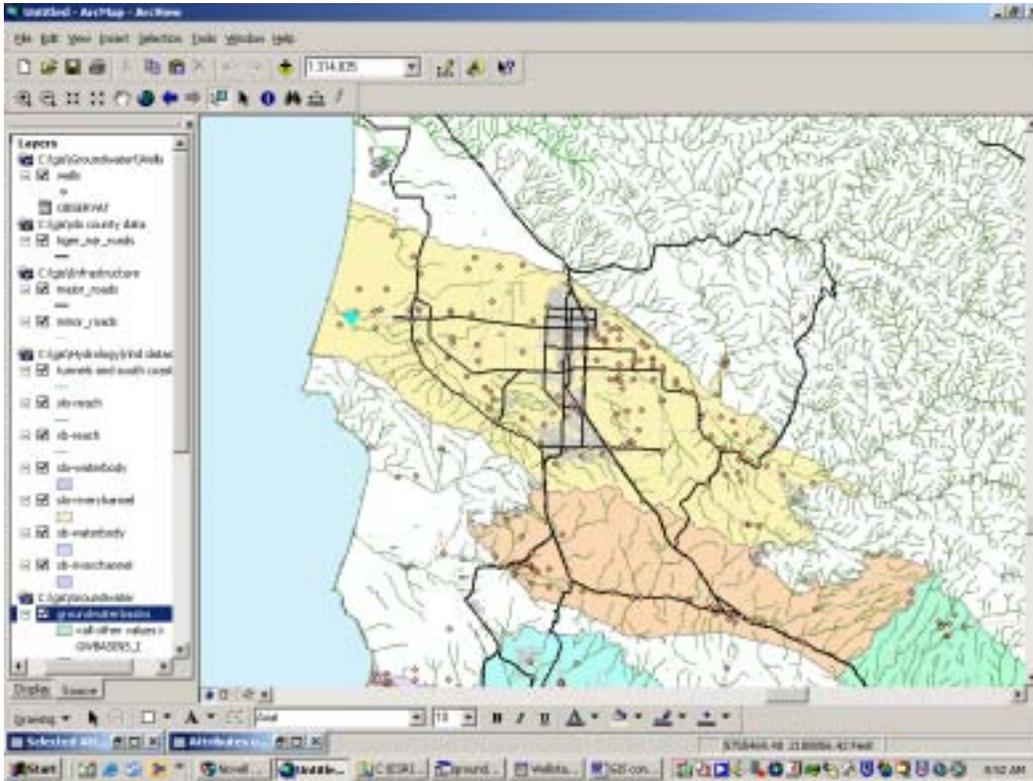
Acquisition of Databases

Before embarking on a long data entry voyage, database designers should investigate public service agencies for existing datasets. Many hydrological databases are available in some format, and simply need molding or “massaging” to fit the needs of the end user. For example, SBCWA was able to acquire the groundwater levels database from the USGS in a fixed width format that was output from their mainframe computer running Fortran and C++. Initially this dataset appeared to be very cumbersome, but after massaging the data with *Excel* and *Access* we were able to get it to a concise PC-based comma delimited format. Acquisition of this database saved hundreds of hours of data entry. Other public agencies such as the National Weather Service (NWS), National Oceanic and Atmospheric Association (NOAA) and the Environmental Protection Agency (EPA) have hydrological datasets available to the public.

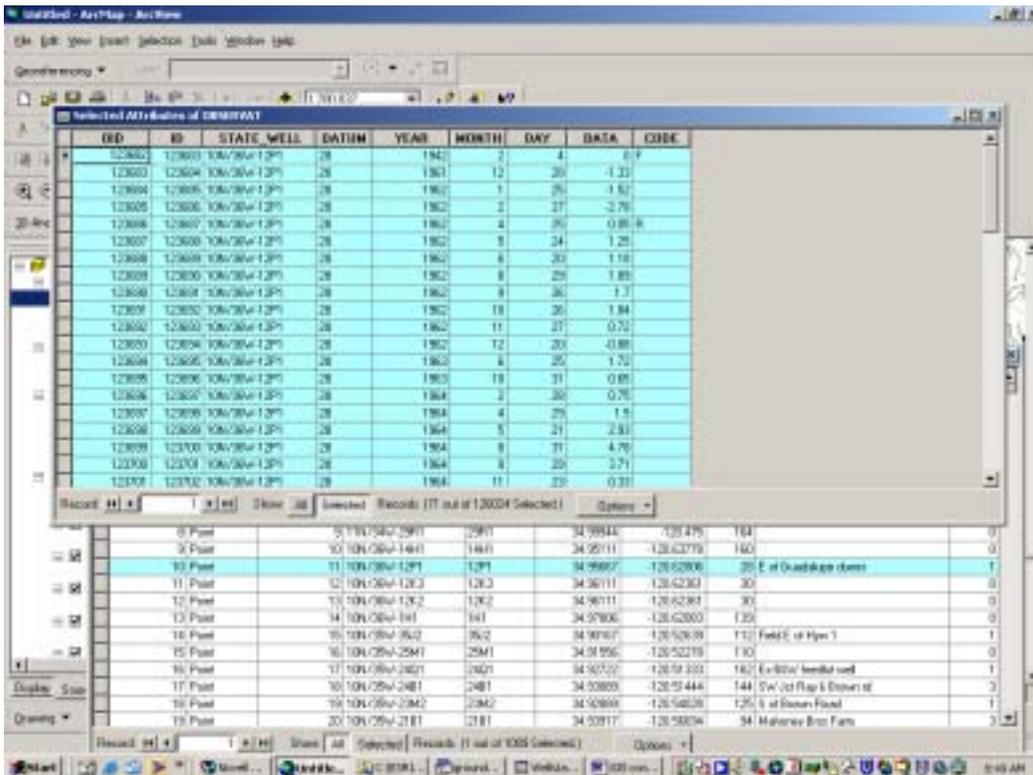
USING A GEOGRAPHIC INFORMATION SYSTEM TO STORE, RETRIEVE AND DISSEMINATE WATER RESOURCES DATA

Now that you have acquired your data and molded it into an efficient database you can begin to utilize the design to quickly and effectively export data to share with those who may need it. The frame on the following page depicts Northern Santa Barbara County and specifically the Santa Maria and San Antonio groundwater basins. Themes displayed are hydrography, transportation, groundwater basins, and groundwater observation wells.

Suppose a customer has asked us to give them groundwater level information for the westernmost part of the Santa Maria Groundwater Basin, the mustard colored polygon. In the past when the Agency was asked to provide this type of information we would go to the file cabinet, find the records manually, copy them and put them in the mail or scan them and email them. This was a labor and time intensive process. Now, utilizing the GIS system we can simply get into the GIS database and relate our groundwater levels database to the observation wells, select the data needed, export it to a standard format directly from *ArcMap* or *ArcView*, and email it to the customer. In this case the customer will get the needed information in a much more timely manner, and it will save a great amount of staff time.



To perform this operation first we add the database table to the view, just as if it were a shape file itself. Next we go to the attribute table for the theme you are relating from, right click, go to joins and relates, relate, and a sub menu will appear where you fill in the field you are relating from and the file and field within the data file you are relating to. Now that this relationship has been established, when you select data from the view, it will not only select it in the attribute table but will also cross select it in the database.

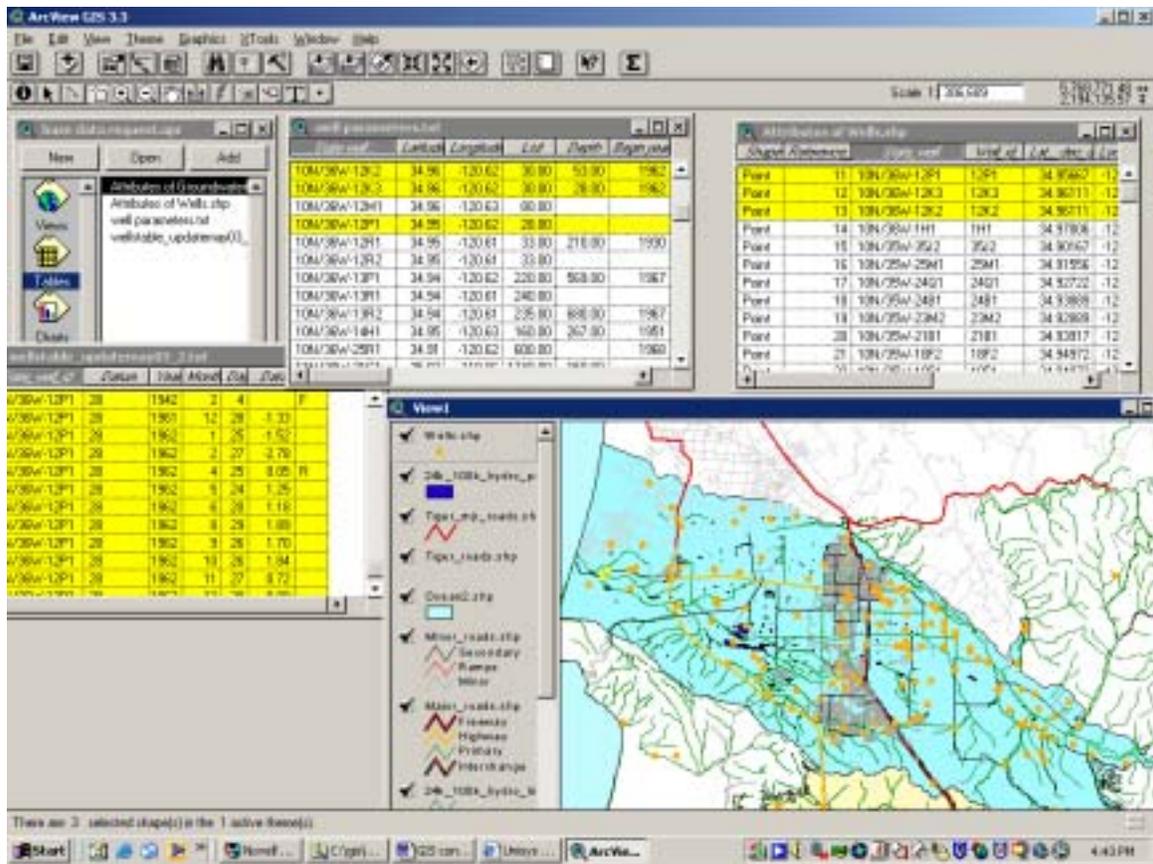


To get to the cross selected records, go to the attribute table (not the related file!), go to options, relates, and the relate you established. Click on selected records and you will see the records that were cross selected. **Be careful as sometimes the data table opens up directly behind the attribute table and until you move the attribute table you cannot see the data table.**

Now it is simply a matter of exporting the selected records in the related table through the options, export menu. Then the data can be quickly emailed or put on diskette for the customer's ease of use.

The procedure is a little different in *ArcView 3.x*. In *ArcView 3.x* you "link" tables instead of "relating" and you go about it differently. To add tables in *3.x* go to the project manager, tables, add table, and navigate to the table to be added (Remember that *ArcView 3.x* supports *text* format files as well as *database* format files). To establish the relationship between the attribute table and the data table(s) you first click on the header in the field of the data table that you want to relate from, then the header of the field in the attribute table that you want to relate to, then go to table in the main menu, and link. Now all records selected from the main view and indicated in the attribute table will also be cross selected in the data table(s).

The graphic below demonstrates the "linking" operation in *ArcView 3.x*.



SUMMARY – CONCLUSIONS

The use of Geographic Information Systems is a prudent way of storing, displaying and disseminating hydrologic data. GIS is well suited for all *environmental* data since it is *all* spatially oriented. Database design is critical in the development of a Geographic Information System. All databases should be developed concisely and relational. Organizational skill in the development of databases is critical.

The Santa Barbara County Public Works Department has found the use of GIS to be an efficient way of maintaining hydrologic records and sharing with those who need them, in addition to other tasks associated with spatial analysis. The Department has plans to keep utilizing GIS in future developments to best serve not only the employees of the Public Works Department but all citizens of Santa Barbara County, California, USA.

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