COST EFFECTIVE USE OF GIS FOR TRACER TEST DATA MAPPING AND VISUALIZATION

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ABSTRACT

Geographic information systems (GIS) have been used in a number of geothermal exploration, data visualization, and data management projects and have been shown to be an efficient tool for related research. This paper presents the use of GIS to enhance tracers analysis through better visualization and faster data handling. To accomplish this, innate GIS functions are coupled with a new data-handling interface. This enables the analyst to process and visualize large tracer data sets in a matter of minutes, thus saving significant cost over time and providing functionality that is not available outside of GIS.

INTRODUCTION

Geographic information systems (GIS), a powerful geospatial data mapping and analysis tool, have been used in geothermal studies as an aid to reservoir characterization (Nielson et al., 1995; Nielson et al., 1993), to visualize and analyze isotopic data (Walters et al., 1996); as an aid for geologic structure interpretation (Nielson and Nash, 1997), to archive and visualize digital core imagery and associated data (White et al., 1996; Nash, 1999), and to create knowledge based exploration models (Prol-Ledesma, 2000; Nash and Wright, 1996). However, GIS has not been widely adapted by the geothermal industry, unlike the petroleum industry, where it has proven itself to be an invaluable tool for data visualization, correlation, analysis, sharing, and archiving, even in smaller companies. The geothermal industry has historically done digital mapping using computer aided design (CAD) software, which lacks important functionality.

The key difference between GIS and CAD is that each object in a GIS is associated with a table or multiple tables within a relational database. Once objects are mapped, such as wells or well courses, any database can be tied to the locations by name. The data can be geochemical, geophysical, structural, or operational. GIS software facilitates mapping data in numerous ways, including contours or coded symbols. Once the data is mapped, queries can be run such as "How many wells have high enthalpy and where are they?" or "Which high chloride wells have low quartz temperatures?" The utility of maps in a GIS can be enhanced by superimposing them on spatially co-registered images, such as satellite, topographic, or geologic, or by associating ancillary data with an object on the map. This paper describes another important use of GIS for the geothermal industry that can save both time and money over the long run – that of visualizing and analyzing tracer test results.

OBJECTIVE

The impetus behind this study was the large amount of data generated by a given tracer test at The Geysers geothermal field in northern California. These data are not only three-dimensional (time and location), but are rapidly generated. Return times in a vapor-phase tracer test are often less than one day for wells within two kilometers. All wells cannot be sampled because of the large number, so data from each day must be examined to determine which wells should be sampled the following day. Plotting data on maps and interpreting the results can be time-consuming. Thus, the objectives of this study were two-fold. The first was to determine which methods of visualization could be quickly and easily interpreted. The second was to determine if GIS could be used in a cost and time effective manner from data handling and input through visualization, and if enhancements could be made to improve the process if necessary.

DISCUSSION

Visualization

The data produced from tracer tests has generally been used to create hand-drawn isarithm maps in the past. This is a slow and tedious process and often times the map maker will make a concerted effort to interpolate the isolines to a degree of accuracy that goes beyond the definition of an isoline, thereby taking even more time. As there is generally a high degree of spatial variability in well locations, spatial control for creating contours is limited. Even so, an isarithm map is appropriate for this purpose, but by definition, this type of map represents a statistical surface, not precise data values, and will not represent sample sites with spatial accuracy. A variety of computer programs, including various GIS systems, can generate isarithm maps using one or a combination of methods. ESRI's ArcView Spatial Analyst® extension was tested using several combinations of algorithms to generate isolines. With some initial experimentation, good statistical surfaces could be generated very quickly. Figure 1 shows an isarithm map plotted from R-134a data, which were normalized to the injection mass of the tracer and then subjected to a log transform. Numeric values are given next to sampled wells for comparison to the computer-generated contours. Contouring parameters could be reset and several new maps created for comparison in a matter of a few minutes. After the user has repeated this a few times a feeling for the proper parameters is ingrained and new maps can be created even more quickly.

However, if a high degree of spatial accuracy is needed in relation to a given sample location, it may be advisable to use another type of data visualization such as graduated circles, also sometimes known as bubbles. Within the GIS environment the user can easily create proportional graduated circles, that are classified for radii values using several methods including: (1) equal intervals, natural breaks, standard deviations, or quantiles, with a few mouse clicks. The relative size of graduated circles is easily discernable by the human eye, so these symbols make meaningful visual comparisons of data very easy. Graduated circles can also be used with or without other geometric shapes to represent multiple data sets per sample point. Figure 2 shows a simple graduated circle map for R-23 data classified into three classes using the natural breaks method. Figure 3 shows a combination of graduated circles and triangles using graduated color, or gray scale in this case, to represent R-134a, R-23, and tritium data, all classified into three classes using the natural breaks method, for samples collected on a single

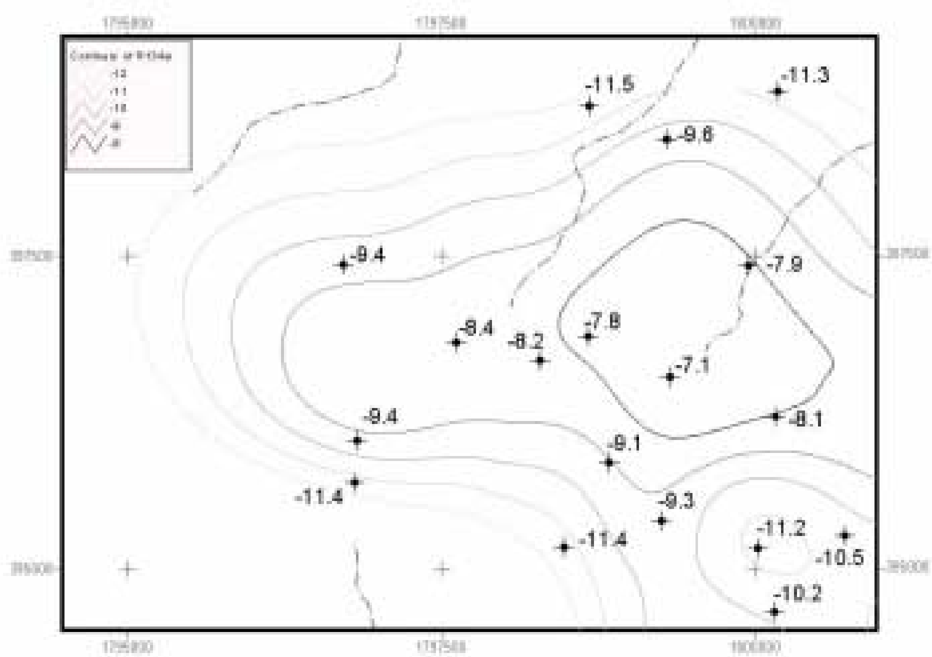

Figure 1. Isarithm map for the R-134a tracer. Values were normalized to the injection mass of the tracer and then subjected to a log transform

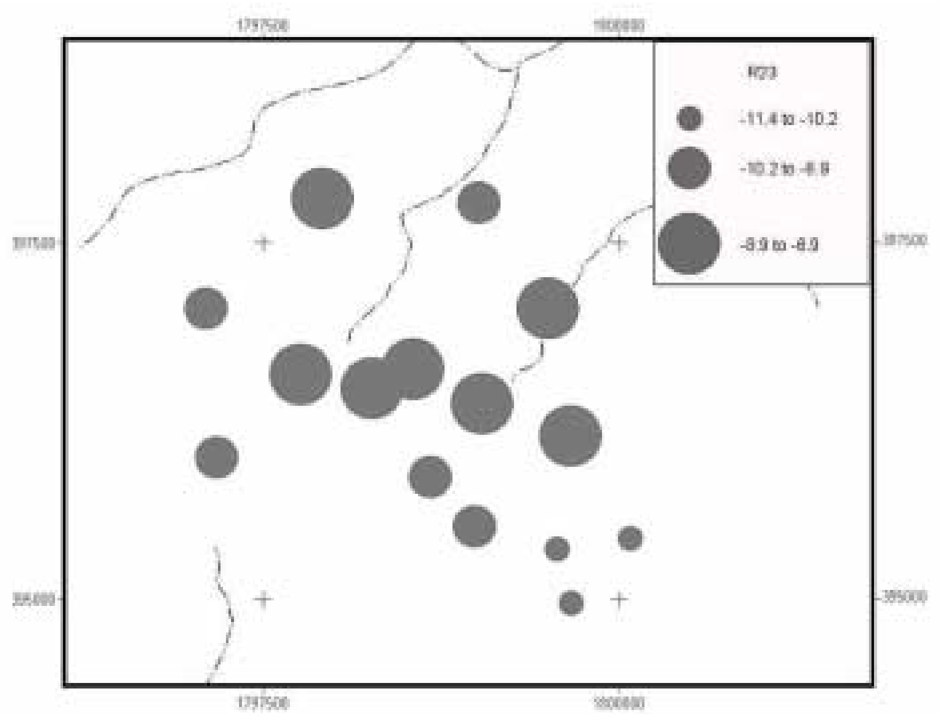

Figure 2. Classified graduated circle map for R-23 normalized to injection mass of tracer with log transformation.

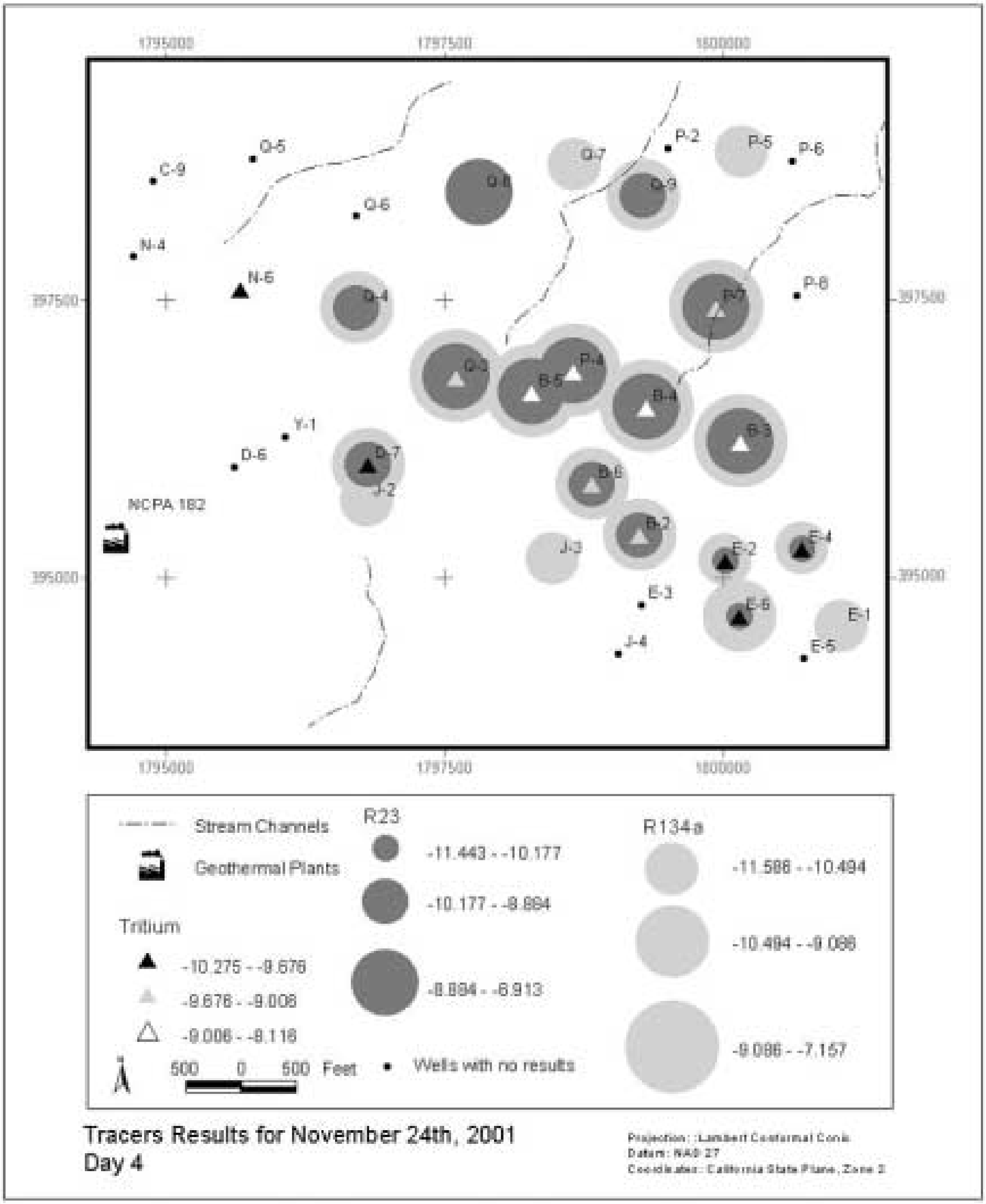

Figure 3. Combination of multicolored graduated circles and graduated gray-scale symbol map displaying comparisons between R-134a, R-23, and tritium.

day. Graduated color is also a very effective method of data representation on a computer monitor or if color printing is available.

Increasing Efficiency

The data used in the above visualizations were obtained in Microsoft Excel® spreadsheets in less than optimal formats for GIS database generation. Therefore, the data had to be manually reformatted within the spreadsheet, after which the table was exported into a dBase table or comma delimited text file for import into ArcView. To eliminate this work a simple new database format was conceived for use as input to a new bridge interface (Figure 4) that is used to create a new database from raw and calculated values to be used in visualization. The term "bridge interface" is used as this software acts as a bridge between the raw data and the GIS through its preparation of a standardized database populated with several data tables. This new interface needs two files, raw tracer and steam flow data, input as comma delimited text files to generate the new database and tables. These can be made in any word processor, text editor, or spreadsheet. The new format is as follows:

Well_ Names, Date1, Date2, Date3…
Well_1, Data1, Data2, Data3…
Well_2, Data1, Data2, Data3…

where the first row consists of field names and the following rows represent data by given well, and the Well_Names field is used as a key to allow relations to be made among tables.

The comma delimited data is imported by the bridge interface where a new Microsoft Access® data base is created consisting of the following tables: (1) raw tracer data, (2) normalized data (normalization value chosen by the user), (3) log transformed normalized data, (4) interpolated data, (5) cumulative values of interpolated data, (6) normalized interpolated data, and (7) log transformed normalized interpolated data. The interpolation process estimates missing values. This tool is extremely fast and easy to use, with the entire process generally taking the user less than 30 seconds to complete if all of the automated processes are used. The user has the choice of allowing the software to name the tables by time and date of generation along with a unique qualifier, or can input table names manually, which takes a little longer. This interface can be used with ESRI ArcInfo or ArcView, or any other GIS software that facilitates an SQL connection to Access. For this project the bridge interface is linked to a customized object oriented user *Tracers Data Analyst* interface within ArcView (Figure 5). The customized ArcView *Tracers Data Analyst* interface can be used to call the bridge interface and then to rapidly create SQL connections to the tables that have been generated. Automatic table joins are also facilitated, as is isarithmic map generation, through this interface. To make this possible,

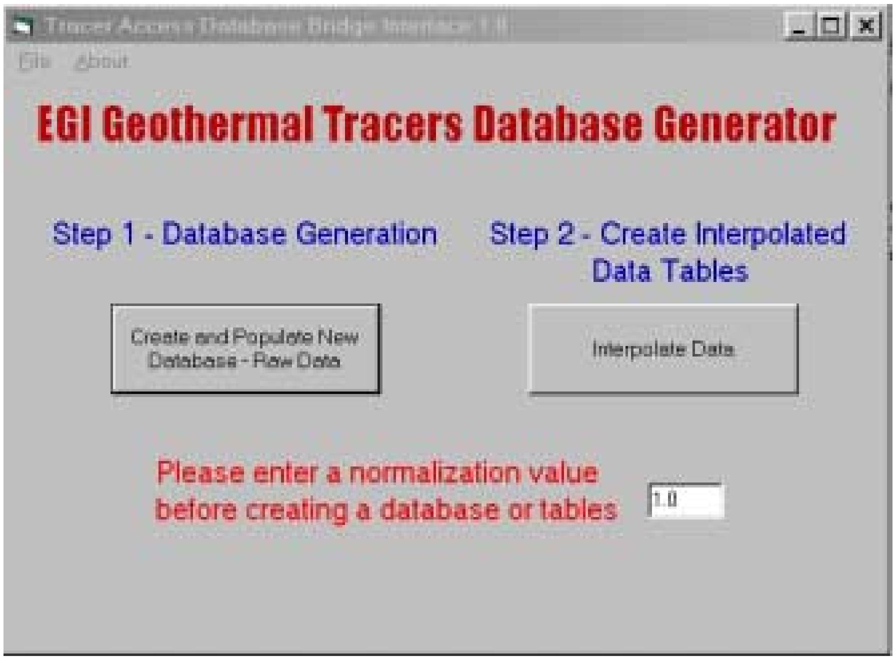

Figure 4. Bridge interface.

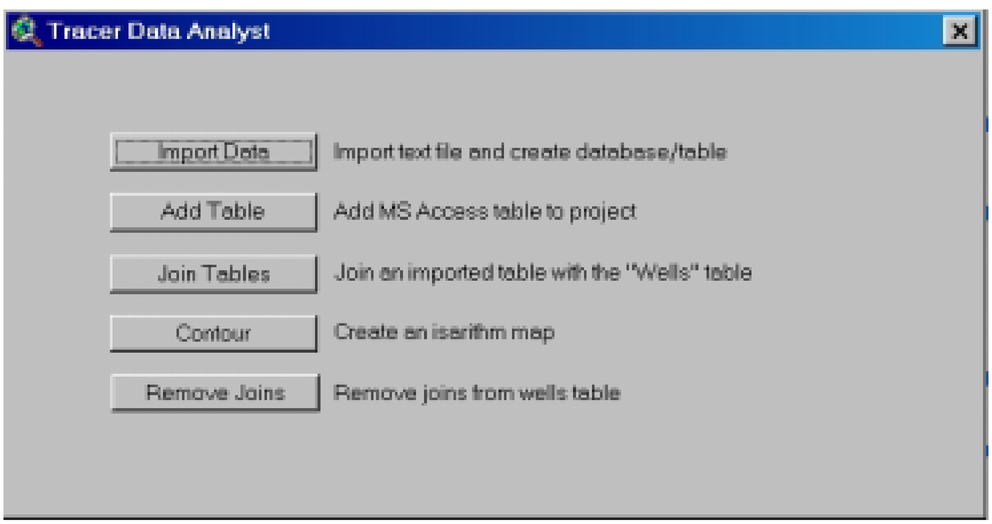

Figure 5. ArcView Tracers Data Analyst user interface.

one additional data set must be in the GIS; this is a table consisting of well names and XY coordinates in any standard coordinate system. The well name field is used as a key to allow joins to be made with the tables generated with the bridge interface.

COSTS/BENEFITS

The principle benefit of GIS in tracers analysis is speed. After database generation and SQL connection, the visualization of data, whether using contours, classified graduated circles, or some other method, can be done in seconds. Using the *Tracers Data Analyst* interface, tracer data can be imported and placed into a database, accessed by the GIS, and be used for visualization or to create a hardcopy map in under five minutes.

As far as costs go, GIS is comparable to CAD in some ways, but generally more expensive up-front. ESRI ArcView 8.1 software is advertised at $1,500.00. This is entry-level GIS software that has good deal of vector functionality and also facilitates raster image viewing and co-registered vector overlay on raster images. The ESRI Spatial Analyst, an ArcView extension, is needed for contouring and other types of spatial analytic functions, such as slope and proximity analysis, at additional cost of $2,500.00. Manifold System GIS, for which the authors are not well acquainted, is a very reasonable $145.00. This package claims functionality similar to ArcView and more.

For comparison, the popular AutoCad LT® 2000i CAD system is advertised at $659.00. Autodesk CAD Overlay®, which is needed for raster vector data integration, is $1,395.00. The full AutoCad 2000i® package is $3295.00.

Although initially a little more expensive then CAD, GIS facilitation of the spatial analysis of tracers and other data related to geothermal exploration and field management make it the clear choice for digital mapping.

CONCLUSIONS

GIS can be rapidly and easily used to process, display, and interpret tracer test data. The resulting plots can be used to plan the next day's sampling, or they can be overlain on geologic, geochemical, or geophysical data sets. Queries can be run to determine correlations such as the correspondence of tracer returns with geochemical trends. Although initially a little more expensive then CAD, GIS functionality and its facilitation of tasks in a time-effective manner make it less expensive in the long run for map making and spatial analysis. The bridge interface and *Tracers Data Analyst* can be found at http://www5.egi.utah.edu under Technology Transfer.

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