Presented at the May 12-15, 2003 USCID 2nd International Conference on Irrigation and Drainage - Water for a Sustainable World — Limited Supplies and Expanding Demand. Phoenix, AZ.
http://www.itrc.org/papers/gis/gismapping.pdf ITRC Paper No. P 03-003

GIS MAPPING FOR IRRIGATION DISTRICT RAPID APPRAISALS

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ABSTRACT

Geographic information system (GIS) mapping is slowly becoming commonplace in irrigation districts as the need for more accurate and organized data becomes increasingly important. The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo commonly uses GIS as a tool in technical assistance packages for irrigation districts. One of the challenges in developing a strategic irrigation district modernization plan is to organize spatial data in such a way that various options can be easily understood. ITRC uses a combination of commercially available software with web-downloadable maps and photographs to organize and present the spatial information. An example of information organization for a Rapid Appraisal Process (RAP) of Tulare Irrigation (TID) district is given, showing how the district boundary, major portions of TID's open channel distribution system, field boundaries, biannual groundwater elevation contours, major water bodies, streams, rivers, and wetland areas are overlaid on two basemaps, one with aerial photographs and the other with USGS topographic maps (1:24,000 and 1:100,000), using ArcView® GIS and the 3D Analyst extension.

INTRODUCTION

Mapping is an important component in irrigation district management and operations. Most irrigation districts have large maps covering the walls of lobbies and boardrooms. Generally, these maps show the district boundaries and the surrounding areas. In many cases, highlighters have been used to indicate the distribution system and the maps are littered with handwritten notes made over the years.

A number of events in the last 10-15 years have changed the way mapping is used throughout the irrigation district community. Some of these events include:

- Pressure from external organizations to show improved water use efficiency, increasing the necessity to record, organize, and present large amounts of data that were not originally needed for day-to-day operations.
- Increase in data made available through the World Wide Web by local, state, and federal government agencies.

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- Increase in personal computing capabilities.
- Availability of user-friendly, affordable, commercial mapping software.

Some, generally large scale, irrigation districts have taken a proactive approach in using geographic information system (GIS) mapping, to the point where they have staff dedicated to the effort. However, most districts are not afforded the luxury of a dedicated staff. This task then falls on district engineers, consulting engineers, general managers, and, in some cases, office staff that may have little or no familiarity with GIS.

Although some irrigation/water districts in the western U.S. are relatively advanced in the use of GIS, in general GIS mapping on the district level is still in its infancy. California Polytechnic State University Irrigation Training and Research Center (ITRC) has assisted many districts to get their GIS program started. As with many technologies, getting started is the biggest step. Once the program gets off the ground, it tends to expand according to the individual district's needs.

ITRC has found broad uses for GIS mapping on the district, as well as the state, level. In general, ITRC uses GIS mapping for the following processes:

1. Data Organization – Spatially organized stream flow data, water quality data, turnout deliveries, distribution system layout and flow rates, groundwater elevations, crop types, irrigation methods, etc.
2. Data Retrieval – Crop and irrigation method acreage, biannual groundwater elevation contour generation, lengths of canals and laterals, analysis of wetland and riparian habitat.
3. Presentation – Presenting the organized data as well as recommendations for to a strategic modernization plan.

The level and approach of GIS analysis conducted by the ITRC is project specific. In projects where a very detailed analysis is necessary, ITRC uses a multitude of tools and analysis techniques to answer every possible question. The majority of this detailed analysis is in the Data Organization process and may include analysis of multiband satellite images, ground truthing of crop types and irrigation methods, GPS surveying, digitizing field boundaries and distribution systems layouts, etc. It is very difficult to define one systematic process that would cover every situation.

However, over the last few years, the ITRC has pioneered a process that allows ITRC personnel to assist agricultural water agencies and water users to quickly identify and prioritize the specific changes in their water management practices that will provide cost-effective improvements in the performance of their distribution system. This is called the Rapid Appraisal Process (RAP) and has been used effectively and extensively throughout the western U.S and internationally. As part of a RAP, the ITRC often uses a GIS process that focuses on Data Retrieval and Presentation. Data Organization is important, but it is not the focus. The ITRC's type of analysis is more systematic and is outlined in the following case study.

ITRC GIS WORK
CASE STUDY: TULARE IRRIGATION DISTRICT

Tulare Irrigation District is located on the eastern side of the San Joaquin Valley approximately 30 miles south of Fresno, California. The district encompasses approximately 65,000 acres. Major crops grown in the district include cotton, corn, alfalfa, grapes, and almonds. The district receives water from Lake Kaweah and from the Friant-Kern Canal (Central Valley Project).

In January 2003, the ITRC conducted a RAP for Tulare Irrigation District (TID). GIS mapping was incorporated to provide spatial information to the project leader and support staff and provide a presentation medium for the final report.

The steps below are only related to the GIS work that supported the basic RAP. The RAP developed by Cal Poly for international work is described in detail in a report found in the following ITRC website:

http://www.itrc.org/reports/RAP/RAP.html

In U.S. RAP, ITRC takes a detailed look at the irrigation/water district operations, hydraulic structures for suitability and operation rules, performance indicators, costs, and other factors to understand external constraints as well as internal performance. The RAP does not focus on just one aspect of irrigation district modernization, but rather looks at the complete range of operations that impact delivery performance, efficiency, and costs. GIS is only one aspect of a RAP, and may not be used in some cases.

Step 1 of GIS-related work for the RAP. Project Setup

The goal of the first step is to determine the datum and planar coordinate system of the project and to organize the main project directory. The ITRC uses ArcView® 3.2a and a number of extensions for GIS mapping and analysis. Therefore, most of the terminology will be consistent with this software. Terms and brief definitions are as follows:

- Aerial photos – Aerial imagery registered to a coordinate system using a world file
- DOQ – Digital orthophoto quadrangle (DOQQ – digital orthophoto quarter quadrangle) are aerial photos registered to a coordinate system and corrected for the geode

- Shapefile – ArcView® format for storing the location, shape, and attribute information of geographic features (ESRI, 1999)
- Topographic map – Digital USGS topographic map
- Projection – Mathematical formula that converts latitude and longitude to a planar coordinate system (ESRI, 1999)
- Basemap – ITRC considers the “image file” to be the basemap
- Image file – Aerial photos, DOQs, and topographic maps

Because it can be time consuming and often difficult to accurately change the coordinate system of image files (aerial photos, DOQs, topographic maps, etc.), the coordinate system(s) and datum(s) used for a project are determined by the basemap selection. It is relatively simple to convert shapefile coordinate systems and datums. ArcView® GIS provides a free extension called ArcView® Projection Utility for this conversion. Once the basemap coordinate system is set, shapefiles are projected into the same system so they can be overlaid on the basemap.

Image files available for Tulare Irrigation District included:
- Black and white DOQQ for purchase from the USGS or at no cost from the California Spatial Information Library (CaSIL)
- Color aerial photos at no cost from the California Department of Water Resources (DWR)
- 1:24,000 and 1:100,000 topographic maps at no cost from California Spatial Information Library (CaSIL) and for purchase from a number of private companies.

The ITRC decided to use the DWR color aerial photos and the CaSIL topographic maps for the project basemaps. The aerial photos and topographic maps were not in the same coordinate system, therefore the aerials were used for the primary map and the topographic images were used as the secondary map. All of the shapefiles were converted into the primary coordinate system, and then, after the initial analysis was complete, they were converted to the secondary coordinate system so they would overlay on the topographic maps.

Step 2. District Layout and Data Organization

A shapefile containing the boundary of the TID was obtained from CaSIL. This shapefile was projected into the primary coordinate system and overlaid on the aerial photos. Aerial photos outside of the analysis area were removed from the project to increase viewer regeneration time and decrease the project directory size.

Shapefiles containing open channels and streams, roads, and open water bodies were also obtained from CaSIL and overlaid on the aerial photos. The shapefiles available through CaSIL include data for the entire State of California. Therefore, data outside of the TID analysis area were removed from each shapefile to simplify the project.

The field boundaries shapefile for Tulare County, containing crop data, was obtained from the DWR Division of Planning and Local Assistance. This data was also trimmed to cover the TID analysis region and overlaid on the aerial photos.

Groundwater elevation data was collected for the region from the DWR Water Data Library. The data was obtained in a tabular format containing the Well ID, ground surface elevation, depth to groundwater, and the geographic coordinates of each well. The groundwater data was imported into ArcView® GIS as a point shapefile, with the data for each well contained in the shapefile attribute table. The points were projected to overlay on the aerial photos.

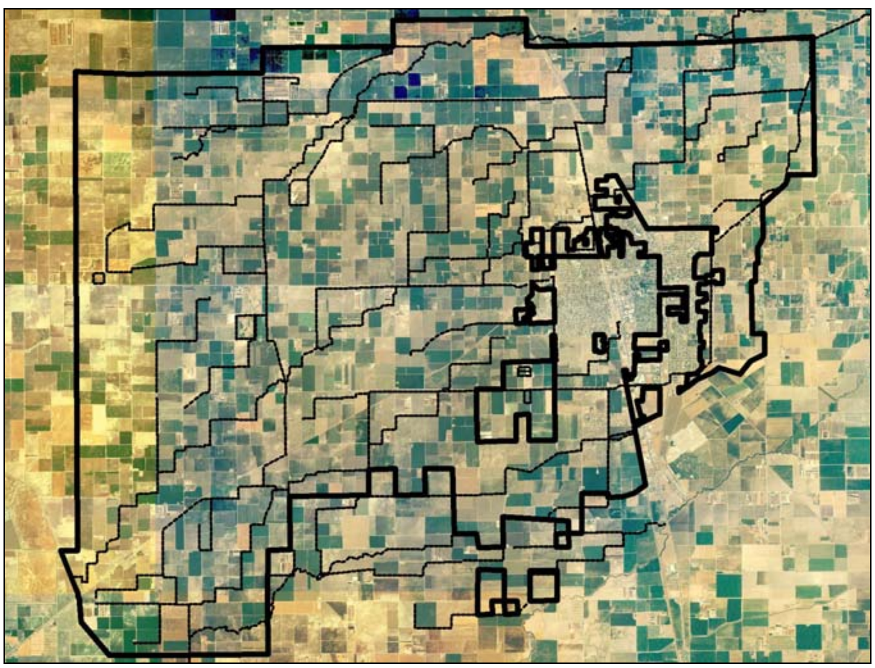

Figure 1. Tulare Irrigation District boundaries and distribution system overlaid on aerial photos obtained through the California DWR

Step 3. Data Retrieval

The amount and types of data that can be obtained from a shapefile depend on the type of file (point, line, or polygon) and the attribute data associated with the file. Line lengths and polygon areas can be calculated in ArcView® for those types of shapefiles. Multiple shapefiles can be overlaid and the data merged. For example, a digital soils map shapefile can be overlaid on a digital field boundaries shapefile and crop acreage by soil type can be obtained.

Providing the spatial layout of Tulare Irrigation District's complex distribution system to the RAP project staff was an important aspect of this GIS project. It not only helped facilitate the modernization recommendations, but it was also instrumental in presenting these recommendations to the District. The open channel shapefile was modified to show only TID distribution components. The key components were labeled and the line weights and colors were modified so that the map could be easily interpreted. In this case, the district personnel had very good estimates of the time it takes for flow rate changes to travel from the sources to key points in the system. However, if a need exists, channel lengths and slopes can be estimated using ArcView® and used to help estimate travel times.

Cropping information can also provide useful information for making irrigation district modernization recommendations. For example, over the last two decades California has seen a dramatic shift from conventional irrigation to drip and microspray on orchard and vineyard crops. Drip and microspray irrigation methods require more flexible irrigation water deliveries than conventional flood irrigation. If the district cannot meet this demand, farmers shift to using groundwater instead of the surface water provided by the district. If a portion of the district is primarily orchards and vineyards, this region may become the focus of an initial modernization effort to provide increased flexibility in district water supplies. The field boundaries shapefile containing crop information was used to show the spatial crop distribution.

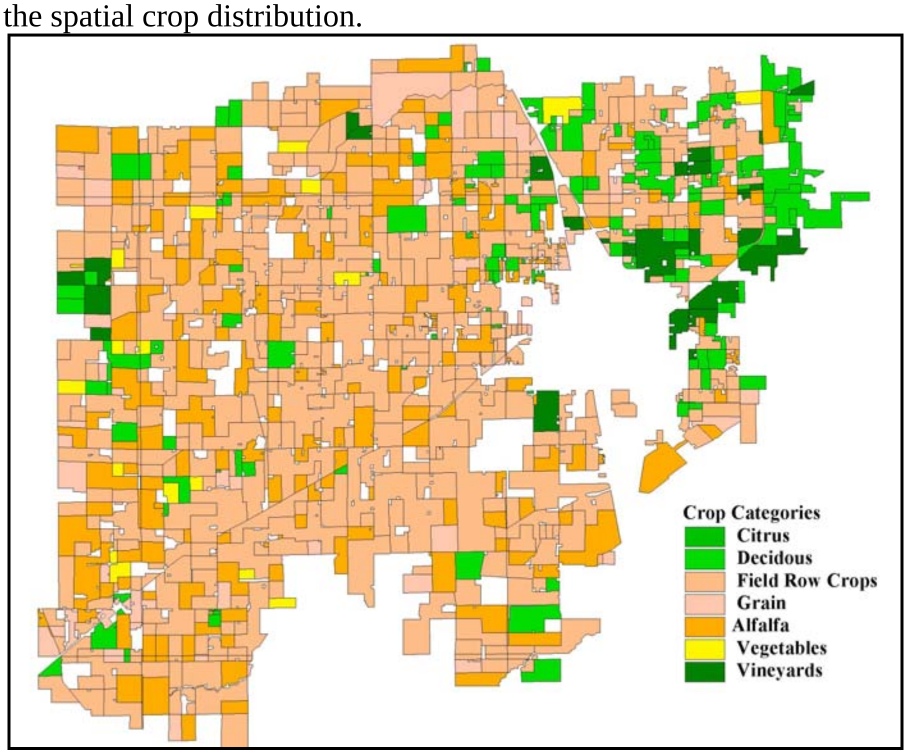

Figure 2. Crop distribution in Tulare Irrigation District

Groundwater elevations and movement have become increasingly important in California because of overdraft and water quality concerns. Subsurface groundwater movement into and out of the district boundaries is an important component of the water management plans that the districts are required to submit to the California Department of Water Resources or the U.S. Bureau of Reclamation and, in some cases, both agencies. Groundwater lines of equal elevations (contours) can assist the district in estimating subsurface lateral groundwater movement as well as areas of significant overdraft. The DWR generally takes well elevation readings in the spring and fall of each year. The ITRC generated TID groundwater contour maps for Spring and Fall of 2002. ArcView® 3D Analyst extension was used to generate these contours in ArcView® GIS.

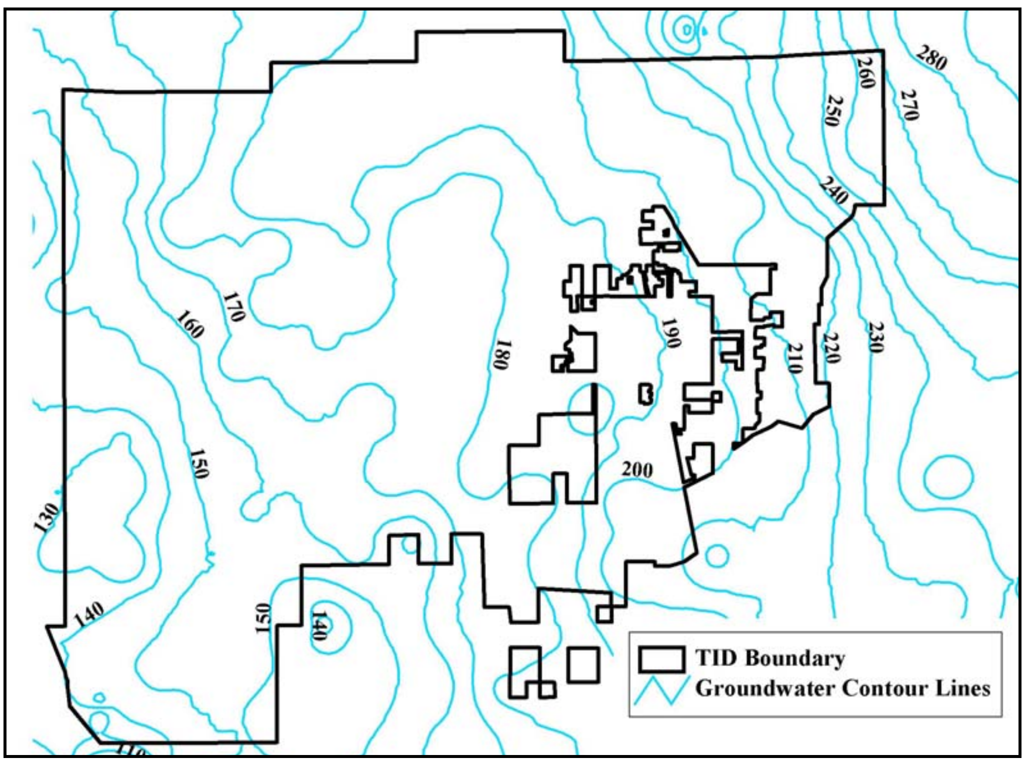

Figure 3. Groundwater lines of equal elevation from mean sea level for Tulare Irrigation District using data for Spring 2002

ArcView® GIS can also be used to generate approximately lengths and areas from scaled aerial photos, which is helpful in the preliminary design of improvement structures. The areas of potential reservoir sites, as well as lengths and elevations of potential pipelines and open channels, are common examples of the data obtained for preliminary designs.

Step 4. Presentation

Once the Tulare Irrigation District modernization plan was complete, GIS mapping was used to present the recommendations to the district in report and PowerPoint format. A simple well-labeled map without a basemap was used at the front end of the document and presentation so the reader and audience had a reference to refer back to when specific sites were mentioned.

Aerial photos were used extensively to layout conceptual designs of each recommendation. The export function in ArcView® GIS allowed ITRC personnel to extract recommended improvement areas as images so they could be imported into the main report and Microsoft™ PowerPoint presentation without making modifications to the overall GIS project. A final version of the GIS project with summarized recommendations was printed out on a large format printer and given to the district with the final RAP report.

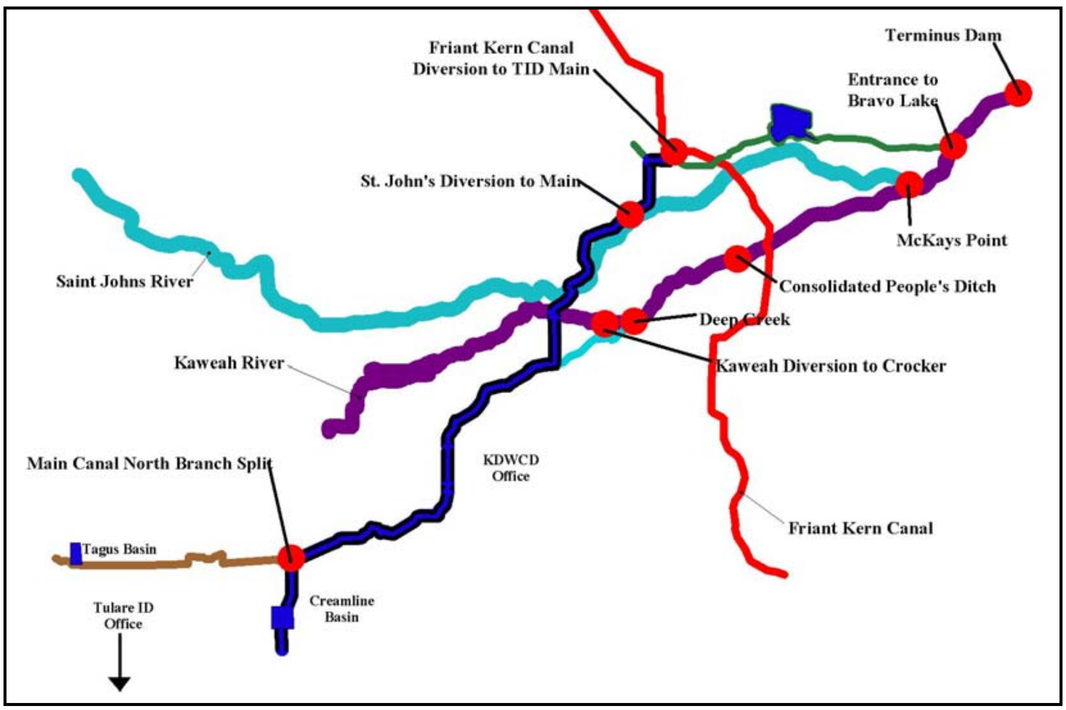

Figure 4. Simple layout of distribution system northeast of Tulare Irrigation District. The labeled points indicate key modernization sites discussed in the report.

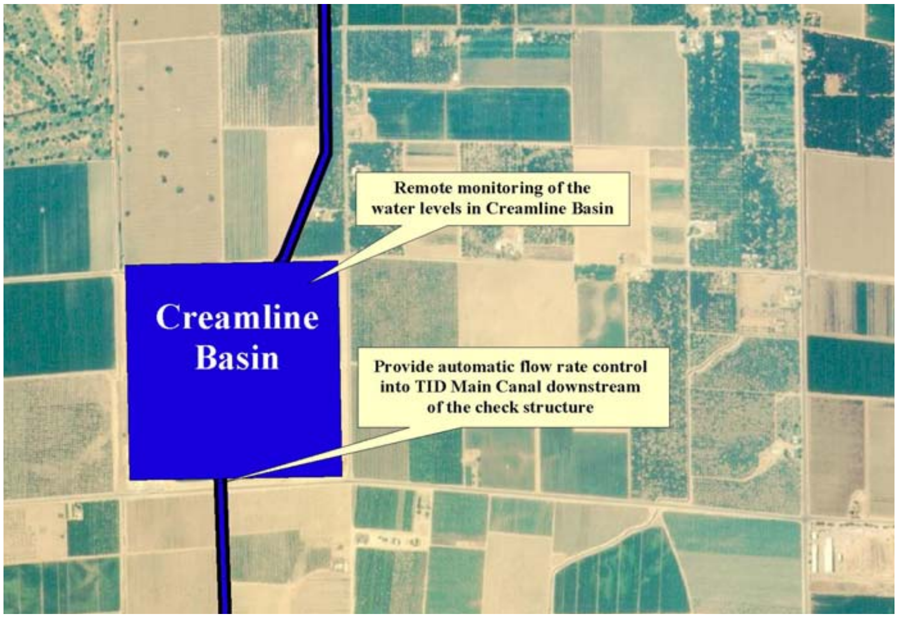

Figure 5. Example of using the export function in ArcView® 3.2a to export images for reports and presentations.

SUMMARY

In summary, GIS mapping can be an effective tool to organize, retrieve, and present spatial data for irrigation districts. The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo uses a combination of commercially available software with web-downloadable maps, photographs, and datasets to organize and present the spatial information.

ITRC has provided similar project datasets to some irrigation districts and has trained district staff in the use of ArcView® GIS. The spatial information offers districts an excellent starting point from which to expand their GIS mapping capabilities.

REFERENCES

Environmental Systems Research Institute. 1999. Getting to Know ArcView® GIS. ESRI Redlands, CA.