

GIS-BASED MANAGEMENT SYSTEM FOR IRRIGATION DISTRICTS

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ABSTRACT

In 1998, eight irrigation districts in the Lower Rio Grande Valley of Texas initiated efforts to develop GIS-based District Management Systems (DMS). This paper provides a description of GIS (geographical information system) as applied to irrigation districts, its potential for improving the day-to-day management of districts, and the progress and difficulties encountered by the 8 districts in GIS mapping and implementation. Examples of how districts are using GIS are given, along with the value and use of the DMS in a regional water planning project.

INTRODUCTION

The Lower Rio Grande Valley (Valley) is located at the Southeast tip of Texas and contains 28 irrigation districts (Fig. 1). The Region has approximately 740,000 irrigated acres and uses 1 to 1.4 million ac-ft of water a year to grow a wide range of fruit, vegetable and field crops. Just across the border in Mexico is a similar irrigated region containing about 1 million ac. All the water used in the region comes from the Rio Grande River which is divided between Texas and Mexico as stipulated by international treaty.

The region is also one of the fastest growing areas in Texas, and the water demand of municipalities and industries is also rapidly increasing. Water to meet the increasing demand must come from agriculture which holds 90% of all the water rights in the basin. A state-mandated regional water resources planning effort is currently underway which includes a detailed analysis of the current conveyance efficiencies of the districts. Planners are attempting to determine how much water could be freed up for other users through improvements in the districts and with on-farm irrigation.

The region is also entering its 5th straight year of reduced water supply due, in part, to a drought in the Lower Rio Grande Watershed of West Texas and

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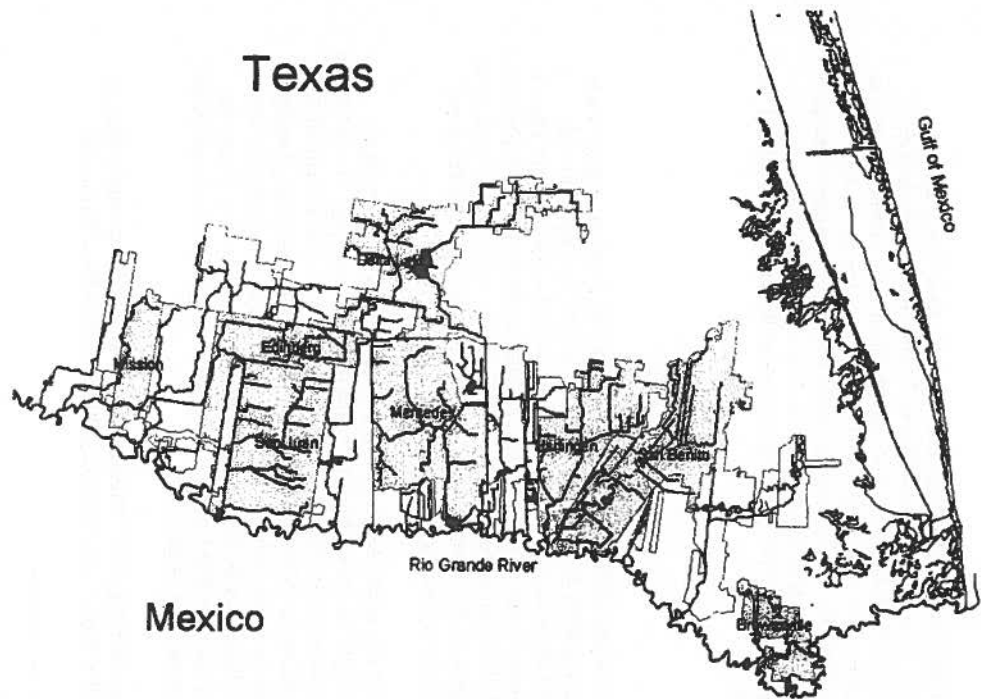


Figure 1: The main distribution canals of the 28 irrigation districts in the Lower Rio Grand Valley of Texas, and the 8 districts implementing GIS-based district management systems.

Northwest Mexico and severe regional droughts in 1996 and 1998. Irrigation districts are beginning to recognize the need to restructure their distribution systems, management decisions, and operating methods in order to improve efficiency.

In 1996, Harlingen Irrigation District and the Texas Agricultural Extension Service (TAEX) began an effort to develop visual system using GIS (geographical information system) that would allow the district to visually display and analyze all data used in daily district management. After evaluating several GIS options, *ArcView* was chosen as the GIS-tool for this effort. In 1998, Harlingen and 7 other irrigation districts began GIS implementation with technical support provided by TAEX and the DMS (District Management System) Team in the Agricultural Engineering Department of Texas A&M University. A description of this program is provided by Fipps and Pope (1998). This paper reviews the progress of GIS development and implementation since 1998.

GIS IMPLEMENTATION IN DISTRICTS

We have developed a program that encourages GIS development and implementation in districts through a step-by-step process. Keys to our success have been focusing the following:

- demonstrating ways in which GIS management systems can be a benefit and an important asset to the district,
- teaching the practical applications of *ArcView* and making suggestions as to what steps should be taken in what order to build GIS-based maps and databases, and
- providing continuous support in the process at each level, from the initial introduction to the software, to the confident use of *ArcView* as a daily management tool.

Common Uses For GIS in Districts

To encourage continuing progress in GIS development by districts, we focus on aspects that are the most beneficial based on their current stage of GIS development. These include the following.

Map Making: Accurate and up to date maps are vital for daily operations. GIS allows districts to quickly produce new maps as changes occur. Maintenance crews and canal riders can obtain maps of specific areas or segments which are tailored to them and contain only the information needed. This map making ability is not only useful for district personnel, but helps districts, municipalities, growers, and utility companies to share and understand information and ideas.

Boundary Disputes: After years of farming, urban development, and canal replacement, district right-of-ways and property boundaries often are not clear when compared to out-of-date maps. In some situations, irrigation districts need to reclaim encroached upon areas and settle property disputes. GIS maps coupled with recent aerial photographs (Fig. 2) are uniquely suited to such tasks.

Determining Net Acreage: Irrigation districts, insurance companies, and others may assess fees based on the water account acreage or the amount of land actually in production. In any given year, the difference between total acreage and net acreage under production may be significant. Extracting net acreage can be easily and accurately determined from the GIS maps and databases

Projecting Water Usage Patterns: Irrigation districts can use GIS to visually represent the distribution of water use in any or all fields over the past week, month, year, or period of record. This process can be taken a step further by overlaying two or more consecutive years to find patterns in water usage. Differences in water use may directly or indirectly occur due to crop rotation, weather, irrigation methods, tillage practices, etc.

Analyzing Other Types of District Information: Proper maintenance and planning for rehabilitation of distribution networks is greatly enhanced by having immediate access to such information as trends in urban development, past and current canal use, changing cropping patterns, and the conditions and dimensions of the canal segments under review.

For example, we developed a canal condition rating system (Table 1) to help identify segments needing increased maintenance or rehabilitation. Figures 3 - 5 show the condition rating system as applied to the Edinburgh Irrigation District. Figure 3 shows the main distribution network consisting of canals and pipelines. In Fig. 4, canals are highlighted by their condition ratings. High rating numbers indicate serious problems. However, the current extent of urbanized land and expected growth patterns (Fig. 5) also impact rehabilitation decisions.

Encountered Obstacles

Problems that have been encountered in GIS implementation include lack of data, existing AutoCAD maps and databases, lack of standardization of terms, improperly registered aerial photographs, and lack of manpower devoted to the task.

Lack of Data: Districts generally have limited updated data readily available on the exact physical dimensions and conditions of their entire distribution networks.



Figure 2. Water account boundaries created in GIS using an aerial photograph as a guide. This photograph is from a USGS DOQQ (digital ortho quarter quad), a high resolution photograph that has been registered.

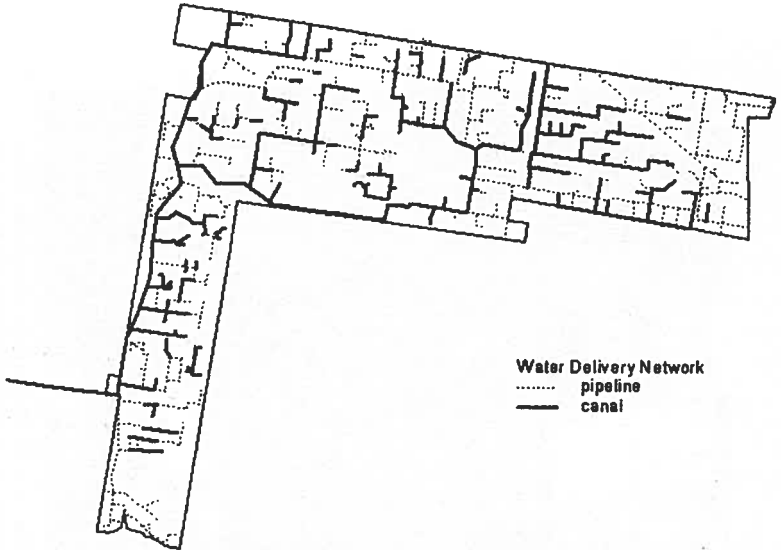


Figure 3. The main distribution network of the Edinburg Irrigation District consisting of canals and pipelines.

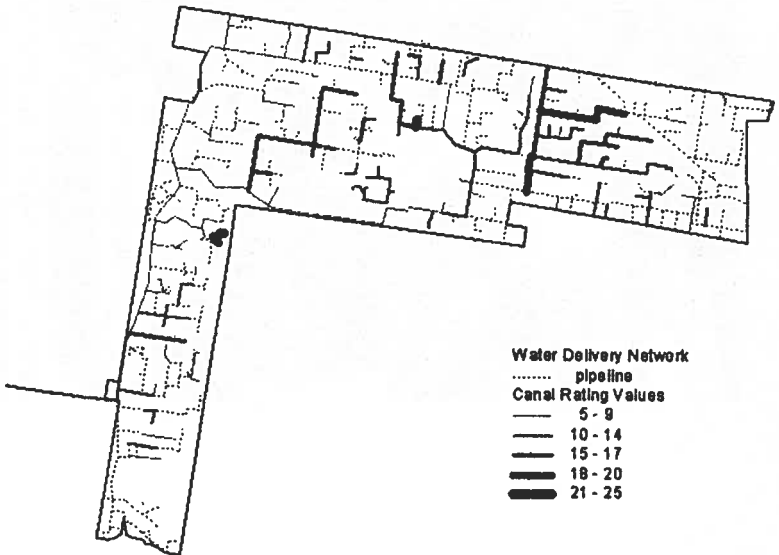


Figure 4. Edinburg canals highlighted based on their condition rating.

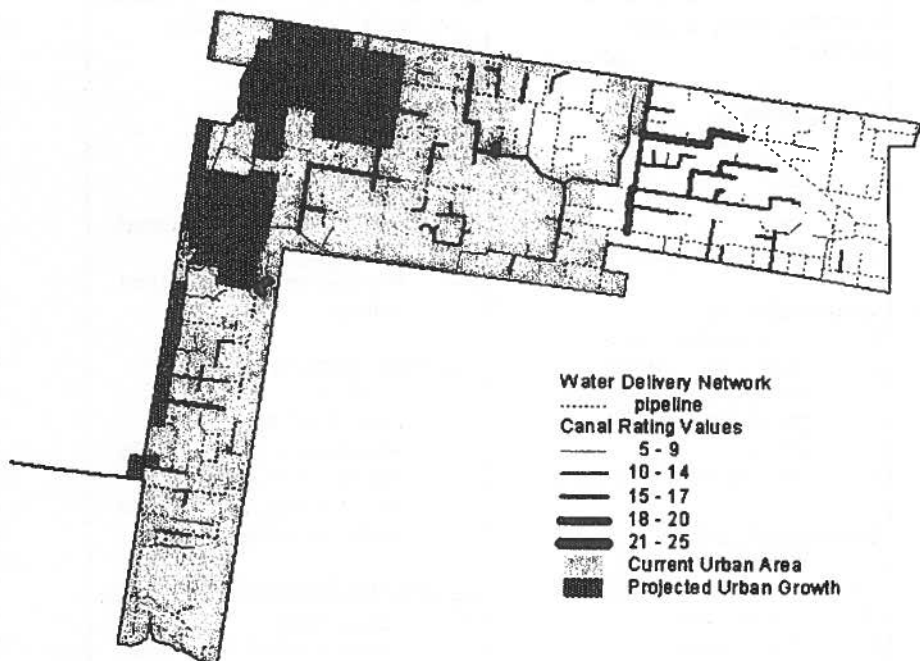


Figure 5. Distribution network, canal condition ratings, and present and projected urban growth of the Edinburg Irrigation District.

Table 1. Rating System for lined and unlined canals. Canal use frequency rating can be combined with the condition rating to help prioritize segments.

LINED CANAL RATING SYSTEM	UNLINED CANAL RATING SYSTEM
<p><u>Lining Condition</u></p> <p>1 - excellent 2 - good 3 - fair 4 - poor 5 - serious problems</p> <p><u>Cracks/holes - size</u></p> <p>1 - a few hairline cracks 2 - hairline to pencil size 3 - predominately pencil size 4 - pencil size and a few large cracks 5 - predominately large cracks</p> <p><u>Frequency of cracks</u></p> <p>1 - sparse 2 - greater than 10' apart 3 - 5' to 10' apart 4 - 3' to 5' apart 5 - less than 3' apart</p> <p><u>Vegetation in Drainage Ditch or along base of embankment</u></p> <p>1 - normal; rain-fed weeds only 2 - above average 3 - moderate 4 - dense 5 - dense and lush</p>	<p><u>Interior condition of canal</u></p> <p>1 - excellent 2 - good 3 - fair 4 - poor, some holes and/or cracks and leakage 5 - seriously eroded and obvious leakage</p> <p><u>Condition of embankment</u></p> <p>1 - excellent 2 - some minor erosion 3 - moderate amounts of erosion 4 - high levels of erosion 5 - severe erosion, levee/canal in danger of failing</p> <p><u>Vegetation in Drainage Ditch or along base of embankment</u></p> <p>1 - normal; rain-fed weeds only 2 - above average 3 - moderate 4 - dense 5 - dense and lush</p>
<p style="text-align: center;">CANAL USE FREQUENCY</p> <p style="text-align: center;">1 - never 2 - rarely 3 - seasonal 4 - regular 5 - constant</p>	

Such information is beneficial when considering reconstruction projects, calculating future demands on particular segments, and evaluating the cost efficiency of rehabilitation options. Assembling this data takes considerable time and may require weeks of field work or reviewing numerous rehabilitation reports going back decades.

Existing AutoCAD Maps: Some districts have investigated the incorporation of existing AutoCAD maps with GIS. After much trial and error, we have found that the process is difficult and time consuming. Due to differences in mapping techniques, warping and overlaying, the resulting GIS maps are often inaccurate and still require modifications, including redrawing of the canals, pipelines and account boundaries in *ArcView*.

Database Design and Connectivity: Effectively structuring and linking data are difficult and critical tasks. *ArcView* allows users to connect themes to data sources external to the software. For example, in the GIS, the water account boundaries are mapped and linked to the existing accounting database. The link typically is through the account number or property identification number which is included in the *ArcView* attribute table. This provides the ability to view all available data directly on the GIS map, such as property owner, water use history, and cropping patterns.

In the Lower Rio Grande Valley, several types of commercial and custom accounting databases software packages are used by districts. Some databases are not structured for accounting at the field level, but for accounting based on owner or water ticket holder. Often growers irrigate several fields which are under the same account number. In such situation, displaying specific field information requires modification of the existing database.

Consolidation of GIS Maps at a Regional Level: Figure 1 shows a portion of the data that is included our *Regional GIS of the Valley*. This GIS contains locations of district boundaries, cities, water ways, the extent of the main distribution networks, etc. The DMS team is attempting to incorporate the more detailed information being assembled by each district into this regional GIS. We have promoted standard attribute names and formats (number, string, decimal places, etc.) among the districts to help streamline the process. Merging of data sources to combine a single, comprehensive map requires a working knowledge of how the software performs this task. Failure to understand the process has resulted in data being overwritten, duplicated, and even removed altogether. However, each crisis has resulted in a better understanding of how the system functions.

PRESENT STATUS OF DISTRICTS' GIS

Large differences exist between the districts in the Lower Rio Grande Valley, including size of the district, revenue, personnel, management, distribution networks, crop types, and degree of urbanization. All of these factors have effected the progress of each district in GIS implementation as discussed below.

Brownsville Irrigation District

Use of aerial photographs as a guide for mapping Brownsville Irrigation District (BID) is limited since the water delivery network is 90% under ground pipeline. Canals are easily distinguished on aerial photographs, while pipelines are not visible except for the stand pipes, if they still exist. The district originally explored the idea of importing their *AutoCAD* engineering maps into *ArcView*, but decided that it would be easier to redraw the district from scratch.

GIS development in the BID was delayed due to lack of personnel for the effort. Initially, a secretary was trained and did GIS mapping as time would allow, but a full-time effort is required in the initial GIS mapping and database linking. In September 1999, BID hired a part-time student intern who has since mapped all of their water account boundaries, resacas, canals, pipelines, and re-lift pumps. BID also acquired a large format plotter and now produces useful maps for maintenance crew and canal riders.

Harlingen Irrigation District

The Harlingen Irrigation District (HID) initially reassigned a canal rider to serve as their GIS technician on a part-time basis. Mapping of the distribution network was completed by the DMS team as part of the Phase II project (see Fipps and Pope, 1998). In 1999, HID hired a summer intern who was able to map 60% of the water accounts and link them to the district's accounting database.

The district uses the GIS regularly to settle land disputes and other spatially related issues. HID is currently evaluating the use of a Global Positioning System (GPS) to map exact easement boundaries and locations of other facilities for incorporation into the GIS.

San Benito Irrigation District

The San Benito Irrigation District (SBID) also reassigned a current employee as a part-time GIS technician. The district had almost no attribute data on their water distribution system. All 8 canal riders were instructed to collect basic information on canal width, depth, lining material, and segment length. It took 6 weeks of full-time work to collect this information. Their water delivery system, consisting of 90% canals, was mapped by the DMS team during the Phase II Project. The

district has now entered all attribute data and mapped 80% of their water account boundaries.

The first efforts to link water account boundaries with the water account database were not successful. The district's accounting system is based on an account number, not a field or location number. When querying an account number, multiple locations appear for the same account. Thus, records for a specific field cannot be separated. SBID has now added a personal identification number associated with each field location.

Delta Lake Irrigation District

Delta Lake Irrigation District began collecting attribute data upon GIS implementation in 1998. Their water delivery system was also mapped by the DMS team during the Phase II Project. During the second half of 1999, Delta Lake hired two part-time GIS technicians to map account boundaries and re-lift pump locations, and to improve and update the work done during the Phase II Project. They mapped 90% of the water account boundaries, complete with account numbers and field identification numbers.

The next step for Delta Lake is to link their accounting database system to the GIS. However, the district has a customized database running on an old mainframe computer. Linking the GIS to this database requires a special connector and customized programing which has not yet been completed.

Edinburg Irrigation District

Edinburg Irrigation District (EID) realized an urgent need for developing maps and databases when the district's senior canal rider, also known as the districts "walking database," announced his upcoming retirement. EID began an intensive mapping effort, compiling and entering as much attribute data on the distribution network as possible.

The mapping completed to date includes 100% of the account boundaries and 80% of the delivery network. Currently, EID is concentrating on mapping excluded areas due to the upcoming board elections. Excluded areas are land that have gone out of irrigation usually due to urbanization. These areas are excluded from the district, and landowners in these areas are not allowed to vote.

San Juan Irrigation District

San Juan Irrigation District (SJID) reassigned a canal rider as their full-time GIS technician. He has made rapid progress in mapping the entire district, including the distribution network, water account boundaries, gates, pumps, turn-out valves, pipeline shutoff valves, and district right of ways. SJID has successfully linked

the GIS and water account databases which are automatically updated whenever changes occur. The district uses the GIS on a daily basis for quickly retrieving information on water accounts, as well as pipelines and canals, including construction material and sizes of specific segments.

The district has also begun using the GIS to help with decisions in canal replacement. The GIS is used to determine total net irrigated acres and cropping patterns serviced by a specific canal network by accessing the water account records. With this information, the district then calculates the size of the replacement pipeline needed to deliver this water volume. A consulting firm, on the other hand, had oversized a pipeline since their calculations were based on the total or gross acres in the area. Thus, SJID saved a considerable amount of money with the reduced pipeline size.

Mission Irrigation District

Mission Irrigation District initially hired a full-time technician for a 3-month period in 1998. The technician began by drawing water account boundaries. Over 90% of the district's water account boundaries were mapped, and this theme was successfully linked to their water account database. With assistance from the DMS Team, all main canals were mapped by the end of Summer '98. However, the district has little attribute data describing the delivery network.

Due to changes in management in 1998, GIS development came to a halt. However, the secretaries routinely use the GIS to verify account information and location when farmers come in to purchase water tickets. Farmers have expressed appreciation about the GIS capabilities to visually show their property and all account information. As a result, the district has been able to update and make numerous corrections in their records.

Mercedes Irrigation District

Mercedes Irrigation District reassigned a secretary to be their full-time GIS technician. Mapping completed including the entire water distribution network, all water account boundaries, and canal rider service areas.

During district elections in 1999, the directors requested maps of all excluded areas and subdivisions to help determine voter eligibility. The GIS maps and database had to be modified for legal descriptions of properties in terms of metes and bounds. Mercedes hired a second part-time GIS technician to help with the work load and purchased a large format plotter. Other endeavors have included coordinating efforts with the U.S. Border Patrol in mapping check points and surveillance areas along the Rio Grande River (the southern border of this district lies on the Rio Grande) and working with land realtors to provide property lines and maps.

REGIONAL GIS USES AND ACTIVITIES

Water Saving Strategies

Currently, we are participating in a Regional Water Planning Project to identify the amount of water that could potentially be freed up from improvements in distribution networks and on-farm irrigation for transfer to other users. This is a major expansion of the efforts conducted in the Phase II Project (see Fipps and Pope, 1998). An intense effort is underway to assemble detailed information on operational methods and physical features of the districts' distribution systems. Canal rider surveys were conducted in all or parts of 6 districts to identify:

- the condition of canal segments (Table 1), including physical dimensions and lining materials
- on-farm irrigation methods and technologies in use on a field by field basis,
- water supply or loss problems identified by canal segment and individual fields, and
- locations of turnout valves, check gates, pipeline control valves, and operational spill drains

In addition, the DMS team is conducting seepage loss tests across the Valley on variety of canals segments, monitoring operational spill sites and recovery projects, and documenting water savings from metering programs. After these surveys and studies are complete, the results will be entered into the appropriate GIS databases for analysis.

GIS Support

As part of the cooperative arrangement with the 8 districts shown in Fig 1., we are offering continuing support on GIS implementation. In 1999, the DMS Team conducted two, 1-day GIS workshops for irrigation districts. A complete set of instructional materials were developed for the workshops and can be found on the District Management System Program Web Site (<http://dms.tamu.edu>).

Monthly support sessions are held with the GIS technicians to foster collaboration on new uses and problems, and to teach advance techniques. Attendance at the workshops and monthly meetings are not limited to district personnel, but includes tax appraisal districts, the US Border Patrol and others implementing GIS. Support is also available by phone and through the internet.

GPS Evaluation

We are investigating the use of GPS receivers for more precise mapping and quick updating of existing maps. GPS receivers determine a location on the Earth

surface from satellites. This information can be exported to the *Pathfinder* software and then converted directly to an *ArcView* theme. The DMS team has used GPS receivers to locate sites, map areas and rectify discrepancies in GIS maps.

District Management System Development

We are currently conducting research to extend GIS applications and create a total District Management System (DMS). This involves three major efforts:

- continued collaboration with districts on developing and implementing GIS,
- development and incorporation of a distribution network accounting and routing simulation model; and
- incorporation of an crop water use and irrigation scheduling simulation model.

A GIS interface for the irrigation district simulation model IRDDESS (see Fipps and Pope, 1998) has been completed and is currently being tested.

REFERENCE

Irrigation District Management System Program Web Site, <http://dms.tamu.edu>.

Fipps, G. and C.N. Pope. 1999. Implementation of a District Management System in the Lower Rio Grande Valley of Texas. Proceedings of the 14th Technical Conference - 1998. US Committee on Irrigation and Drainage, Denver.

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