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Potential Water Savings in Irrigated Agriculture in the Lower Rio Grande Basin of Texas

Final Report

August 1, 2001

by

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December 22, 2000

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SUMMARY

This report was completed as a part of Senate Bill 1 regional water planning study for the Rio Grande Region (Region M) to determine the potential water savings in irrigated agriculture. Regional water savings potential are shown below. County estimates are also included in this report.

WATER SAVING POTENTIAL IN IRRIGATION DISTRICTS AND ON-FARM IN ACRE-FEET PER YEAR

Water Supply Condition	District Conveyance Efficiency Improvement	On-farm Practices and Methods	
		With district improvements	Without district improvements
drought	159,631	174, 537	105,029
normal	210,944	226,178	142,852

Conveyance Efficiency Improvements are water savings from the reduction of transportation, operation and accounting water losses in irrigation districts, and were calculated based on increasing conveyance efficiency from current average of 70.8% to 90%.

On-farm Practices and Methods are water savings from the expansion of water measurement and metering, replacement of field ditches with poly pipe, and adoption of improved water management practices and irrigation technologies

Other findings and conclusions are as follows.

Description of Districts

- ? The 9 largest districts (out of 28 active districts) hold 72% of the 1.6 million acre-feet of agricultural water rights.
- ?? The main distribution networks consist of 790 miles of canals, 124 miles of pipeline, and 76 miles of resacas.
- ?? The secondary and tertiary networks ("laterals") consist of about 670 miles of canals and 1690 miles of pipelines.
- ? There are 552 miles of lined canals, 614 miles of unlined canals, and about 294 miles of canals with unknown lining status.

Conveyance Efficiency

- ?? The lined canals are in poor condition with an average condition rating of 6.4 (on a 10 point

scale).

- ?? Measured seepage loss rates in 15 concrete canals were extremely high, ranging from 1.42 to 27.07 gal/ft^2/day. The smaller canals had the highest seepage loss rates. The annual water loss from these canal segments ranges from 90 to 1220 ac-ft/mi/yr.

- ? High seepage losses in lined canals indicate that improper construction methods and materials are being used in the region, and that some districts have inadequate maintenance programs.

- ? When classified by soil type, seepage loss rates measured in 8 unlined canals were similar to those reported in the scientific literature, and ranged from 0.20 to 5.84 gal/ft^2/day. The annual water loss from these canal segments ranges from 54 to 1037 ac-ft/mi/yr.

- ? There are at least 192 miles of concrete pipelines with mortar joints. Inflexible pipeline joints are likely to have high leakage rates. We have no information on the type of joints in 658 miles of concrete pipelines.

- ? Four spill loss and recovery sites were monitored and found to have spill rates ranging from 28 to 4684 ac-ft/yr. There are at least 34 major spill sites in the region.

<u>On-farm</u>

- ? At least 33% of the area experiences frequent head problems, causing insufficient water volume at the field turn-out to allow for efficient furrow irrigation. Some estimates indicate that at least 50% of the area experiences occasional to frequent head problems.

- ? Currently, 54% of the water delivered in the region is under consistent water measurement or metering programs by districts.

- ? On-farm, about 36% of the water applied in the region is through poly (or gated) pipe, and 30% is applied with high water management and/or improved irrigation technology.

<u>General</u>

- ? Questions have been raised on the accuracy of the information districts use to estimate conveyance efficiency including metering at the river pumping plants.

- ?? Uniform database formats and software are needed among districts to help support water measurement and district rehabilitation programs and to promote district accounting system modernization and integration with GIS.

- ? To achieve the projected water savings, a comprehensive and integrated program is needed that addresses all aspects of water supply and use in districts. The Imperial Irrigation District's program with the Municipal Water District is one model to use in designing a program for the Rio Grande Planning Region.

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INTRODUCTION

This report was completed for the *Senate Bill 1 Rio Grande Regional Water Planning Project (Region M)* by the District Management System (DMS) team under the direction of Dr. Guy Fipps. Funding was provided through the Texas Agricultural Experiment Station under a contract from Turner, Collie and Braden, Inc. Project activities began in March 1999, and the draft final report was submitted on June 19, 2000.

We also conducted a similar, but more limited analysis for the *Integrated Water Resource Plan Project - Phase II* (Phase II) which was completed in February 1999. That project was confined to the counties of Cameron, Willacy and Hidalgo and was administrated by the Lower Rio Grande Valley (LRGV) Development Council. For the Phase II project, mapping and data collection was limited to the main water distribution networks of the LRGV's irrigation districts. Generally, data and estimates provided by the district managers were used to calculate water savings with little independent verification.

For this study, our analysis was extended to the entire Rio Grande Planning Region (Region M). To the degree possible, we obtained information independently and verified data provided by districts. Detailed mapping and data collection was also initiated for the Maverick Irrigation District, the only district not a part of the Phase II project.

LITERATURE REVIEW

Very little information has been reported in the scientific literature on canal seepage and reduction from district rehabilitation projects. All the data found is given in Tables I-1 through I-5. Table I-4 summaries canal seepage measurements from the LRGV. Table I-5 shows the results of a testing program on the reduction of seepage with various canal lining materials.

We also investigated the Imperial Irrigation District's (IID) program with the Municipal Water District (MWD). IID received $109 million to save 100,000 ac-ft/yr of water which was then leased to the MWD for a period of about 40 years. IID's program is summarized in Tables I-6 and I-7. Key points relevant to Region M are:

- This is an integrated program that includes elements aimed at improving both conveyance efficiency and on-farm irrigation.
- The program includes elements that are resulting in large water savings, as well as those needed to improve the overall operation of the district.
- About 16% of the total budget is spent on program verification which saves no water.

However, program verification is important in order to develop confidence in achieved water savings among all parties, including the growers of the district. This program also produced the data needed in various lawsuits questioning the success of the program.

MATERIALS AND METHODS

Table II-1 summaries our main activities on this project, which included:

- ?? Completion of a District Bio and Survey
- ?? GIS mapping of mains and laterals using *ArcView* software
- ?? Seepage loss tests conducted in 24 canal segments
- ?? Monitoring 4 spill loss and recovery sites
- ?? Review of other district rehab programs
- ?? Surveying canal riders to help verify district information
- ?? Implementation of a canal rating procedure
- ?? Evaluation of water metering and measurement programs

Table II-2 provides details on the canal rider survey, and the canal rating system is detailed in Tables II-3 through II-5.

Twenty-four (24) canal seepage loss tests were conducted using the ponding method. In this method, the two ends of a canal segment are closed or sealed, as are any valves or gates located within the segment. Once sealed, water elevations were taken for at least 24 hours. Two continuous stage level recorders were used to supplement the 2 to 3 locations where stage levels were recorded manually.

Four (4) existing spill sites were monitored continuously during the project. Two of the sites allow excess canal water to flow into pipes. The third is a drop inlet in a reservoir to control water levels, and the fourth is a pump-back system to return water from a reservoir to a canal.

Spill rates for the first three sites were calculated using the equation for a drop inlet which was calibrated for each site. Stage levels above each inlet were recorded continuously by a data logger connected to a pressure transducer. For the pump-back system, we measured pumping rates using a ultrasonic flow meter and developed an energy/flow rate relationship. Electric records were then used to determine annual spill recovery amounts.

Some GIS mapping was done collaboratively with 8 irrigation districts in a separate program partially funded by the districts. The DMS team provided training and technical assistant to these 8 districts and worked with each district's GIS technician in mapping of the distribution systems and water account boundaries. All maps produced have a resolution of 1 meter and are based on aerial photographs obtained from the U.S. Geological Survey. This program was renewed in 2000 and expanded to include 10 districts in Region M.

DESCRIPTION OF THE DISTRICTS

Water Rights

The names and authorized water rights of 29 water districts in Hidalgo, Cameron, Willacy and Maverick Counties are listed in Table IV-1. This information was obtained from the Rio Grande Watermaster office. One district listed (Cameron #17) is no longer functioning. Figure 1 shows the irrigation district boundaries in the LRGV, and Figure 4 shows Maverick ID.

These districts hold authorized agricultural water rights totaling 1,603,214 ac-ft. Based on water rights, the districts vary greatly in size, with the smallest active district having 1,120 ac-ft and the largest district 174,776 ac-ft.

- The 5 largest districts (Mercedes, Delta Lake, San Benito, Maverick and San Juan) account for 49% of all agricultural water rights.

- The largest 9 districts (adding Harlingen, Donna, Edinburg, and Santa Cruz) account for 72% of the total.

Water Distribution Networks

The main irrigation distribution networks of the LRGV districts are shown in Figure 2, and Figure 4 shows both the mains and laterals for Maverick ID. Figure 3 shows both the mains and laterals for 7 districts. These maps were created in a cooperative mapping program between the DMS team and districts as discussed above.

Distribution Networks of Districts (miles)

	Canals				Pipeline	Resaca
	Lined	**Unlined**	**Unknown**	**Total**		
Mains	351	438	0	**790**	124	76
Laterals	201	175	294	**670**	1690	
Totals	**552**	**613**	**294**	**1459**	**1814**	**76**

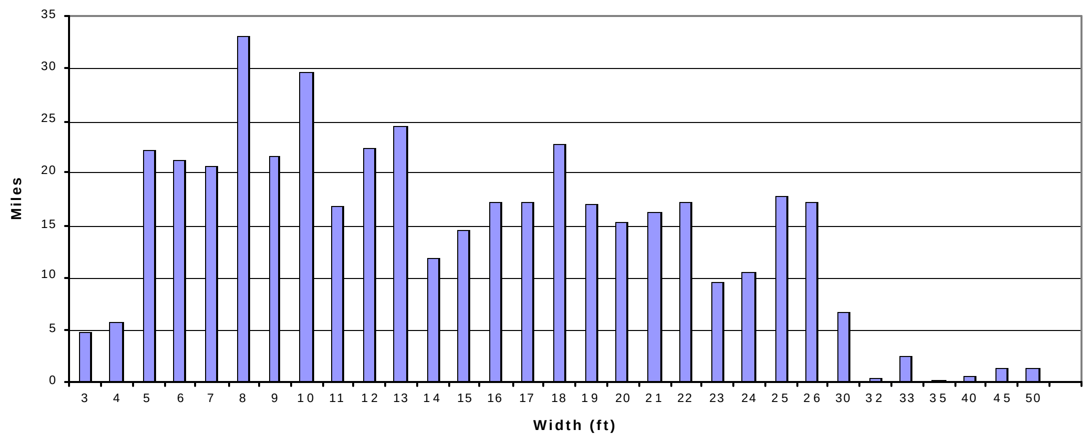
Our best estimate of the total length of the distribution networks is shown on the left. We obtained information on the lining status of all but 294 miles of canals (see Tables III-1 and III-2).

“Laterals” refers to the secondary and tertiary networks of districts, which carry water from the mains to the field turnouts.

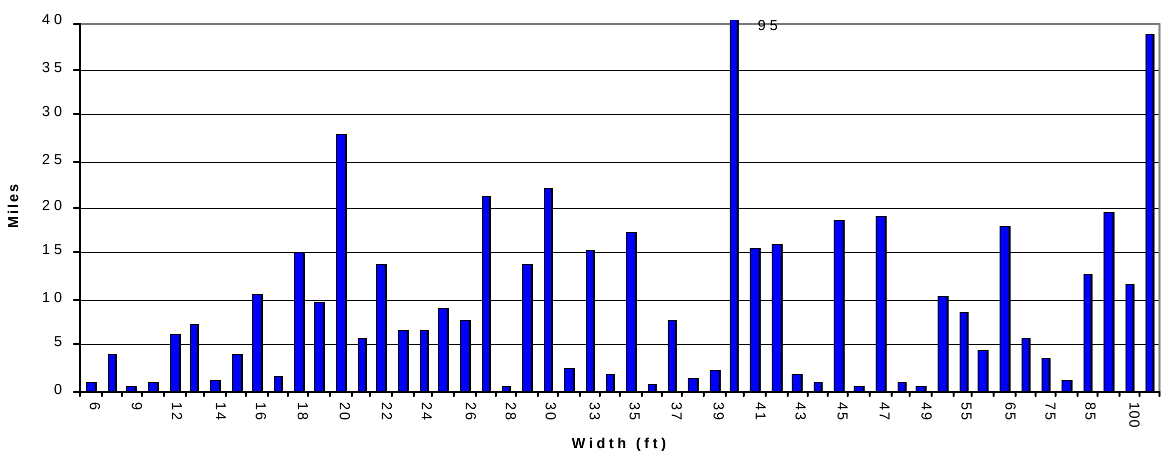
“Resaca” refers to ox bow lakes common in the LRGV. These are used by districts for water storage and transportation channels.

The lengths of lined and unlined canals by known top widths are shown in the two charts below. See Tables III-11 and III-12 for information on the storage reservoirs and pumping plants. Additional details on the water distribution networks are provided in Tables III-3 through III-5. County breakdowns of canal lengths by known widths and lining status are given in Tables III-6 and III-7.

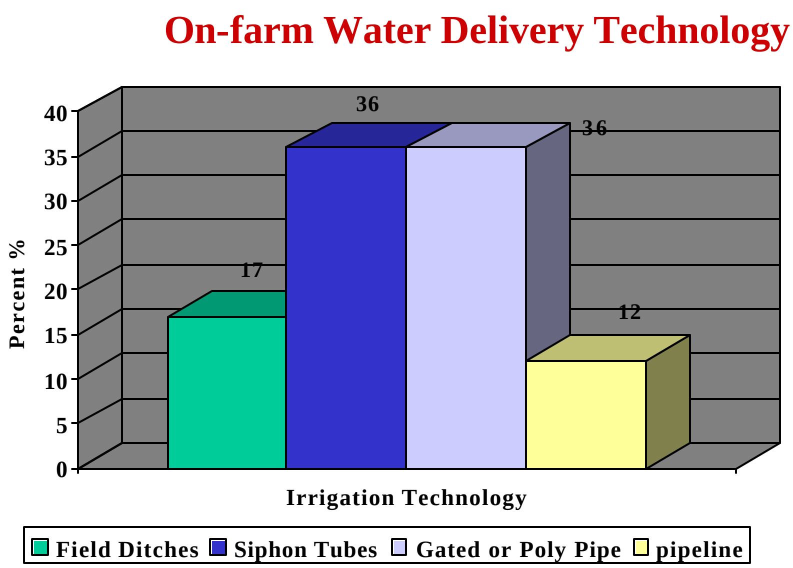
Total Miles of Concrete Canals by Width



Total Miles of Unlined Canals by Width



<u>On-Farm Water Delivery Technology</u>

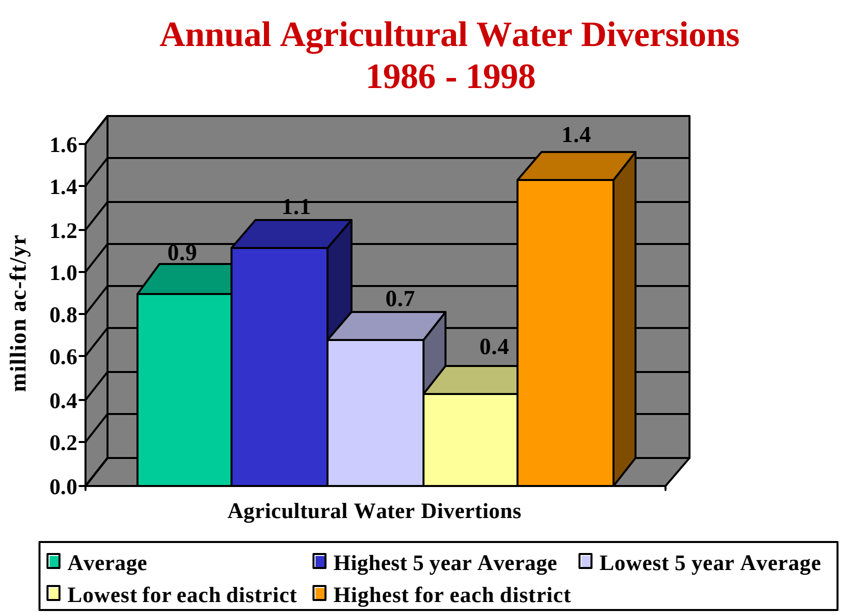


This chart shows the current use of on-farm water supply methods. More details are provided in Tables III-8 and III-9.

Poly pipe generally has the least water loss and can promote good surface irrigation efficiency.

Cutting of field ditches and siphon tubes generally provide insufficient control over water flow for good surface irrigation efficiency.

DIVERSIONS



As shown above, agricultural water diversions vary greatly from year to year depending on water supply, weather, and crop economics. Diversions for each district during this period are listed in Tables

IV-2 and IV-3.

WATER MEASUREMENT PROGRAMS

About 57% of on-farm water deliveries are directly measured or metered by districts. Several districts have also implemented pricing programs as detailed in Tables IV-4 and IV-5. This is a large increase that has occurred over the last few years. Most districts that do not require metering now allow the use of meters if requested by their growers.

Maverick and Donna have had the longest measurement programs. Donna uses upflow meters in standpipes that were calibrated in place. Some meters monitor water to more than one grower. Donna does not meter consistently, and some questions have been raised about the accuracy of their meters.

Maverick delivers water through gates to "head canals" belonging to farmers. These gates have been calibrated, and generally, canal riders measure the height of the water flowing through the gate twice during an irrigation event. This is a very cost effective and accurate method of water measurement that suits the Maverick district quite well.

In 1999, Delta Lake began an universal water measurement program at the field turnout and required growers to pay 50% of the cost of the meters. Most growers are using propeller flow meters in tubes that are inserted into the valve bonnet. A growers' survey on Delta Lake's metering program is summarized in Table IV-6. While some problems were identified in this survey, the metering program is generally effective and has resulted in water savings.

The most effective programs are those that provide incentives through water pricing or credit programs, and in which district personnel provide technical assistance to growers on improved irrigation water management. For example, Brownsville uses a combination of incentives, tailwater fines and technical assistance. The district moved valves to the center of fields at no cost to the grower to facilitate the use of poly pipe and surge flow valves. Similarly, Bayview provided poly pipe to growers at low cost when first implementing a water metering program.

However, water measurement programs require additional manpower for collecting and recording the data. Districts without modern databases and water accounting systems have had difficulty in managing the large amounts of information being collected.

Some districts have custom (i.e., non-commercial) databases which district personnel do not know how to modify. Thus, the database programmer must be contracted to make changes which are needed for water accounting and for integration with GIS-based management systems. Uniform database formats and software among districts would help promote district accounting system modernization.

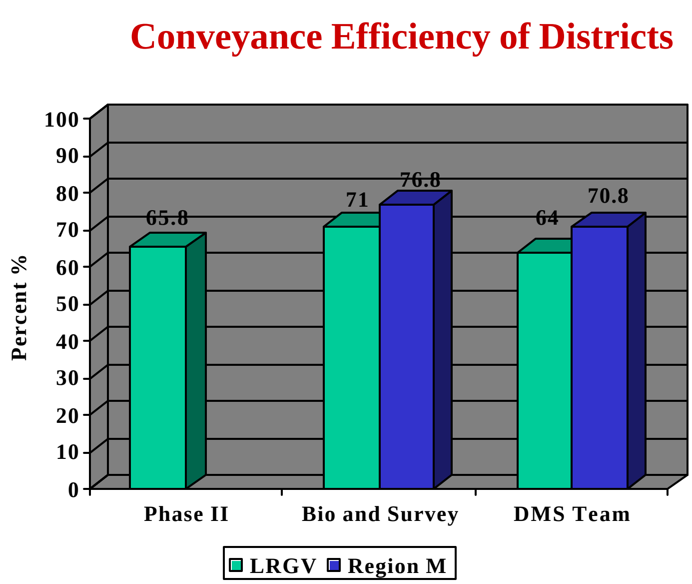
CONVEYANCE EFFICIENCY

The term conveyance efficiency (or water duty) is a measurement of all the losses in an irrigation distribution system from the river (or diversion point) to the field. Conveyance efficiency is calculated from the total amount of water diverted in order to supply a specific amount of water to a field (6 inches for most districts that do not meter or measure).

Districts express conveyance efficiency in terms of efficiency, the percent of water lost, or amount of water pumped (in feet). For example, District A must pump 8 inches from the river in order to deliver 6 inches to the field. District A's losses can be expressed as a:

- conveyance efficiency of 75%,
- water duty of 25%, or
- water duty of 0.67 ft.

Conveyance loss includes other factors in addition to seepage and evaporation. Table V-1 shows the various components of conveyance efficiency under the three major categories of Transportation, Accounting, and Operational losses. County estimates of district conveyance efficiencies are given in Table VI-5.



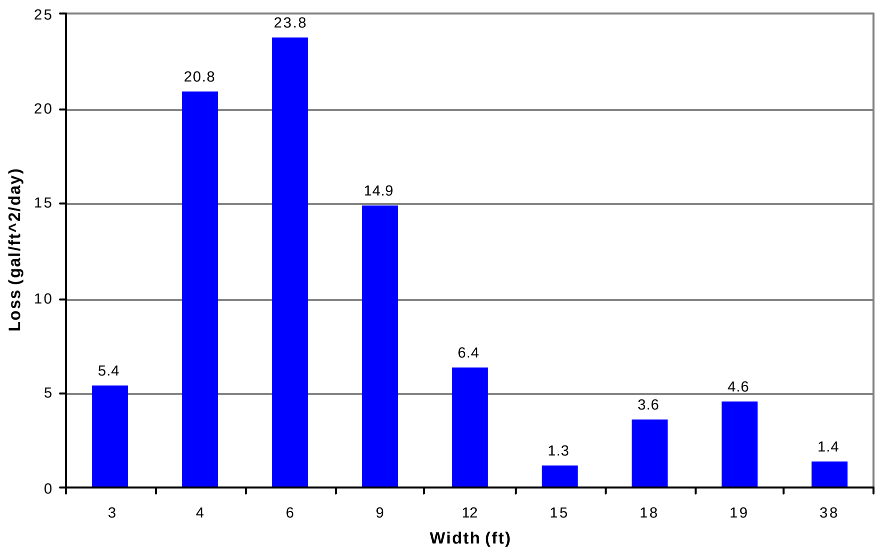
The chart to the left shows the average district conveyance efficiency for the LRGV and for Region M (which also includes Maverick ID).

The efficiencies shown by the green bars are those reported to us by the districts. The DMS team's estimate (blue bars) was used to calculate the water saving potential reported here

Lined Canals

We measured seepage losses in 15 concrete canals using the ponding method. The results are shown on the next page and in Table V-2. Note, these numbers include canal seepage and evaporation, as well as water that may have leaked undetected through gates and valves.

Seepage Loss in Concrete Canals by Width

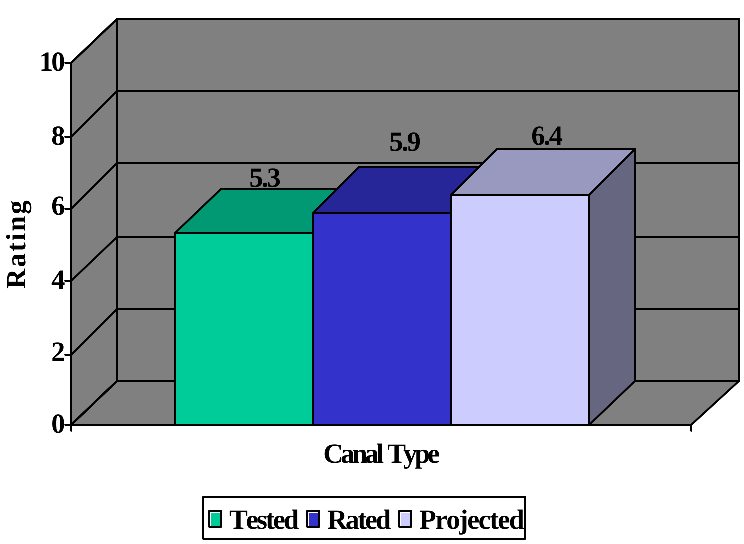


The chart on the left shows the measured seepage loss rates in concrete canals for representative widths.

The highest loss rates occurred in canals less than 12 feet in width.

Table II-3 shows the rating system for lined canals developed for this project which considers lining condition, crack size and frequency, and the amount of vegetation in the canal and embankment. We rated all canals for which seepage tests were conducted, as well as 57% of all canals in the region.

Average Rating of Lined Canals



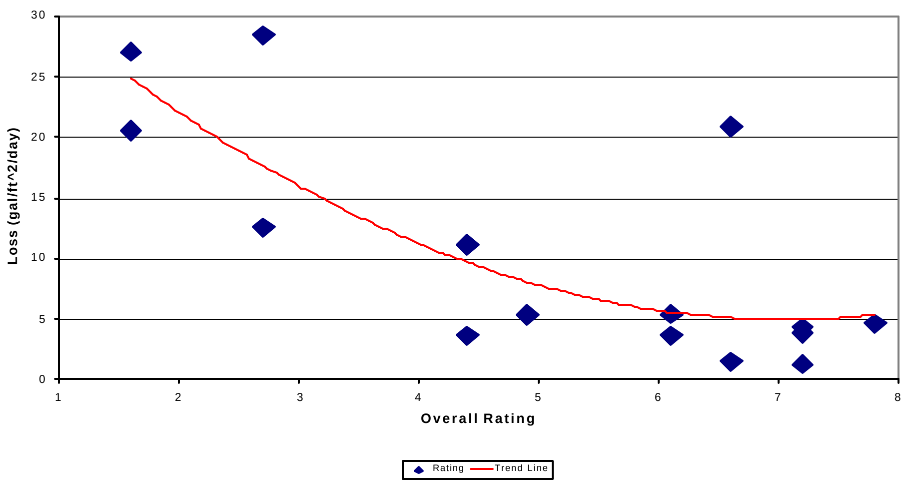
The condition of the lined canals that were rated are in poor condition with an average rating of 5.9. We estimate that the average rating of all concrete canals in Region M is 6.4.

The poor condition of these canals indicate problems with materials and construction methods. Most canals are lined with unreinforced concrete, which are susceptible to cracking due to shrinking and swelling soils.

For larger canals, consideration should be given to composite construction with reinforced concrete and membranes.

As shown below, we found a clear relation between the overall condition rating and measured seepage loss rate for the 15 concrete canals tested.

Seepage Loss in Concrete Canals by Rating



Lining and pipeline replacement of canals to reduce seepage is not the only consideration.

Leaking gates and valves can also be a major source of water loss and should be considered as part of any rehabilitation program.

The chart below gives the miles and square feet of canals at and below each rating. In a district rehabilitation program, all concrete canals rated 5 and below should be investigated for replacement with pipeline or reconstruction, particularly canals less than 12 feet wide.

Miles and Areas of Concrete Canals with Low Ratings

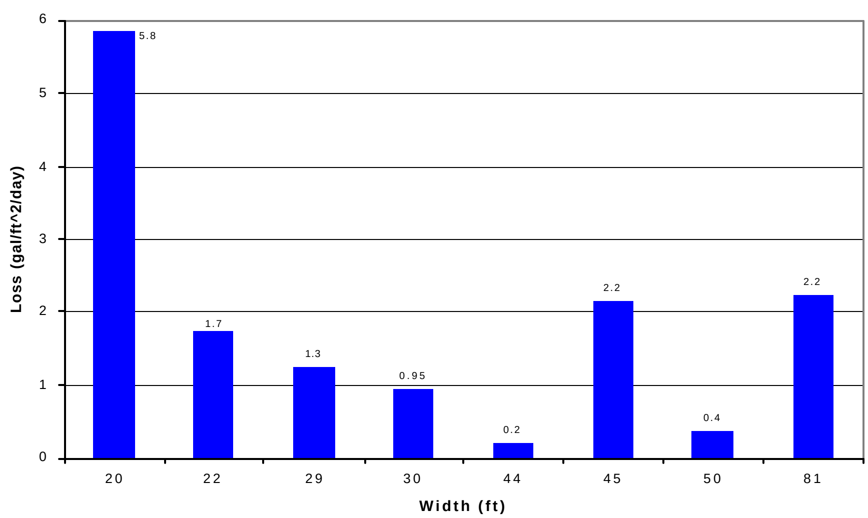
Rating	Total Length of Canals (miles)*					Total Area (million ft^2)
	top width (ft)					
	0-5	>5-10	>10-15	>15-20	>20-25	
6	9	34	16	18	5	8.5
5	4	25	7	14	2	5.2
4	2	14	3	8	2	3.1
3		3		4		0.6

* includes only the 185 miles of concrete canals that have been rated.

Unlined Canals

Seepage losses were measured in 8 unlined canals (Table V-3). These loss rates were similar to those reported in the scientific literature based on soil type (Tables I-1 and I-4). We found no clear relationship between visual rating (Table II-4) and seepage loss rates, indicating that the rating procedure needs modification.

Seepage Loss in Unlined Canals



For the LRGV, the extent of unlined canals that are located in loamy to sandy soils are given below, along with the total canal surface area for lining. This information was not completed for Maverick ID since a GIS-based soil series map for the county was not available.

Unlined Canals in Sandy and Loamy Soils*

Width (ft)	Extent (miles)	Area (million ft^2)
0-39	48	9.4
40-69	39	13.5
>70	31	17.9

* includes all mains and 64 % of laterals for LRGV.

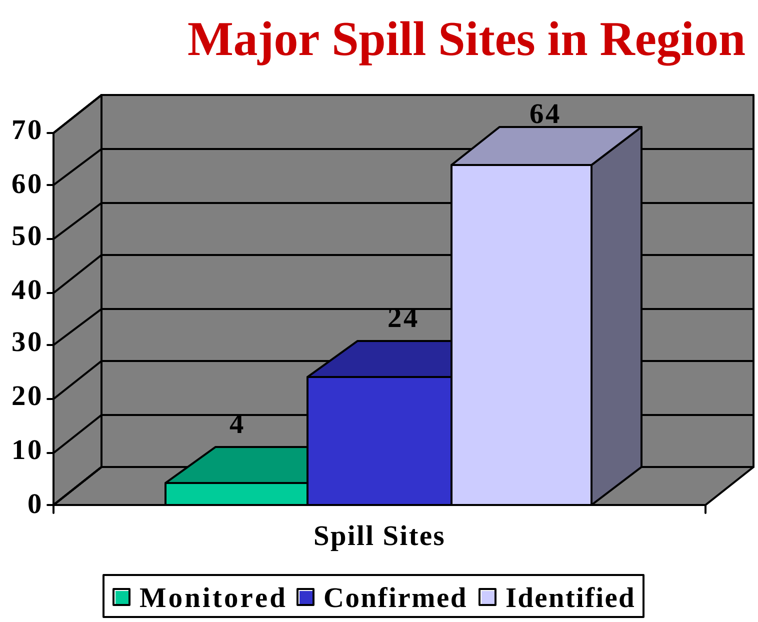
In a rehabilitation program, unlined canals in lighter, more permeable soils should be investigated for possible lining or replacement with pipelines, particularly canals that are less than 40 feet in width.

Spills

Four (4) spill loss and recovery sites were monitored continuously during the project. Two of the sites allow excess canal water to flow into pipes. The third is a drop inlet in a reservoir to control water levels, and the fourth is a pump-back system to return water from a reservoir to a canal.

The spill loss rates for the first 3 sites ranged from 28 to 1118 ac-ft/yr for the period 1999-2000 (Table V-4). The one spill recovery site monitored saved 4684 ac-ft/yr that otherwise would have been lost without this facility.

We conclude that spills are a major source of water losses in the region. We have independently verified 34 major spill sites in the region out of a total of 87 identified in surveys (Tables V-5 and V-6).



Spill loss reduction involves rehabilitation of distribution networks such as increasing the capacity of segments and the construction of storage, interception and recycling facilities.

It also involves better management through automatic gate control and training of canal riders and other district personnel on distribution system management.

GIS mapping and GIS-based management systems (i.e., DMS) are emerging as powerful tools for district planning, management and operation.   Research is underway to integrate design and management software into the GIS systems of districts.

POTENTIAL WATER SAVINGS

Tables VI-1through VI-4 summarize the procedures and assumptions used in calculating the potential water savings shown below. Individual county estimates of water saving potential are provided in Tables VI-5 through VI-9.

WATER SAVING POTENTIAL IN IRRIGATION DISTRICTS AND ON-FARM (acre-feet per year)

Water Supply Condition	District Conveyance Efficiency Improvement	On-farm Practices and Methods	
		With district improvements	Without district improvements
drought	159,631	174, 537	105,029
normal	210,944	226,178	142,852

For these estimates, drought conditions are based on the year 2010 water supply scenario of 0.8 million ac-ft developed by R.J. Brandes for this project. Normal conditions are based on the average diversions for the highest 5 years during the period 1986 - 1988 (Table IV-3).

The water savings listed under *District Conveyance Efficiency Improvement* (above) are based on increasing current efficiencies to 90%. Individual county estimates of current efficiencies and water saving potential are provided in Table VI-5 for Cameron, Willacy, Hidalgo and Maverick, the four counties containing irrigation districts.

The water savings listed under *On-farm Practices and Methods* (above) would result from the expansion over current levels of practices and technology related to:

- ? implementation of water measurement or metering programs
- ? replacement of field ditches and siphon tubes with poly pipe or gated pipe
- ? adoption of improved water management practices and technologies

Achievable on-farm water savings are broken out by county in Tables VI-6 and VI-7. No significant on-farm water savings are expected in Web, Zapata and Jim Hogg Counties.

Water savings are given for two cases: with and without improvements in district conveyance efficiency. Conveyance efficiency determines how much water reaches the field turnout. Its improvement will also help eliminate the "head" problems experienced in the region and enable the use of improved water management practices and technologies.

Uncertainties in Estimate

There is uncertainty about the accuracy of the basic information that districts use to estimate conveyance efficiency, particularly:

- the amount of water pumped or diverted into the system, and
- the actual amount of water delivered to the field.

The doppler flow meters currently used at many river pumping plants were "calibrated" for each site based on estimates of pumping rate, pumping plant capacity, or engine/motor and pump performance. Due to the physical layout of the pumping plants, it is difficult to independently verify these rates. Historically, little water measurement was done at the field turn-out, and the amount delivered is also an estimate in many districts. Some districts have antiquated database and accounting systems, making it difficult to extract water use records for analysis.

ABREVEATIONS

ID Irrigation District

DMS District Management System
(for more information, see http://dms.tamu.edu)

GIS Geographical Information System

LRGV Lower Rio Grande Valley of Texas,
includes the counties of Cameron, Hidalgo, Willacy and Starr

Phase II Integrated Water Resources Planning - Phase II Project,
involving Cameron, Hidalgo, and Willacy Counties.

Region M Rio Grande Planning Region,
defined by the Texas Water Development Board as:
Cameron, Hidalgo, Willacy, Starr, Maverick, Web,
Zapata, and Jim Hogg Counties

REFERENCES

Bramley, M. E.: 1987. Improving Irrigation Conveyance and Distribution Systems. Proceedings of Seminar on Rehabilitation or Irrigation Schemes.

Chohan, M. A.; Rydzewski, J. R.; Ward, C. F.: 1989. Canal Irrigation in Pakistan. Irrigation Theory and Practice. Proceedings of the International Conference, South Hampton, UK. September 1989.

DeMaggio, J. 1990. Technical Memorandum: San Luis unit drainage program project files. U.S. Bureau of Reclamation, Sacramento, CA.

El- Shibini, F.; Zuberi, F. A. (ed.); Bodia, M. A.: 1995. Canal Lining and the Egyptian Experience. Proceedings of the International Workshop on Canal Lining and Seepage, Lahore, Pakistan, 18-21 October 1993.

Johnson, S. H.; Kemper, W. D.; Lowdermilk, M. K.: 1979. Improving Irrigation Water Management in the Indus Basin. Water Resources Bulletin v. 15(2).

High Plains Underground Water Conservation District No. 1. 1999. An Analysis of Irrigation Ditch Losses, Pump Plants, and the Cost of Pumping Water. Report 99-1. Lubbock, TX

Khan, A. S.; Zuberi, F. A. (ed.); Bodia, M. A.: 1995. Baluchistan Minor Irrigation and Agricultural Development Project- Approach to Channel Lining. Proceedings of the International Workshop on Canal Lining and Seepage, Lahore, Pakistan, 18-21 October 1993.

Koruda, M. and Cho, T.: 1988. Water Management and Operation of Irrigation System in Low Lying Paddy Area with Creek Network. Journal of Irrigation Engineering and Rural Planning. v.13.

Kraatz, D. B.: 1975. Reduction in Conveyance Losses in Sandy Soils. In Sandy Soils; FAO Soils Bulletin v.25.

Manz, D. H.: 1991. Eastern Irrigation District Water Delivery Management/ Operation Improvement Project. Proceedings International Commission on Irrigation and Drainage Special Technical Session, Beijing, China. Vol. 1-B Operation of Irrigation Systems.

Mitchell, T. E.; Zuberi, F. A. (ed.); Bodia, M. A.: 1995. Report on Canal Linings used by the Bureau of Reclamation. Proceedings of the International Workshop on Canal Lining and Seepage, Lahore, Pakistan, 18-21 October 1993.

Murray-Rust, D. H.; Vander- Velde, E. J.; Zuberi, F. A. (ed.); Bodia, M. A.: 1995. Changes in Hydraulic Performance and Comparative Costs of Lining and Desilting of Secondary Canals in Punjab, Pakistan. Proceedings of the International Workshop on Canal Lining and Seepage, Lahore, Pakistan, 18-21 October 1993.

Nayak, S., B.C. Sahoo, P. K. Mohapatra, and G. P. Pattanaik. 1996. Profit potential of lining watercourses in coastal commands of Orissa. *Environment & Ecology*, 14(2):343- 345.

Nofziger, D.L. 1979. The influence of canal seepage on groundwater in Lugert Lake irrigation area. Oklahoma Water Resources Research Institute, OSU.

Texas Board of Water Engineers. 1946. Seepage Losses from Canals in Texas, Austin, July 1.

Texas Water Development Board. 1997. Water for Texas. Austin.

U.S. Bureau of Reclamation. 1963. Lining for Irrigation Canals.

U.S. Department of Agriculture: 1991. Wellton- Mohawk Irrigation Improvement Program. U.S. Dept. of Agriculture, Soil Conservation Service, Phoenix, AZ.

Wehry, A.; Man, T. E.; Kleps, C.; 1988. Research on Improving the Efficiencies of Water Conveyance and Distribution Within Irrigation Systems. Proceedings 15th ICID European Regional Conference. v.2.

Yoo, K. H. and Busch, J. R.: 1985. Least- Cost Planning of Irrigation Systems. Journal of Irrigation and Drainage Engineering. v.111(4).

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Table IV-5. Incentive water pricing programs as reported in the District Bio & Survey.

District	% of growers under rate	Flat rate	Per irrigation charge	Volumetric charge	Irrigation basis	Other
Bayview	100	$17		$18.50/ac-ft		
Brownsville	100	$20 first ac: $5 additional ac		$6 first 4 in: $2/in over 4 in:10 ac or less with no meter $12/ac	4"	
Donna	5		$4		6"	
Delta Lake						Water is charged at $20/ac-ft (for 1/10 ac-ft)
Mercedes	10			Drip sprinkler $14.25/ac-ft	6"	Metered flood irrigation @ $6/ with any water saved credite back into farmer's account
Harlingen	5					
Edinburg	20	$18		$13.50/ac-ft as incentive to meter	Charged for actual water metered	
Baptist Seminary	90			$18.25 (metered)		
Sharyland Plantation						$28 for out of district pumpin $18 for in district pumping
San Juan	1			Not provided		
La Feria	3		$7.50 charged quarterly			
United	10		$10 /hour for drip			
Maverick						Flat assessment rate:$7/yr/ac Water assessment rate:$7/yr/a Delivery charge /surcharge:$3.50/ac-ft

Table IV-6. Evaluation of district metering programs through a growers' survey.

1. Received adequate instruction or support from district on:

a) meter installation and use - *63% YES, 38% NO*
b) reading the meter and calculating water use - *58% YES, 42% NO*
c) answering questions and providing technical information - *59% YES, 41% NO*

2. Has the meter provided a good measurement of flow rate:

a) not even close - *0 responses*
b) in the "ball park" - *50%*
c) good estimate - *50%*
d) exact - *0 responses*

3. Has the meter provided a good measurement of total amount of water used:

a) not even close - *4%*
b) in the "ball park" - *38%*
c) good estimate - *58%*
d) exact - *0 responses*

4. Problems with meter clogging occurred:

a) never - *0 responses*
b) occasional - *41%*
c) frequent - *37%*
d) constant - *22%*

5. Type of clogging material:

a) trash - *31%*
b) turtles - *20%*
c) fish - *22%*
d) construction debris - *9%*
e) other - *14%: moss, hydrilla, plants, weeds*

6. Direct knowledge of deliberate interference with, slowing or disabling meter:

1% YES, 96% NO

7. Compared to water use before metering, did use of the meter result in:

a) less water per irrigation - *65% YES, 35% NO*
b) less water per crop over the season - *75% YES, 25% NO*

8. Do you believe that in principle metering should be continued:

83% YES, 17% NO

Table V-1. Classification of the sources of water loss in irrigation districts.		
Transportation	**Accounting**	**Operation**
1) seepage in main, unlined canals 2) seepage in secondary and tertiary unlined canals (laterals) 3) leakage from lined canals 4) leakage from pipelines 5) evaporation (canals, reservoirs, resacas) 6) leaking gates and valves	1) accuracy of field-level deliveries (estimates of canal riders/irrigators) 2) unauthorized use 3) metering at main pumping plant 4) water rights accounting system	1) charging empty pipelines and canals 2) spills 3) partial use of water in dead-end lines

Table V-2. Seepage loss rates of concrete canals as measured by the DMS Team.

Canal ID	Overall Rating	Soil Type	Top Width (ft)	Loss Rate (in/day)	Loss Rate (gal/ft^2/day)	Loss Rate (gal/ft/day)	Loss Rate (ac-ft/mi/yr)
1	2.7	clay	9	20.1	12.52	112.71	776.5
2	1.6	sandy clay loam	6	43.4	27.07	162.41	1186.0
5	7.2	clay loam	12	6.9	4.28	51.31	271.8
9	4.4	sandy loam	9	5.8	3.61	32.50	215.3
10	7.2	sandy loam	15	2.0	1.25	18.77	89.9
11	6.6	sandy clay loam	4	33.5	20.87	83.46	520.8
12	6.1	sandy clay loam	3	8.7	5.39	16.16	141.0
13	1.6	sandy clay loam	6	32.9	20.52	123.14	856.2
14	4.9	fine sandy loam	6	8.5	5.32	31.90	375.4
15	6.1	fine sandy loam	18	5.8	3.63	65.29	357.4
18	2.7	silty clay loam	9	45.6	28.46	256.18	1219.5
20	7.2	clay loam	12	6.1	3.77	45.28	239.5
21	7.8	sandy clay loam	19	7.3	4.58	87.04	473.0
23	4.4	sandy clay loam	12.5	17.8	11.08	138.53	610.6
24	6.6		38	2.3	1.42	53.92	281.6
Total for all 15 canals							7614.5

Table V-3. Seepage loss rates of unlined canals as measured the DMS team.

Canal ID	Overall Rating	Soil Type	Top Width (ft)	Loss Rate (in/day)	Loss Rate (gal/ft^2/day)	Loss Rate (gal/ft/day)	Loss Rate (ac-ft/mi/yr)
3	4.8	silty clay	30	1.5	0.95	28.62	132.6
4	9.3	silty clay	22	2.8	1.74	38.17	263.3
6	4.8		20	9.4	5.84	116.84	507.1
7	7.0		50	0.6	0.39	19.45	128.3
8	5.5	fine sandy loam	81	3.6	2.23	180.55	1037.0
16	3.3	silty clay loam	44	0.3	0.20	8.84	54.3
19	5.5	sandy clay laom	29	2.0	1.27	36.69	215.4
22	7.0	sandy clay loam	45	3.5	2.16	97.25	571.6
						Total for all 8 canals	2909.6

Table V-4. Spill loss and recovery sites monitored by the DMS team.

Spill Site ID	Rate* (ac-ft/yr)	Spill Type
Rio Farms	510	Loss
J-System	28	Loss
M-Reservoir	1118	Loss
M-Reservoir	4684	Recovery

* during the period of 1999-2000

Table V-5. Operational spills identified in the canal rider survey and verified by the DMS Team.					
District	**Total**	**Verified**			**Not Verified**
		Automatic (canal)	**Manual**	**Pipeline Vent**	
San Juan	28	2		25	1
Edinburg	30	5	7		18
Mercedes	16	15			
Delta Lake	3	7			
Harlingen	7	5			2
Total	84	34	7	25	21

Table V-6. Additional automatic canal spills that have been identified but not classified.[1]		
District	**Source**	
	DMS Team	**Bio and Survey**
Los Fresnos		10
Engleman		6
Mission #6		2
Donna	1	4
San Benito	1	28
Mission #16	1	
Delta Lake	7	
Total	10	50

[1]Types of spills include pipeline vents, manually operated spills, and automatic control spills.

Table V-7. Weighted average (based on average diversions) conveyance efficiency of irrigation and water districts in the Rio Grande Planning Region.	
Source of Data	**Conveyance Efficiency**
Phase II Project Survey[1]	65.8%
District Bio and Survey	76.8%
DMS Team's Estimate	70.8%[2]

[1] does not include the Maverick Irrigation District
[2] the DMS Team's Estimate was used to calculate potential water savings

Table VI-1. Water savings observed or estimated from metering, poly pipe, and surge flow irrigation demonstrations in the Lower Rio Grande Valley during the 1990's.	
District	**Water Savings Observed**
Bayview	36%[1]
Brownsville	33%[1]
Donna	20%[2]
La Feria	10%[2]
Delta Lake	33%[1]
San Benito	40%[1]

[1] may include additional benefits from implementing improved on-farm water management practices or due to changes in irrigation technology
[2] metering only

Table VI-2. Factors used for calculating on-farm water saving potential.		
Technique	**Expected Water Savings**	**Factor Used**
Metering/measurement	0 - 15 %	10 %
poly/gated pipe replacement of field ditches/siphon tubes	5 - 20 %	12.5 %
high management/improved irrigation technology	10 - 30 %	20 %

Table VI-3. Example of the assumptions for applying water savings factors in Table VI-2 to determine on-farm potential water savings.	
Technique	**Assumptions for Calculations**
water measurement/metering	- 54% of region is under consistant water mesurement or metering - factor applied to remaining 46%
poly/gated pipe	- will be adopted in 90% of LRGV - 36% of the LRGV already using gated/poly pipe - factor applied to remaining 0.36 of area not currently using poly/gated pipe (0.9 - 0.36 = 0.54)
high management/improved irrigation technology	- will be adopted in 90% of LRGV - approximately 30% of area currently under high management or using improved technologies - factor applied to 50% of area (0.9 - 0.3 = 0.6)

Table VI-4. On-farm water savings factors used for calculating county potential water savings.	
Counties	**Overall On-farm Water Saving Factor**
Hidalgo, Cameron	0.234
Web, Zapata, Jim Hogg	0
Starr	0.060
Maverick	0.134
Willacy	0.188

Table VI-5. Potential savings in irrigation districts by increasing the average conveyance efficiency to 90%.

County	**Average Conveyance Efficiency (%)**	**Water Supply Scenario (ac-ft)**		**Water Savings Potential (ac-ft)**	
		Normal	**Drought**	**Normal**	**Drought**
Cameron	69.8	307,109	251,678	62,036	50,839
Willacy	65.0	47,831	37,174	11,958	9,293
Hidalgo	72.4	623,416	469,823	109,721	82,689
Maverick	67.0	118,390	73,091	27,229	16,810
Region	70.8	1,096,746	831,766	210,944	159,631

Table VI-6. Achievable on-farm water saving potential under drought water supply conditions for 5 counties of the Rio Grande Planning Region with conveyance efficiency improvements. No significant savings are projected for Jim Hogg, Webb and Zapata Counties.

Practice	**On-farm Water Savings with Conveyance Efficiency Improvement for Drought of Record (ac-ft/yr)**					
	Cameron	**Willacy**	**Hidalgo**	**Maverick**	**Starr**	**Total**
Measurement	10,420	0	19,451	0	0	29,871
Gated pipe	15,403	2,275	28,753	888	0	47,319
Improved management/ technology	27,181	4,015	56,741	7,894	1,516	97,347
Total	53,004	6,290	104,945	8,782	1,516	174,537

Table VI-7. Achievable on-farm water saving potential under normal water supply conditions for 5 counties of the Rio Grande Planning Region with conveyance efficiency improvements. No significant savings are projected for Jim Hogg, Webb and Zapata Counties.

Practice	**On-farm Water Savings with Conveyance Efficiency Improvement for Normal Water Supply Conditions (ac-ft/yr)**					
	Cameron	**Willacy**	**Hidalgo**	**Maverick**	**Starr**	**Total**
Measurement	12,714	0	25,809	0	0	38,523
Gated pipe	18,795	2,927	38,153	1,438	0	61,313
Improved management/ Technology	33,168	5,165	67,329	12,786	7,894	126,342
Total	64,677	8,092	131,291	14,224	7,894	226,178

Table VI-8. Achievable on-farm water saving potential under drought water supply conditions for 5 counties of the Rio Grande Planning Region with no conveyance efficiency improvements. No significant savings are projected for Jim Hogg, Webb and Zapata Counties.

Practice	**On-farm Water Savings without Conveyance Efficiency Improvement for Drought of Record (ac-ft/yr)**					
	Cameron	**Willacy**	**Hidalgo**	**Maverick**	**Starr**	**Total**
Measurement	8,081	0	15,647	0	0	23,728
Gated pipe	11,946	1,643	23,130	661	0	37,380
Improved management/ technology	12,648	1,740	24,491	3,526	1,516	43,921
Total	32,675	3,383	63,268	4,187	2,021	105,029

Table VI-9. Achievable on-farm water saving potential under normal water supply conditions for 5 counties of the Rio Grande Planning Region with no conveyance efficiency improvements. No significant savings are projected for Jim Hogg, Webb and Zapata Counties.

Practice	**On-farm Water Savings without Conveyance Efficiency Improvement for Normal Water Supply Conditions (ac-ft/yr)**					
	Cameron	**Willacy**	**Hidalgo**	**Maverick**	**Starr**	**Total**
Measurement	9,861	0	20,762	0	0	30,623
Gated pipe	14,577	2,114	30,692	1,071	0	48,454
Improved management/ Technology	15,434	2,239	32,497	5,711	7,894	63,775
Total	39,872	4,353	83,951	6,782	7,894	142,852

Table IV-4. Conventional water pricing programs as reported in the District Bio & Survey.

Name	% of growers under rate:	rate charge	per irrigation charge	special p
San Benito	100	$30/1st ac; $8.50 additional acre	$7	
Los Fresnos	100	$11	$8	
Delta Lake	100	$10	$2 per 1/10 ac-ft used	
Donna	95		$8	
Engleman				Drip Irrigation: $53.99/ac-ft ; F Flood Irrigation: $15/ac-ft ; Ya
Mercedes	90	$6		
Harlingen	95		$6	
Edinburg	80	$18	$9	
Baptist Seminary	10			
Sharyland Plantation	100	$27		
San Juan	99	$8.25	$7.50	
Mission	100	$21	$27 /ac-ft	
Monte Grande	100	$18.50		
McAllen #3	100	$4.50	$4.75	
Progreso	100	$6.25, $20 benefit tax	$7.50	Over 6 inches $15 /ac-ft
La Feria	97	$13.50	$ 8	
Santa Cruz	100		$20	$40/ac-ft if metered
United	90	$18.75	8.00 per hr	
Valley Acres	30	$10	$10/yr	
Adams Garden	100		$7.50	
Rutherford-Harding	100	$14	$9	$18/ac-ft under metered condit
Santa Maria	100	$20	$7	
Mission #16	100	$16.50	$5.00 per hr	

Table IV-3. Summary of the annual agricultural water diversions by districts (ac-ft). The lowest and highest annual divisions are for individual districts and did not occur in the same years.

District	Avg over all yrs	Avg for 5 high years[1]	Avg for 5 low years	Lowest for each district	Highest for each district
Adams Garden	11030	13321	8732	5177	17605
Bayview	8464	8701	6617	4439	13668
Brownsville	14537	17936	9014	6070	21288
San Benito	78474	91874	57581	45343	106476
Los Fresnos	31683	41337	18360	4896	54555
Cameron #16	2254	2800	1714	811	3545
Delta Lake	96478	110350	79132	58940	159024
Donna	56495	71348	41428	29740	89214
Engelman Gardens	7597	7955	6089	2941	13023
Harlingen	44523	50059	37237	16724	64854
Edinburg	55667	74180	37121	9970	101281
San Juan	84031	103989	62840	52129	134174
McAllen #3	4623	5809	2969	684	8012
Progreso	10298	13494	8678	4743	16809
Mission #6	18575	23172	15123	10133	30599
United	33213	36165	31907	20062	55037
Mercedes	113138	147596	81066	49795	166103
Baptist Seminary	1435	1828	1061	669	3043
Mission #16	15563	19442	11357	9275	25381
Monte Grande	2320	3323	1024	571	5505
Sharyland Plantation	9366	11758	8133	4520	15794
La Feria	50218	65977	36426	25970	84605
Santa Cruz	36668	39579	30643	4383	57686
Santa Maria	6504	9289	4226	2604	10183
Russell Plantation	6225	7081	5960	3616	8893
Maverick	88356	118390	65523	42677	144976
Valley Acres	10602	10602	10602	8384	13502
MUD	688	688	688	584	871
Total	899027	1108042	681250	425852	1425706

[1] The average of the five highest years were used to calculate potential water savings for “normal” or “average” water supply conditions

Table IV-2. Annual agricultural water diversions (ac-ft/yr) by districts as obtained from the Rio Grande Watermaster Office.

District	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Adams Garden	12569	7987	12440	17605	14907	10753	5177	9469	12183	9147
Bayview	7353	4439	8294	8360	6357	9130	6272	9662	10835	13668
Brownsville	11198	9132	14351	21288	17571	19176	6070	19853	16616	21074
San Benito	72398	45343	72638	100138	106476	93283	48465	73657	106461	101465
Los Fresnos	4896	22958	31630	41313	54555	42312	17598	32780	46406	43610
Cameron #16	3285	1297	2677	3518	3545	2697	1382	2129	2133	1956
Delta Lake	87315	70631	71856	159024	126574	93469	58940	99929	94364	99721
Donna	49290	52545	67232	89214	72542	67645	35906	59932	67822	52078
Engelman Gardens	4714	3792	7253	13023	9293	8302	2941	4313	5895	7799
Harlingen	42199	26649	44638	58554	64854	47449	16724	34047	48201	40921
Edinburg	42068	49035	46226	92462	82906	83631	61346	101281	48027	43841
San Juan	79231	68976	90586	134174	111914	96482	55067	90321	92948	79616
McAllen #3	4811	3130	6095	8012	4900	4856	684	3791	6246	6739
Progreso	10720	10315	13523	16809	10826	12942	8850	14912	11402	4743
Mission #6	20686	19271	26549	30599	19250	15806	10133	12717	26744	15601
United	52659	35560	40191	55037	30401	23354	20062	29647	25548	31233
Mercedes	102607	95083	135484	166103	144119	121608	77987	155298	136974	123955
Baptist Seminary	1087	1591	3043	1049	2842	976	669	1440	764	1371
Mission #16	12168	13075	19300	25381	9800	9275	9318	17385	25344	19724
Monte Grande	2169	571	2216	2072	5505	3397	998	3725	3096	2085
Sharyland Plantation	9594	10054	13300	15794	4820	11877	10555	13481	11394	4520
La Feria	48584	41730	52372	84605	71131	57618	33663	55434	66344	42887
Santa Cruz	44591	32718	49049	57686	40801	25215	18264	4383	45975	55908
Santa Maria	4984	6049	7304	9972	10183	8019	3732	9827	9159	6323
Russell Plantation	7274	6933	7102	8421	8893	6847	5743	4977	6011	3616
Maverick	51791	77168	131719	144976	77168	87585	87747	132196	105893	68231
Valley Acres										11408
MUD										584
Total	790241	716031	977065	1365188	1112132	963703	604291	996588	1032786	901831

Table II-3. Rating system for lined canals. Totals from each category were summed and converted into a 1 to 10 scale.

Rating	Rating Category and Description			
	Lining Condition	**Cracks size**	**Crack frequency**	**Vegetation in canal and embankment**
1	Excellent	A few hairline cracks	Sparse	Normal; rain-fed weeds only
2	Good	Hairline to pencil	Greater than 10'	Above average
3	Fair	Predominately pencil size	5' to 10' apart	Moderate
4	Poor	Pencil size and a few large cracks	3' to 5' apart	Dense
5	Serious problems	Predominately large cracks	Less than 3' apart	Dense and lush

Table II-4. Rating system for unlined canals. Totals from each category were summed and converted into a 1 to 10 scale.

Rating	Rating category and Description		
	Interior condition of canal	**Condition of embankment**	**Vegetation in canal and embankment**
1	Excellent	Excellent	Normal; rain-fed weeds only
2	Good	Some minor erosion	Above average
3	Fair	Moderate amounts of erosion	Moderate
4	Poor-some holes and/or cracks and leakage	High levels of erosion	Dense
5	Seriously eroded and obvious leakage	Severe erosion, levee/canal in danger of falling	Dense and lush

Table II-5. Rating scale for frequency of canal use.

Rating	Description
1	never
2	rarely
3	seasonal
4	regular
5	constant

Table III-1. Total extent of the main irrigation water distribution networks ("mains").

	Main Irrigation Distribution Network (miles)		
District	**Canals**	**Pipeline**	**Resacas**
Adams Garden	20.8	1.9	2
Bayview	16.8	0.5	12
Brownsville	2.0	0.0	25
San Benito	103.0	0.0	14
Los Fresnos	17.8	0.0	11
Rutherford-Harding	4.5	0.9	8
Cameron #16	3.5	0.0	4
Delta Lake	98.0	14.9	0
Donna	31.4	0.0	0
Engleman Gardens	10.0	2.0	0
Mercedes	69.2	3.1	0
Harlingen	56.7	0.0	0
Edinburg	38.1	17.7	0
McAllen #3	9.4	3.5	0
Baptist Seminary	0.0	4.7	0
HCID #14	0.0	0.0	0
Mission #16	14.5	3.8	0
Monte Grande	0.0	0.0	0
San Juan	43.8	33.1	0
Progreso	0.8	19.6	0
Mission #6	19.3	0.0	0
Sharyland Plantation	5.9	0.1	0
La Feria	39.3	3.3	0
Maverick	116.7	0.0	0
Santa Cruz	30.6	4.9	0
Santa Maria	2.8	0.0	0
United	30.0	0.0	0
Valley Acres	5.5	9.9	0
Total	787.9	123.4	76

Table III-2. Total extent of the secondary irrigation water distributions networks (laterals) and percent that has been mapped[1]

	Canals		Pipeline	
District	**Total miles**	**% mapped**	**Total miles**	**% mapped**
Adams Garden	2.0	100	25	2
Bayview	2.6	100	76	1
Brownsville	0.0		100	100
San Benito	112.2	78	34.7	8
Los Fresnos	27.6	0	25	0
Rutherford-Harding	1.0	70	2	55
Cameron #16	0.0		0.0	
Delta Lake	87.4	100	165.5	100
Donna	55	0	35	0
Engleman Gardens	10	6	30	0
Mercedes	4	75	245	94
Harlingen	1.1	100	155	98
Edinburg	50	97	92	92
McAllen #3	8	0	19	0
Baptist Seminary	0.0		0.0	
HCID #14	0.0		0.0	0
Mission #16	8	0	26.3	0
Monte Grande	0.0	0	0.0	0
San Juan	25.5	100	198.4	100
Progreso	0.0		14	83
Mission #6	45	72	60	0
Sharyland Plantation	0		2	1
La Feria	20.9	0	115	0
Maverick	160	86	0.1	0
Santa Cruz	6	0	150	0
Santa Maria	0.5		14	72
United	43	0	90.5	0
Valley Acres	0.0		15	100
Total	430.5	64	972.0	58

[1] based on the District Bio & Survey and DMS Team estimate

Table III-3. Miles of pipelines for 22 irrigation districts in the Rio Grande Planning Region classified by known and unknown diameters.

District	**Known Diameters (mi)**	**Unknown Diameters (mi)**
Adams Gardens	0	26.9
Bayview	>1	76.5
Brownsville	98.8	1.2
San Benito	2.63	32.1
Rutherford-Harding	1.0	1.9
Delta Lake	112.44	68
Engleman Gardens	0	32
Mercedes	0	248.1
Edinburg	48.99	220
Baptist Seminary	4.03	.7
San Juan	224.66	6.84
Progreso	8.24	24.8
Mission #16	0	30.15
McAllen #3	3.54	19
Sharyland Plantation	0	2.1
Harlingen	0	269
La Feria	0	118.30
Maverick	0	0.11
Santa Cruz	3.59	114.7
Santa Maria	10.10	3.9
United	0	90.5
Valley Acres	23.90	1
Los Fresnos	0	25
Donna	0	35
Mission #6	0	60
Total	**541.78**	**553.2**

Table III-4. Extent of canals, canal top width, and lining status in the Rio Grande Planning Region.

Concrete		**Unlined**	
Top Width (ft)	**Extent (mi)**	**Top Width (ft)**	**Extent (mi)**
unknown	136.25	unknown	14.58
<= 4	10.50	<=10	6.52
4 - 6	43.70	10 - 18	56.76
6 - 7	20.68	18 - 20	41.28
7 - 8	35.42	20 - 25	62.87
8 - 9	21.70	25 - 27	28.96
9 - 10	29.73	28 - 30	36.71
10 - 11	16.86	30 - 35	36.96
11 - 12	22.41	35 - 39	12.29
12 - 13	24.47	40	97.74
13 - 14	16.41	40 - 45	52.82
14 - 15	28.41	45 - 50	33.66
15 - 16	18.72	50 - 60	14.19
16 - 17	24.48	60 - 80	28.34
17 - 18	22.60	80 - 100	49.91
18 - 20	24.11	117	7.64
20 - 21	10.22	139 - 150	31.18
21 - 24	17.75		
24 - 30	15.69		
30 - 40	7.61		
50	1.35		
Total	548.76	**Total**	614.50
Gunite		**Unknown lining status**	
45	1.89	unknown	294

Table III-5. Irrigation district pipeline in the Rio Grande Planning Region listed by pipe diameter and type (miles)

Diameter (in)	**Total**	**Flexible Joints**			**Mortar Joint**	**Unknown Joints**			
		PVC	**Reinforced Concrete**	**Concrete**	**Concrete**	**Concrete**	**Steel**	**PVC**	**Unknown**
2	0.14				0.14				
4	0.48				0.48				
6	0.21				0.21				
8	0.48				0.34	0.14			
10	0.97					0.97			
12	25.81	0.71	0.46	1.89	2.10	20.64	0.01		
12.5	0.02					0.02			
13	0.07					0.07			
14	34.06			1.71	16.07	16.21			0.07
15	45.29	3.39	3.47	0.29	0.78	34.25	0.04	3.07	
16	57.04		0.81	0.90	40.01	13.17			2.15
18	91.14	0.79	6.83	5.98	31.70	43.36		1.84	0.64
20	9.98			0.92	0.72	8.34			
21	31.95	0.59	3.03	1.04	0.88	26.41			
24	106.53	0.24	16.28	11.13	39.25	37.42			2.20
25	8.22					8.22			
27	0.47			0.47					
30	54.35		10.24	3.02	12.33	28.76			
36	25.51		9.45	3.94	7.07	5.06			
42	14.71		4.68	1.43	5.55	3.05			
48	14.92		5.44	3.60	5.87				
54	7.79		2.65	1.22	0.97	2.96			
60	4.57		0.95	1.58	2.05				
72	7.23			4.27	2.14	0.82			
Unknown	1272	3.40	2.84	107.42	23.04	407.93		0.28	8.51
Total	1814	9.11	67.12	126.94	191.71	657.82	0.05	5.19	13.57

Table III-6. Miles of concrete canals by county and known canal top width.

Top Width (ft)	Maverick	Hidalgo	Cameron	Willacy	Total
<= 10	34.4	64.9	17.7	44.6	161.7
10-15	0.0	73.6	24.0	10.9	108.6
15-20	0.0	77.2	12.7	0.0	89.9
20-30	0.0	39.6	4.0	0.0	43.7
30-51	0.0	8.8	0.2	0.0	9.0
Total	34.4	383.3	60.4	70.9	549.0

Table III-7. Miles of unlined canals by county and known top width.

Top Width (ft)	Maverick	Hidalgo	Cameron	Willacy	Total
≤ 20	46.4	17.4	40.7	0.0	104.6
20-30	25.5	21.6	81.5	0.0	128.6
30-45	68.0	14.9	116.9	0.0	199.8
45-80	3.4	27.8	52.0	5.7	89.0
≥90-150	20.1	39.4	16.4	0.0	75.9
Total	163.5	126.2	317.0	5.7	612.4

Table III-8. Types of water delivery and extent of metering, head problems and double cropping as reported on the District Bio and Survey Unless noted, all percentages are based on average agricultural water diversion.

Category	**Percent of Region**
On-farm water measurement/metering	54%
Double Cropping	31% of irrigated land
Head Problems	33%
<u>Water Delivery to fields by</u>:	
valves	63%
gates	29%
standpipes and “wells”	5%
pumps	3%
<u>On-farm Water Delivery by</u>	
poly/gated pipe	36%
pipeline	12%
siphon tubes	36%
ditches	17%

Table III-9. Number of acres for each irrigation technology reported in the Canal Rider Survey.							
Irrigation Technology	**Brownsville**	**Delta Lake**	**Harlingen**	**Edinburg**	**San Juan**	**Total Acres**	**% of district surveyed**
1	0	856	8883	19646	17287	46672	34%
2	0	0	8883	5143	12670	26696	20%
3	20043	17540	17409	1183	3889	60064	44%
4	0	641	0	878	63	1582	1%
5	0	0	0	115	30	145	0.1%
Other	0	0	0	0	523	523	0.9%
Total	20043	19037	35175	26965	34462	135682	

Key codes for irrigation technologies

1 flood irrigation through cutting of field ditches
2 flood irrigation with siphon tubes
3 flood irrigation through gated or poly-pipe
4 drip irrigation through subsurface or surface drip tubing or drip tape
5 sprinkler

Table III-10. Number of accounts and growers reported in the District Bio and Survey.

District	Water Accounts	Growers
Bayview	120	20
Brownsville		94
San Benito	2600	150
Los Fresnos	3000	150
Cameron #16	300	10
Delta Lake	530	530
Donna	1400	
Engleman Gardens	275	20
Mercedes	7000	350
Harlingen	3309	100
Edinburg	4200	1250
Baptist Seminary	7	7
Sharyland Plantation	1	1
San Juan	4000	
Mission	450	150
Monte Grande	1	1
McAllen #3	180	6
Progreso		12
La Feria	5750	30
Santa Cruz		100
United	1139	
Valley Acres	7	7
Adams Garden	1007	25
Rutherford-Harding		9
Santa Maria	265	10
Mission #16	1754	
Maverick	849	500

Table III-11. Main pumping plants and number of relift stations as reported in the District Bio and Survey.

Name	Age of main pumping plant (yrs)	Maximum capacity (cfs)	Typical peak pumping rate (cfs)	Number of pumps, capacity (cfs), and power unit	Number of relift stations in district:
Bayview					48
Brownsville	50	180	100	2 - 40 cfs ;1- 100 cfs -	20
San Benito	92	595	595	2- 150 cfs ;2- 110 cfs- ;1- 95 cfs	10
Los Fresnos	70	400	300	1- 45 cfs- electric; 1- 70 cfs- electric ; 1- 135 cfs- electric 1-90 cfs- electric; 1- 60 cfs- electric	12
Cameron #16	32	18	18	3- 6 cfs- electric	0
Delta Lake	60	640	640	4 - 160 cfs - electric	50
Donna	70	430	300	2 - 50 cfs ; 3 - 100 cfs -	4
Engleman Gardens	12			3 electric	
Mercedes	13	750	600	6- 75 cfs- electric ; 4- 75 cfs- gas	2
Harlingen	75	470	410	1- 60 cfs ; 2- 50 cfs- ; 1- 75 cfs- 1- 110 cfs; 1- 125 cfs-	55
Edinburg	72	600	450	1 - 100 cfs - electric ; 5 - 100 cfs - natural gas	12
Sharyland Plantation	47	50	35		0
San Juan	15	650	390	10- 65 cfs- electric	1
Mission	65	150	100	1 - 74 cfs - electric ; 1 - 34 cfs – electric, 1 - 17 cfs - electric	0
Monte Grande	20	2500	2500	4	2
McAllen #3				3- 2.5 cfs- electric	1
Progreso	20	88	44	4 - 22 cfs - electric	1
La Feria	70	425	300	1 - 125 cfs ; 1 - 100 cfs ; 1 - 85 cfs 1 - 65 cfs ; 5 - 50 cfs	1
United	50	400	120	2- 130 cfs- natural gas ; 1- 130 cfs- electric	2
Valley Acres	22			2- electric ; 1- Gas	1
Adams Garden	70	115	65	1- 50 cfs- electric ; 1- 65 cfs- electric	7
Rutherford-Harding	52	213	11	1- electric ; 1 electric	11
Santa Maria	35	54	36	3 - 18 cfs	1
Mission #16	44	90	34	2 electric	4
Maverick		1700	1500		0

Table III-12. Storage capacity of districts as reported in the District Bio and Survey.

District	Storage Reservoirs Near Main Pumping Plant	Surface area (ac)	Storage Volume (ac-ft)	Storage Reservoirs Within District	Surface Area (ac)	Storage Volume (ac-ft)
Bayview					339	1600
Brownsville				5	700	2000
San Benito	2	843	5000	2	140	
Los Fresnos	1	669	3000	1	464	2000
Cameron #16	1	165	150			
Delta Lake	0			1	2400	12000
Donna					360	1200
Engleman Gardens	1	51	669	1	40	250
Mercedes	1	750	5000	3	30	200
Harlingen	1	160	500	2	110	440
Edinburg	0	0	0	1	84	500
Baptist Seminary				2	2	9
San Juan	1	350	1800	0	0	0
Mission	1	30	200			
Monte Grande	0			0		
McAllen #3				1	47	600
Progreso	1	130	400	0		
La Feria				1	302	2000
Santa Cruz				4	828	4225
United	0	0	0	0	0	0
Valley Acres	1	325	1625			
Adams Garden	2	470	1950	0	0	0
Rutherford-Harding	1		700	1		700
Santa Maria	0	0	0	0	0	0
Mission #16	1	400	3800			
Maverick	0	0	0	1	35	200

Table IV-1. The official and common names of 29 irrigation and water supply districts in the Rio Grande Planning Region and their authorized agricultural water rights.

Official Name	**Common Name**	**Water Right (ac-ft)**
Adams Gardens Irrigation District No. 19	Adams Garden	18,737
Bayview Irrigation District No. 11	Bayview	17,978
Brownsville Irrigation District	Brownsville	34,876
Cameron County Irrigation District No. 3	La Feria	75,626
Cameron County Irrigation District No. 4	Santa Maria	10,182
Cameron County Irrigation District No. 6	Los Fresnos	52,142
Cameron County Water Improvement District No. 10	Rutherford-Harding	10,213
Cameron County Water Improvement District No. 16	Cameron #16	3,913
Cameron County Water Improvement District No. 17	Cameron #17	625
Cameron County Irrigation District No. 2	San Benito	151,941
Delta Lake Irrigation District	Delta Lake	174,776
Donna Irrigation District Hidalgo County No. 1	Donna	94,063
Engleman Irrigation District	Engleman	20,031
Harlingen Irrigation District No. 1	Harlingen	98,233
Hidalgo and Cameron Counties Irrigation District No. 9	Mercedes	177,151
Hidalgo County Improvement District No. 19	Sharyland Plantation	11,777
Hidalgo County Irrigation District No. 1	Edinburg	85,615
Hidalgo County Irrigation District No. 2	San Juan	147,675
Hidalgo County Water Irrigation District No. 3	McAllen #3	9,752
Hidalgo County Irrigation District No. 5	Progreso	14,234
Hidalgo County Irrigation District No. 6	Mission #6	42,545
Hidalgo County Irrigation District No. 16	Mission # 16	30,749
Hidalgo County Irrigation District No. 13	Baptist Seminary	4,856
Hidalgo County Water Control and Irrigation District No. 18	Monte Grande	5,505
Hidalgo County Municipal Utility District No. 1	MUD	1,120
Santa Cruz Irrigation District No. 15	Santa Cruz	82,008
United Irrigation District of Hidalgo County	United	69,491
Valley Acres Water District	Valley Acres	22,500
Maverick County Water Control and Improvement District	Maverick	134,900
	Total	1,603,214

Table II-2. Extent of distribution networks and areas that information was obtained in the Canal Rider Survey.

District	Rated Miles of Canal (by lining status)				Canals with Frequent Head Problems		Pipelines		Irriga Iden
	Unlined	Lined	Total	% of District	miles	% of District	miles	% of District	Acre
San Juan	42.3	24.0	66.3	100%	1.5	2%	126.0	54%	276
Edinburg	19.5	48.2	67.759	78%	2.7	3%	56.5	55%	217
Mercedes	18.3	52.6	70.9	98%					
Delta Lake	0	100.9	100.85	54%	24.9	13%	36.0	20%	189
Harlingen	36.1	18.7	54.9	95%	12.5	22%	108.5	71%	186
San Benito					63.4	33%			
Brownsville									200
Total	116.2	244.4	410.6		105.0		331.2		107,

[1] Types of spills include pipeline vents, manually operated spills, and automatic control spills.

Table I-1. Canal seepage rates reported in published studies.	
Lining/soil type	**Seepage rate (gal/ft^2/day)**
Unlined[1]	2.21-26.4
Portland cement[2]	0.52
Compacted earth[2]	0.52
Brick masonry lined[3]	2.23
Earthen unlined[3]	11.34
Concrete[4]	0.74 – 4.0
Plastic[4]	0.08 – 3.74
Concrete[4]	0.06 – 3.22
Gunite[4]	0.06 – 0.94
Compacted earth[4]	0.07 – 0.6
Clay[4]	0.37 – 2.99
Loam[4]	4.49 – 7.48
Sand[4]	4.0 – 19.45

[1] DeMaggio (1990).
[2] U.S. Bureau of Reclamation (1963).
[3] Nayak, et al. (1996).
[4] Nofziger (1979).

Table I-2. Seepage losses on two canal reaches before and after lining in Boise, Idaho with asphaltic prefabricated liners with fiber reinforcement		
	Unimproved (gal/ft^2/d)	**Improved (gal/ft^2/day)**
Reach 1	20.42	0.22
Reach 2	4.03	0.15

Source: U.S. Bureau of Reclamation (1963).

Table I-3. Seasonal Infiltration losses from field ditches based on soil infiltration rate, calculated as 25% of the published soil permeability range.

Soil Series	**Losses (gal/ft^2/day)**
Amarillo fine sandy loam	15.9
Amarillo loamy fine sand	18.7
Amarillo loam	11.2
Acuff Loam	14.6
Brownfield Fine Sand	28.1
Estacado Clay Loam	14.6
Mansker Loam	18.7
Mansker Fine Sandy Loam	28.1
Olton Loam	9.4
Portales Loam	18.7
Portales Fine Sandy Loam	28.1
Portales Loamy Fine Sand	37.4
Potter caliche soils	18.7
Pullman Clay loam	5.2
Pullman clay	3.0
Tivoli Fine Sand	86.0

Source: High Plains Underground Water Conservation District No. 1 (1999).

Table I-4. Canal seepage rates reported for the Lower Rio Grande Valley.	
Soil Type	**Seepage Loss Rate (gal/ft^2 /day)**
clay	1.5
silty clay loam	2.24
clay loam	2.99
silt loam earth	4.49
loam	7.48
fine sandy loam	9.35
Sandy loam	11.22

Source: Texas Board of Water Engineers (1946).

Table I-5. Results of the Bureau of Reclamation's canal lining demonstration program. All canal segments are in a volcanic soil with gravel and sand.

Liner Type	**Pre-lining Seepage Loss (gal/ft^2/day)**	**Post Construction Seepage Losses(gal/ft^2/day)**			**Construction Cost ($/ft^2)**
		after 1 year	**after 5 years**	**after 6 years**	
Geomembrane with shotcrete cover	10.47	.37 - .82	0 - 2.24		$2.43 - $2.52
Exposed Geomembrane	10.47	0 - .90	0 - 3.74	0.299	$1.03 - $1.38
Geomembrane with grout mattress cover	4.79	0.75	0 - 2.99	0.37	$2.54
Grout mattress	4.79	0.15	2.24 - 3.74	2.17	$1.79 - $1.92
Roller Compacted Concrete Invert Only	23.18 - 40.39	18.92			$2.64 - $4.33
Shotcrete		3.29 (@ 2 yrs)		2.99	$2.14 - $2.43

Table I-6. Elements of Imperial Irrigation District's water conservation program with the Municipal Water District.				
Water Conservation Practice	**Capital Costs (1999$)**	**O&M Costs[2] for 1999**	**Water Conserved**	
			Ac-Ft	**$/ac-ft (1988$)**
Spill Recovery (3 sites)	28,782,805	1,019,340	32,060	84
Canal Lining (210 miles)	46,023,975	1500	25,550	132
Water Measurement	0	1,525,207	21,750	57
Non-leak Gates (15 out of 127)	212,595	10,421	630	37
On-farm Evaluations and Demonstrations	0	297,565	280	787
System Automation	12,918,625	1,202,090	14,600	124
Tailwater Return Systems (25, 6,779 ac)	3,502,320	335,627	4540	111
Program Verification[1]	17,432,682	854,324		
Total	108,873,002	5,246,074	99,410	127

[1] costs of the verification program are included in the Total Program costs of $127/ac-ft
[2] O&M costs vary from year to year

Table I-7. Relative proportions of the main elements of Imperial Irrigation District's water conservation program.			
Water Conservation Practice	**Capital Costs (% of total)**	**O&M Costs for 1999 (% of total)**	**Water Conserved (% of total)**
Spill Recovery	26	19	33
Canal Lining	42	0.03	26
Non-leak Gates	0.2	0.2	0.6
System Automation	12	23	15
On-farm	3.2	41	27
Program Verification	16	17	0

A. District Bio and Survey

- obtaining basic information on districts through a survey form sent to all irrigation district managers

B. GIS Mapping

- mapping of the districts' main distribution networks and assembling basic attribute data
- assisting individual districts with mapping laterals, water accounts, and other district features; and obtaining and organizing attribute data
- mapping the water distribution network of Maverick ID and assembling attribute data

C. Seepage Lost Test

- conducting ponding tests to measure seepage lost rates in lined and unlined irrigation canal segments

D. Spill Lost and Recovery Measurement

- measurement of spill loss and recovery systems

E. Review of Other District Rehab Programs

- obtaining information on the water savings and costs of district rehab programs carried out in other regions

F. Canal Rider Survey

- obtaining detailed information on distribution systems and on-farm irrigation from individual canal riders

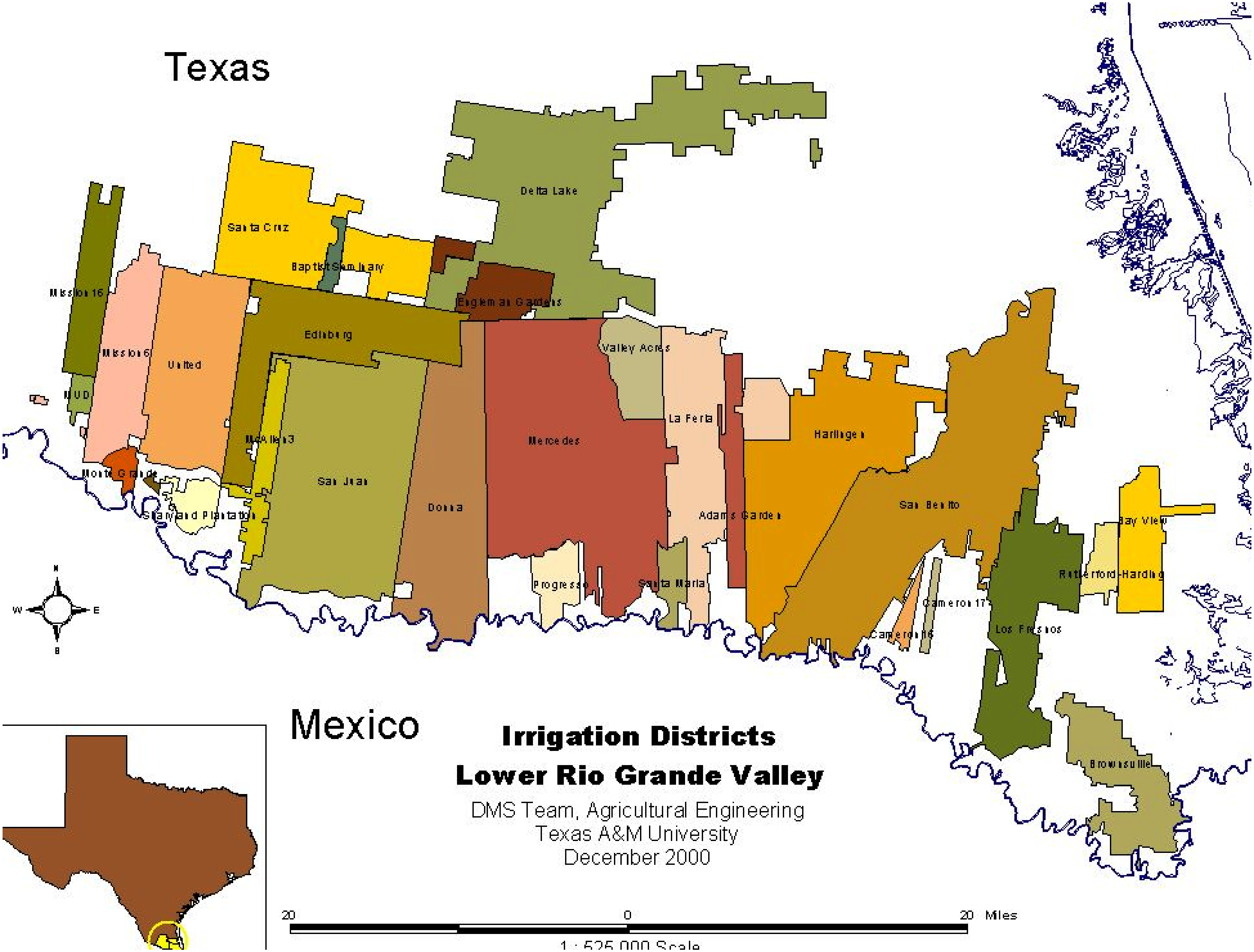
G. Canal Rating Procedure

- development and implementation of a canal rating procedure

H. Water Measurement Program Evaluation

- conducting a growers' meeting and survey documenting metering programs
- obtaining information on the types and extent of other district water measurement programs

Table II-1. Major activities of the DMS Team on the Rio Grande Region Water Resources Project.


Texas
Delta Lake
Santa Cruz
Baptist Seminary
Engleman Gardens
Mission 16
Edinburg
Mission 6
United
Valley Acres
MUD
La Feria
Harlingen
McAllen 3
Mercedes
Monte Grande
San Juan
Donna
San Benito
Sharyland Plantation
Adams Garden
Bay View
Progresso
Santa Maria
Rutherford-Harding
Cameron 17
Los Fresnos
Cameron 16
N
W
E
S
Brownsville
Mexico
Irrigation Districts
Lower Rio Grande Valley
DMS Team, Agricultural Engineering
Texas A&M University
December 2000
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20 Miles
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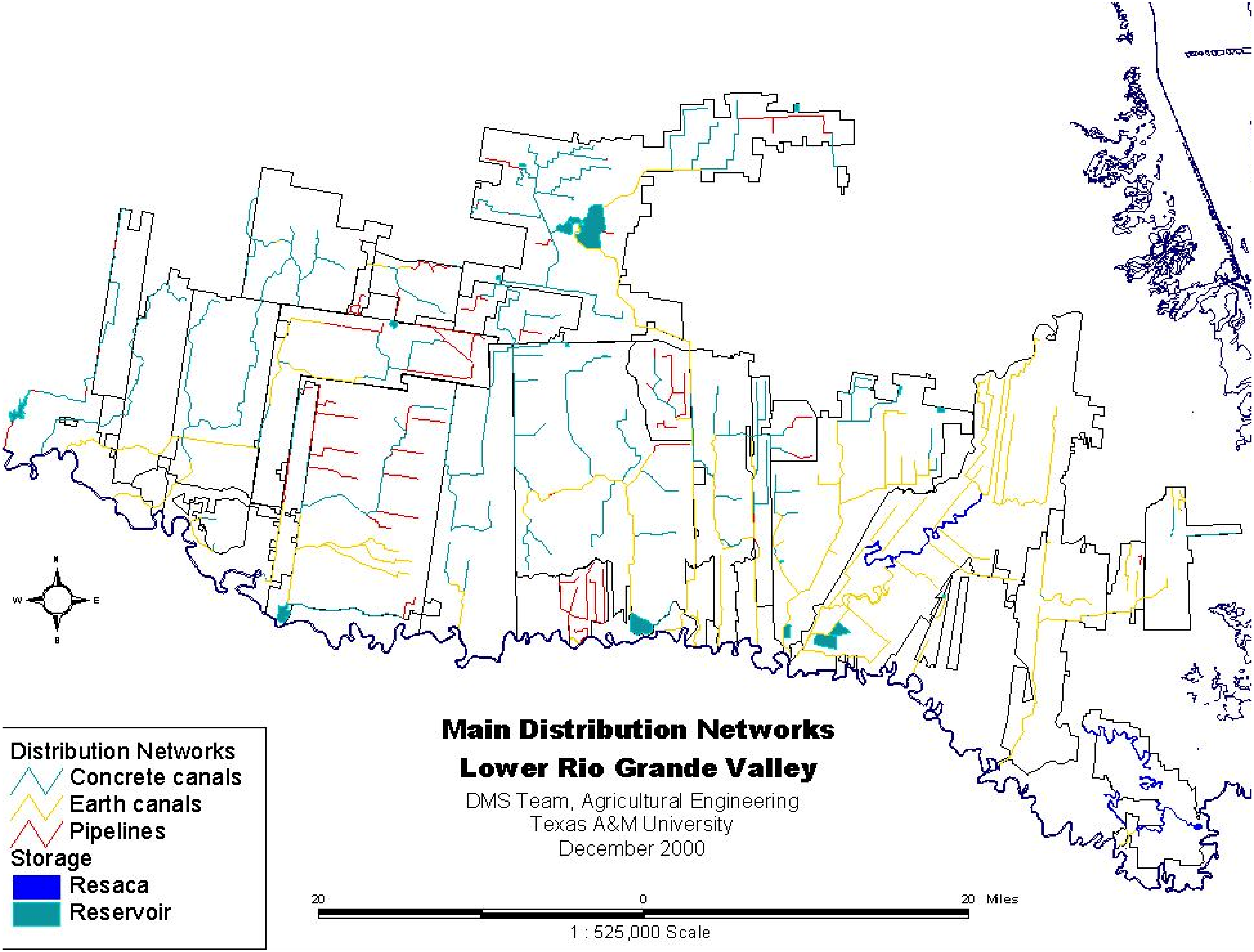
Main Distribution Networks
Lower Rio Grande Valley
DMS Team, Agricultural Engineering
Texas A&M University
December 2000
Distribution Networks
Concrete canals
Earth canals
Pipelines
Storage
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Reservoir
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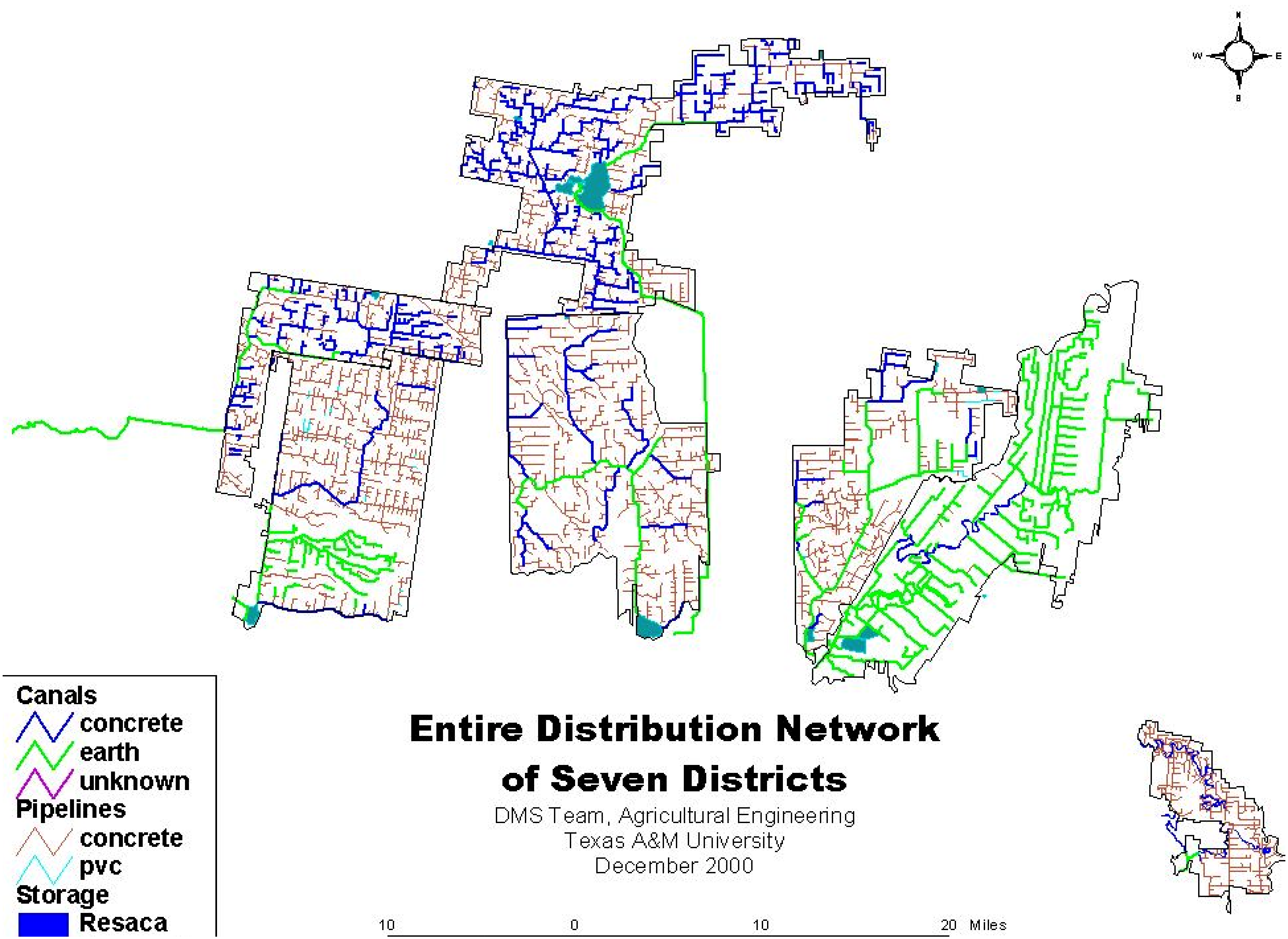

Canals
concrete
earth
unknown
Pipelines
concrete
pvc
Storage
Resaca
Entire Distribution Network
of Seven Districts
DMS Team, Agricultural Engineering
Texas A&M University
December 2000
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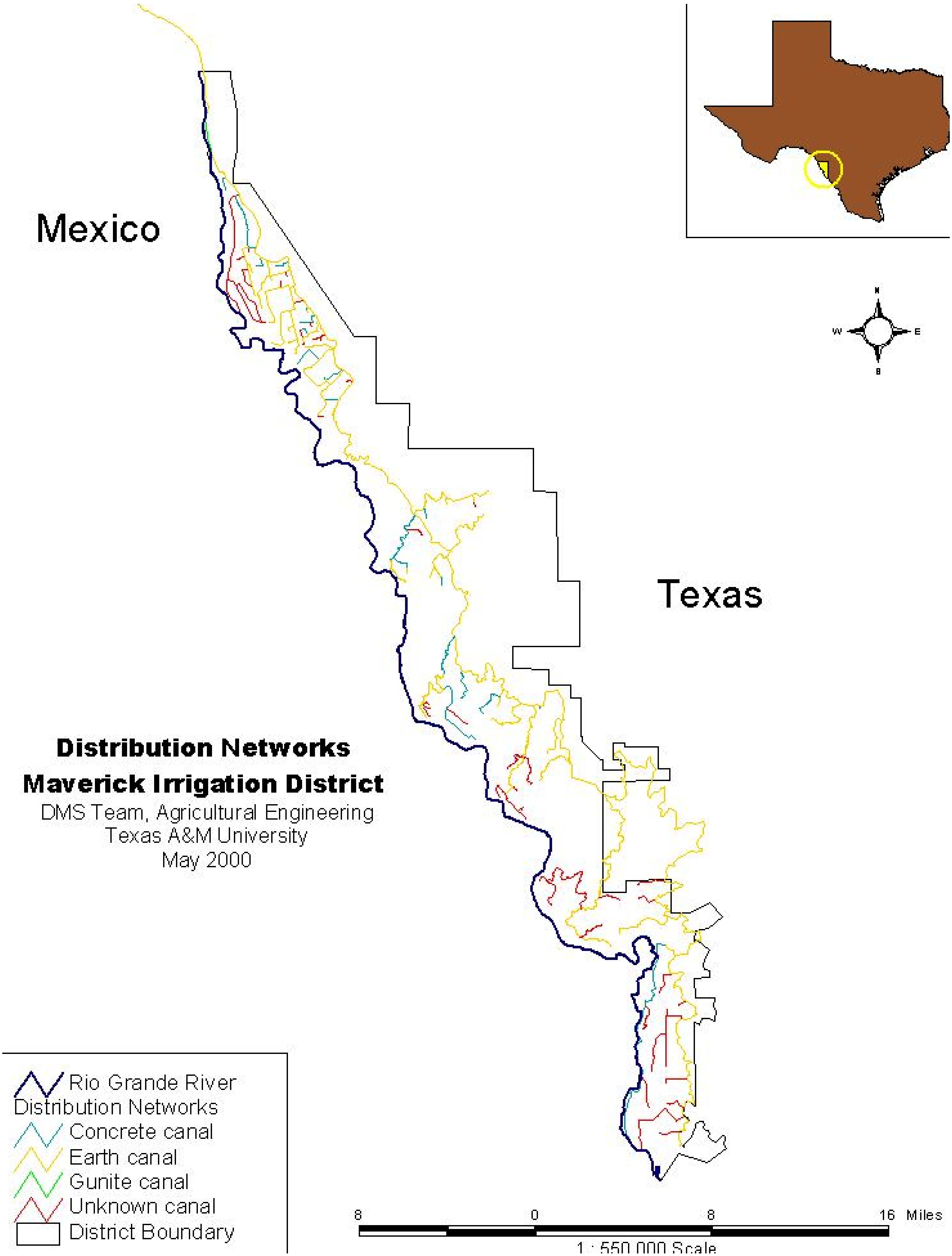
10
20 Miles


Mexico
Texas
Distribution Networks
Maverick Irrigation District
DMS Team, Agricultural Engineering
Texas A&M University
May 2000
Rio Grande River
Distribution Networks
Concrete canal
Earth canal
Gunite canal
Unknown canal
District Boundary
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16 Miles
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