Estimating the Required Investment to Attain Region M Water Savings Through Rehabilitation of Water-Delivery Infrastructure – 2005 Perspectives

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Preface

In the 1990s, water emerged as a critical issue for the Texas Lower Rio Grande Valley (LRGV) (Region M in the Texas water planning activity) because of rapid population growth, a prolonged drought, and shortfalls in delivery of water from Mexico over many years. Opportunities for and investigations into easing the stress from limited water has taken many paths, with water conservation in irrigation district water-conveyance systems being a major area of focus.

The issue is twofold – estimating the potential water savings and then identifying the expected costs to achieve those savings in the LRGV irrigation districts. This report brings together the current estimates of potential water savings within LRGV irrigation districts and the economics of achieving the savings. The material presented herein provides such an estimate, as well as the methods and data used in calculating the estimate. Periodic updating is an important component of regional water planning for Region M.

Acknowledgments

As this report relies heavily upon prior economic analyses by the authors, we wish to reiterate our appreciation to the many collaborators and associates who selflessly assisted, for without their prior assistance, this work would not have been possible. A detailed listing can be found in Rister et al. 2004. In summary, however, we sincerely thank those many individuals from the Lower Rio Grande Valley irrigation districts, consulting engineering firms, U.S. Bureau of Reclamation, Texas Water Development Board, Texas Water Resources Institute, and our peers and associates in the Agricultural Economics and the Biological and Agricultural Engineering Departments at Texas A&M University who furthered our efforts in many ways. Also, we thank the Region M Water Planning Committee, and in particular Bill Norris with NRS Consulting Engineers, for allowing us the opportunity to assist.

Abstract

Irrigation districts in the Texas Lower Rio Grande Valley use an antiquated water-delivery conveyance system; which loses substantial water from seepage, evaporation, etc. Pressures are increasing for districts to improve their operational efficiencies. Rehabilitation of the system has been estimated to save approximately 211,000 ac-ft of water annually; which can benefit agricultural, municipal, and industrial users in the region. Combining these estimated savings with prior economic and financial analyses of 17 proposed rehabilitative project components result in an extrapolated estimated required initial capital investment of $157.8 million in rehabilitative measures to attain the 211,000 ac-ft of annual savings. A caveat to the exactness of this dollar estimate is warranted, however, because this single-point estimate is built upon other estimates (e.g., water savings, initial construction costs, etc.) by irrigation district management, consulting engineers, and university scientists. Future application of on-going economic work, combined with an 'in-process' revised estimate of potential water savings (i.e., from the current 211,000 ac-ft), could provide an improved investment estimate in the future.

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Issue Background[e]

Senate Bill 1 in 1997 created the State's (i.e., Texas') regional water planning process, in which 16 Regional Water Planning Groups were formed to assess the water needs of each region and to develop regional water plans to meet those needs. Those plans, overseen by the Texas Water Development Board (TWDB), became the basis for the first State Water Plan that evolved from local and regional efforts rather than being developed centrally out of Austin. The 2002 State Water Plan catalogued $18 billion worth of water projects to meet future needs. Senate Bill 2 in 2001 provided for amendments and refinements to the regional water planning process, which are still ongoing (Bowen). The area known as the Lower Rio Grande Valley (LRGV) in south Texas is part of the Region M water-planning area.

Approximately 98 percent of raw water demanded by agriculture, municipal, and industrial users in Region M is delivered by local irrigation districts (IDs). Many of these IDs rely on an dated conveyance system of pipelines, canals, laterals, pumping facilities, etc. The diminished abilities of IDs to efficiently provide delivery services with this dated system has been exacerbated by a simultaneous increase in urban water demand and a fluctuating supply of water in the LRGV. This two-sided squeeze, along with other changing socio-economic factors, has intensified the need for IDs to improve their delivery efficiencies which range from 40-90% (Fipps and Pope). Various local, regional, state, and federal stakeholders are familiar with the needed improvements and have provided assistance in diverse ways.

Previously and without regard to comprehensive project costs, the Texas Cooperative Extension (TCE) quantified preliminary water-saving potential via infrastructure rehabilitation.[1] Specifically, Fipps estimated in calendar year 2000[2] a potential 159,631 to 210,944 ac-ft of water-savings with improvements to the LRGV water-delivery infrastructure system.[3]

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Table 1. Estimated Potential Water Savings with Improvements to the LRGV Water-Conveyance Infrastructure System.

Water Supply Conditions	District Conveyance Efficiency Improvement (ac-ft)
drought	159,631
normal	210,944

Source: This is a partial reproduction of the water-savings estimates contained in Fipps' (2000) technical memorandum.

Fipps concluded, assuming a "normal" water-supply year,[4] that almost 211,000 ac-ft of annual water savings could be realized with improvements to the ID conveyance system. Fipps' (2000) method:

(a) extrapolated that high diversions from the Rio Grande translated into a large available supply of water, which therefore translated into a 'normal' water-supply year, and
(b) assumed that the estimated average delivery efficiency of 70.8% could be increased to 90% across all IDs in the LRGV.

Fipps' (2000) work, along with that of many others, precipitated a broad initiative focused on identifying, prioritizing, and implementing projects to improve the LRGV water-delivery infrastructure. Various agencies and organizations are providing financing for these projects, including:

(1) $6.5 million in U.S. Congressional appropriations (in FYs 2003-04) via the U.S. Bureau of Reclamation (USBR) [of $85 million in federal authorizations during FYs 2000 and 2002];
(2) $25.6 million in grants (in FY 2003) from the North American Development Bank (NADB);
(3) $3.8 million in State Energy Conservation Office (SECO) funding for project analyses and development channeled through the TWDB; and
(4) additional internally-generated funds by the IDs (Rister et al. 2004).

Also of note are Texas Agriculture Experiment Station (TAES) and TCE agricultural economists' collaborative efforts with the USBR, NADB, TWDB, IDs, and several consulting engineers to provide estimates of costs-of-saving-water using the spreadsheet model RGIDECON© (Rister et al. 2002) on projects proposed to the USBR by IDs during 2003-2005.[5] Because of these analyses, TAES and TCE have access to unique construction cost and water-savings data appropriate for use in estimating the required investment (basis 2005 dollars) to attain Region M water savings via rehabilitation of the LRGV water-delivery infrastructure.

Issue and Purpose Statements

To date, beyond pure speculation, no comprehensive, economically and financially-based estimate of the total construction-cost funding required to attain the potential 211,000 ac-ft of water savings in Region M has been calculated and published. TAES/TCE economists address this shortcoming herein with an objective estimate of the capital investment funding (basis 2005 dollars) required to attain such savings.

The need for this estimate originates with the Region M water-planning committee's effort to update and submit its revised plan to the TWDB in 2005. Region M's possession of this information will:

(a) allow Region M to more accurately describe and quantify the "problem" to other stakeholders and policymakers;
(b) provide confidence that the action plan developed by local, regional, state, and federal agencies reasonably reflects the level of needs in the LRGV water-delivery infrastructure; and
(c) provide valuable data which refines and improves the updated Region M water plan.

Methodology

With a projected future imbalance in Region M's water supply (Rio Grande Regional Water Planning Group), the priority for establishing funding for rehabilitation is elevated. With this noted, estimating potential construction costs to attain a specified level of water savings on yet undefined projects is more complex, and inherently subject to more criticism than standard project costing of a known set of defined projects.[6] Thus, in lieu of a pre-defined, targeted, full set of projects capable of attaining the entire 211,000 ac-ft of potential savings, TAES/TCE economists use previously-completed work for several project components (e.g., Rister et al. 2004) to serve as a basis for making an extrapolated estimate herein. That is, several LRGV ID projects (made up of one or more project components) and their related data, analyzed for their economic and financial *cost-of-saving-water* (with RGIDECON©) (**Tables 2** and **3**), provide a basis of construction costs, anticipated water savings, etc., from which to estimate the level of needed investment for yet-to-be-determined projects.[7] In summary, different project components representing three project types (e.g., meters and telemetry, linings, and pipelines) previously identified by ID managers and consulting engineers were organized by type, aggregated, and then combined with Fipps' (2000) estimated water savings to extrapolate a baseline investment-requirement estimate.

The approach followed herein is based on the premise that the current process of project selection (e.g., planning, design, funding, etc.) and construction will continue to be similar (i.e., *status quo*) to that currently observed across Region M stakeholders as a whole. Further, 17 project components previously analyzed by TAES/TCE (**Table 2**)[8] are assumed to be representative of the additional projects required to accomplish the total 211,000 ac-ft of water savings potential previously estimated by Fipps (2000).[9]

Extrapolated Results and Assumptions

For the baseline extrapolated results, it is estimated **$157.8 million** of initial capital investment in the water-delivery system (in Region M) will be required to attain the estimated 211,000 ac-ft of annual water savings estimated by Fipps (2000). Inherent assumptions in this forecast baseline value include:

(1) all project components analyzed by TAES/TCE will be built;
(2) all data received from ID managers and consulting engineers about construction costs, water savings, life expectancies, etc. are accurate, being neither under- nor over-represented; and
(3) a constant (i.e., linear) relationship between the average cost of a project/component and its estimated waters savings is expected (i.e., marginal costs to attain savings are not increasing, or decreasing).

The $157.8 million estimate is an extrapolated value determined by (a) dividing the annuity equivalent[10] of water savings of 53,602 ac-ft identified in the 17 components (**Table 2**) evaluated by TAES/TCE into the total estimated water-savings potential of 211,000 ac-ft (Fipps 2000), and then (b) multiplying that ratio by the initial investment cost of $40,089,121 for the 17 components (**Table 2**), as shown below:

$$\frac{\textit{total estimated water-savings potential}}{\textit{annuity equivalent water savings}} \times \textit{\$ initial investment of 17 analyzed components} = \textit{\$ extrapolated total investment required}$$

$$\frac{211{,}000 \text{ ac-ft}}{53{,}602 \text{ ac-ft}} \times \$\,40{,}089{,}121 = \$\,157{,}806{,}657\,.$$

Table 2. Key Input and Results for 17 LRGV Irrigation District Project Components Analyzed in the *Baseline, Status-Quo* Results, Grouped by Project Type, 2005.

Project Type / ID / Component	Estimated Initial Construction Cost ($)	Expected Useful Life (years)	Estimated Annual Water Savings (ac-ft)	Calculated Annuity Equivalent of Water Savings (ac-ft)	Net Change in Annual O&M Expenses ($/year)	Cost of Saving Water ($/ac-ft)	Length (miles)
Meters & Telemetry							
1 - CCID #1 (Harlingen)	$756,761	15	2,022	1,855	$83,375	$ 84	-
2 - HCID #2 (San Juan)	$564,500	20	280	261	($22,294)	$ 81	-
sub-aggregate	$1,321,261		2,302	2,116	$61,081	$ 83	n/a
Lining							
3 - CCID #1 (Harlingen)	$349,031	20	961	895	($2,960)	$ 23	2.45
4 - CCID #2 (San Benito)	$3,585,300	49	9,557	9,129	$1,704	$ 23	2.39
5 - CCID #2 (San Benito)	$3,296,000	49	7,503	7,167	($3,997)	$ 26	13.98
6 - CCID #2 (San Benito)	$2,996,000	49	4,536	4,333	($2,033)	$ 41	9.33
7 - HCID #2 (San Juan)	$3,154,200	49	2,661	2,542	$300	$ 74	7.26
8 - HCID #2 (San Juan)	$2,495,000	49	644	615	$0	$ 251	5.34
9 - MCWCID #1 (Eagle Pass)	$4,509,819	49	8,463	8,084	($23,211)	$ 33	3.00
sub-aggregate	$20,385,350		34,325	32,765	($30,197)	$ 37	43.75
Pipeline							
10 - Brownsville ID	$2,356,000	49	1,959	1,872	($68,308)	$ 28	2.31
11 - CCID #1 (Harlingen)	$1,397,786	49	2,381	2,275	($8,492)	$ 27	6.07
12 - CCID #2 (San Benito)	$4,396,000	49	6,089	5,817	($24,865)	$ 40	11.65
13 - CCID #2 (San Benito)	$2,646,000	49	1,694	1,618	($11,549)	$ 93	7.22
14 - CCID #2 (San Benito)	$826,000	49	675	645	($4,962)	$ 70	2.04
15 - HCID #1 (Edinburg)	$1,333,299	49	2,364	2,258	($15,621)	$ 25	1.12
16 - HCID #1 (Edinburg)	$3,847,125	48	3,412	3,259	($70,431)	$ 16	5.42
17 - HCID #2 (San Juan)	$1,580,300	49	1,023	977	($17,192)	$ 71	1.98
sub-aggregate	$16,802,210		19,597	18,721	($221,420)	$ 40	37.81
Overall Aggregate	$40,089,121	n/a	56,225	53,602	($190,536)	$ 40	81.56

Extended Analyses and Results

Beyond the extrapolated investment estimate, the analysis by TAES/TCE economists also lends itself to providing other related and useful information which is shared here. The co-product of this analysis, or the *cost-of-saving-water*, is also discussed because of its key relevance and interactive relationship with the $157.8 million extrapolated estimate (**Table 2**).

> Annuity Equivalent
>
> Here, we introduce the financial term *Annuity Equivalent* (AE), and explain two intermediate AE calculations which are the parameters used in determining the *cost-of-saving-water* values on a per acre foot (ac-ft) basis. [For additional information about AEs, refer to Rister et al. 2002 and appropriate finance and accounting text books].
>
> *'Annuity' is derived from annum, meaning yearly, while 'Equivalent' can be taken to mean uniform, so a literal translation in the area of finance would be "a uniform series of annual payments/costs."*
>
> *Annuity Equivalent of Net Cost Stream – Water Savings ($/yr)* - the annual (uniform) 'net impact' investment cost (basis CY 2005) associated with saving water, with a specified project component or aggregate group of projects. Zero salvage values and a continual replacement of the respective project/component(s) with similar capital items as their useful life ends are assumed.
>
> *Annuity Equivalent of Water Savings (ac-ft)* - the annual (uniform) volume of water savings (basis CY 2005) provided by a project component or aggregate group of projects. A social-preference time value is incorporated in related calculations.
>
> Dividing the first annuity equivalent by the second results in a $/ac-ft value which is the estimated *cost-of-saving-water*; a value depicting the 'net impact' cost (e.g., initial cost, O&M changes, energy cost changes, etc.) which accounts for time and inflation, thereby presenting the value in 2005 dollars. These values can be compared across project components with different useful lives on an 'apples-to-apples' basis.

That is, the *cost-of-saving-water* associated with the $157.8 million is an aggregated value of $40/ac-ft of water saved (basis 2005 dollars) (**Tables 2**, **3**, and **4**). A closer look reveals the *cost-of-saving-water* ranges from $37/ac-ft to $83/ac-ft across the three project types analyzed. As described in Rister et al. 2002, the interpretation of these values are the costs per year, in present-day dollars, of saving one ac-ft of water into perpetuity through a continual series of replacements of the listed components, with all of their associated data input. With this, the 'net impact' (i.e., initial cost, longevity, changes in operations and maintenance costs, level of water savings, etc.) of a project/component over its life is considered, not just the initial construction cost. The net impact value is, obviously, a more realistic measure of a project/component's economic and financial worthiness than an estimate which ignores these factors.

The comprehensive financial analysis view encompassed in TAES/TCEs evaluation requires consideration of not only a project component's initial construction cost, but also other factors such as: how many years will the components be useful and save water, what is the impact of inflation and time, and what is the impact of changes in operations and maintenance costs (O&M), as well as what are the expected changes in energy costs, etc. Seldom is a capital asset purchased or built where the benefits are a one-time occurrence, and/or where the effects on O&M expenses end after the initial investment has been made. This 'net-impact' approach is known as *capital budgeting*, the preferred approach to project analysis by banks, businesses, and others involved in analyzing and comparing capital projects; and, the foundation supporting the results presented below. Engineers sometimes refer to this approach as *life-cycle costs* (Michalewicz).

The results of this 'net impact' method potentially allows for priority ranking of multiple projects and/or components on an apples-to-apples basis. This could be very useful information if optimization of the spending of limited project-investment monies was desired. As shown in **Tables 2** and **3**, the lining projects/components provide the most 'bang for the buck' as they have the lowest *cost-of-saving-water* value, while the meters and telemetry are shown to be a relatively higher-costing rehabilitative measure analyzed here.

A detailed view of the aggregated *cost-of-saving-water* for all 17 components analyzed by TAES/TCE economists is provided in **Table 4**, with a breakdown of like data provided for the three individual project types (i.e., meters and telemetry, lining, and pipeline) provided in **Tables 5**, **6**, and **7**, respectively. Using component #1 in **Table 4** and the text box information about 'Annuity Equivalents' from the previous page shows that dividing the A.E. of the net cost stream of $155,513/year by the A.E. of all water savings of 1,855 ac-ft/year results in an A.E., or *cost-of-saving-water* value of $83.83/ac-ft. Other *cost-of-saving-water* values are similarly calculated. Also presented in **Table 4** is an aggregate capital investment cost of $40,089,121 and an A.E. value of 53,602 ac-ft of water savings associated with the 17 components - - (these values correspond with replicate values found on Tables 2 and 3). Also, the aggregated *cost-of-saving-water* from rehabilitation is a calculated $39.77/ac-ft (i.e., which is highlighted, and corresponds to a rounded-up $40/ac-ft value in found in Tables 2 and 3).

A detailed look at the 2 meters and telemetry components in **Table 5** reveals a range of $80.88 - $83.83 per ac-ft cost of saving water, with an aggregated value for the 2 components of $83.46 per ac-ft, which corresponds to the rounded-down value of $83/ac-ft in **Tables 2** and **3**. Further, **Table 6** depicts a range of $22.58 - $251.35 per ac-ft cost of saving water with lining, with an aggregated value for the 7 lining components of $36.83 per ac-ft, which corresponds to the rounded-up value of $37/ac-ft in **Tables 2** and **3**. Finally, a detailed look at the 8 pipeline components in **Table 7** reveals a range of $24.42 - $93.34 per ac-ft cost of saving water with pipelines, with an aggregated value for the 8 pipeline components of $39.97 per ac-ft, which corresponds to the rounded-up value of $40/ac-ft in **Tables 2** and **3**.

Table 3. Summary of Data and Results for 17 LRGV Irrigation District Project Components Analyzed by TAES/TCE, by Project Type, 2005.

	Project Type			
Item	Meters & Telemetry (2)	Lining (7)	Pipeline (8)	Aggregate (all 17)
Projects' Total Length (miles)	0	43.75	37.81	81.56
Estimated Initial Investment Cost ($)	$1,321,261	$20,385,350	$18,382,510	$40,089,121
Expected Useful Life (years)	15, 20	20, 49	48, 49	n/a
Net Changes in Annual O&M ($)	$ 61,081	($ 30,197)	($ 221,420)	($190,536)
Annuity Equivalent of Net Cost Stream – Water Savings ($/yr)	$ 176,606	$ 1,206,745	$ 748,296	$ 2,131,647
Annuity Equivalent of Water Savings (ac-ft/yr)	2,116	32,765	18,720	53,602
Cost of Saving Water ($AE/ac-ft)	**$ 83**	**$ 37**	**$ 40**	**$ 40**

Table 4. Economic and Financial Summary of 17 Selected Rehabilitative Project Components Analyzed by TAES/TCE.

Item	1 CCID #1 (Harlingen) Meters & Telemetry	2 HCID #2 (San Juan) Meters & Telemetry	3 CCID #1 (Harlingen) Lining	4 CCID #2 (San Benito) Lining	5 CCID #2 (San Benito) Lining	6 CCID #2 (San Benito) Lining	7 HCID #2 (San Juan) Lining	8 HCID #2 (San Juan) Lining	9 MCWCID #1 (Eagle Pass) Lining
	Component No. / ID Abbreviation / ID Common Name / Project Type								
Total Discount Period (years)	16	21	21	50	50	50	50	50	50
Cost Discount Rate -- Ag, $ (%)	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%
Discount Rate -- Water & Energy Volume (%)	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%
Cost of Water Saved									
NPV of Net Cost Stream ($)	$1,558,197	$245,552	$235,301	$3,206,881	$2,900,884	$2,764,563	$2,933,491	$2,395,243	$4,179,406
- annuity equivalent ($/yr)	$155,513	$21,093	$20,212	$207,017	$187,264	$178,464	$189,369	$154,622	$269,797
NPV of Capital Investment Costs ($)	$756,761	$564,500	$349,031	$3,585,300	$3,296,000	$2,996,000	$3,154,200	$2,495,000	$4,509,819
- annuity equivalent ($/yr)	$75,527	$48,491	$29,982	$231,445	$212,770	$193,404	$203,616	$161,062	$291,127
NPV of All Water Savings (ac-ft)	21,617	3,659	12,561	196,105	153,971	93,078	54,610	13,215	173,660
- annuity equivalent (ac-ft/yr)	1,855	261	895	9,129	7,167	4,333	2,542	615	8,084
NPV of Net Cost Stream per Ac-Ft of Water Savings	$72,082	$67,110	$18,733	$16,353	$18,841	$29,702	$53,718	$181,248	$24,067
Cost of Saving Water ($/ac-ft) [1]	$83.83	$80.88	$22.58	$22.68	$26.13	$41.19	$74.49	$251.35	$33.38

[1] i.e., Annuity equivalent, assuming perpetuity, zero salvage values, and replacement with identical technology.

Table 4. Economic and Financial Summary of 17 Selected Rehabilitative Project Components Analyzed by TAES/TCE, continued.

Item	Component No. / ID Abbreviation / ID Common Name / Project Type								Aggregate (17 components)
	10 BID (Brownsville) Pipeline	11 CCID #1 (Harlingen) Pipeline	12 CCID #2 (San Benito) Pipeline	13 CCID #2 (San Benito) Pipeline	14 CCID #2 (San Benito) Pipeline	15 HCID #1 (Edinburg) Pipeline	16 HCID #1 (Edinburg) Pipeline	17 HCID #2 (San Juan) Pipeline	
Total Discount Period (years)	50	50	50	50	50	50	50	50	
Cost Discount Rate -- Ag, $ (%)	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	
Discount Rate -- Water and Energy Volume (%)	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	
Cost of Water Saved									
NPV of Net Cost Stream ($)	$811,403	$936,099	$3,637,960	$2,339,578	$696,657	$863,339	$1,232,675	$1,074,075	$32,011,302
- annuity equivalent ($/yr)	$52,379	$60,429	$234,845	$151,029	$44,972	$55,732	$79,574	$69,336	$2,131,647
NPV of Capital Investment Costs ($)	$2,356,000	$1,397,786	$4,396,000	$2,646,000	$826,000	$1,333,299	$3,847,125	$1,580,300	$40,089,121
- annuity equivalent ($/yr)	$152,089	$90,233	$283,779	$170,810	$53,322	$86,070	$241,976	$102,015	$2,627,717
NPV of All Water Savings (ac-ft)	40,208	48,869	124,954	34,760	13,849	48,509	70,013	20,989	1,171,269
- annuity equivalent (ac-ft/yr)	1,872	2,275	5,817	1,618	645	2,258	3,259	977	53,602
NPV of Net Cost Stream per Ac-Ft of Water Savings	$20,180	$19,155	$29,114	$67,307	$50,302	$17,798	$17,606	$51,174	
Cost of Saving Water ($/ac-ft) [1]	$27.99	$26.56	$40.38	$93.34	$69.76	$24.68	$24.42	$70.97	$39.77

[1] i.e., Annuity equivalent, assuming perpetuity, zero salvage values, and replacement with identical technology.

Table 5. Economic and Financial Summary of 2 Meters & Telemetry Project Components Analyzed by TAES/TCE.

Item	1 CCID #1 (Harlingen) Meters & Telemetry	2 HCID #2 (San Juan) Meters & Telemetry	Aggregate (2 components)
	Component No. / ID Abbreviation / ID Common Name / Project Type		
Total Discount Period (years)	16	21	
Cost Discount Rate -- Ag, $ (%)	6.1250%	6.1250%	
Discount Rate -- Water and Energy Volume (%)	4.0000%	4.0000%	
		Cost of Water Saved	
NPV of Net Cost Stream ($)	$1,558,197	$245,552	$1,803,748
- annuity equivalent ($/yr)	$155,513	$21,093	$176,606
NPV of Capital Investment Costs ($)	$756,761	$564,500	$1,321,261
- annuity equivalent ($/yr)	$75,527	$48,491	$124,018
NPV of All Water Savings (ac-ft)	21,617	3,659	25,276
- annuity equivalent (ac-ft/yr)	1,855	261	2,116
NPV of Net Cost Stream per Ac-Ft of Water Savings	$72,082	$67,110	
Cost of Saving Water ($/ac-ft) [1]	$83.83	$80.88	$83.46

[1] i.e., Annuity equivalent, assuming perpetuity, zero salvage values, and replacement with identical technology.

Table 6. Economic and Financial Summary of 7 Lining Project Components Analyzed by TAES/TCE.

Item	3 CCID #1 (Harlingen) Lining	4 CCID #2 (San Benito) Lining	5 CCID #2 (San Benito) Lining	6 CCID #2 (San Benito) Lining	7 HCID #2 (San Juan) Lining	8 HCID #2 (San Juan) Lining	9 MCWCID #1 (Eagle Pass) Lining	Aggregate (7 components)
	Component No. / ID Abbreviation / ID Common Name / Project Type							
Total Discount Period (years)	21	50	50	50	50	50	50	
Cost Discount Rate -- Ag, $ (%)	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	
Discount Rate -- Water and Energy Volume (%)	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	
Cost of Water Saved								
NPV of Net Cost Stream ($)	$235,301	$3,206,881	$2,900,884	$2,764,563	$2,933,491	$2,395,243	$4,179,406	$18,615,768
- annuity equivalent ($/yr)	$20,212	$207,017	$187,264	$178,464	$189,369	$154,622	$269,797	$1,206,745
NPV of Capital Investment Costs ($)	$349,031	$3,585,300	$3,296,000	$2,996,000	$3,154,200	$2,495,000	$4,509,819	$20,385,350
- annuity equivalent ($/yr)	$29,982	$231,445	$212,770	$193,404	$203,616	$161,062	$291,127	$1,323,406
NPV of All Water Savings (ac-ft)	12,561	196,105	153,971	93,078	54,610	13,215	173,660	697,199
- annuity equivalent (ac-ft/yr)	895	9,129	7,167	4,333	2,542	615	8,084	32,765
NPV of Net Cost Stream per Ac-Ft of Water Savings	$18,733	$16,353	$18,841	$29,702	$53,718	$181,248	$24,067	
Cost of Saving Water ($/ac-ft) [1]	$22.58	$22.68	$26.13	$41.19	$74.49	$251.35	$33.38	$36.83

[1] i.e., Annuity equivalent, assuming perpetuity, zero salvage values, and replacement with identical technology.

Table 7. Economic and Financial Summary of 8 Pipeline Project Components Analyzed by TAES/TCE.

Item	Component No. / ID Abbreviation / ID Common Name / Project Type								Aggregate (8 components)
	10 BID (Brownsville) Pipeline	11 CCID #1 (Harlingen) Pipeline	12 CCID #2 (San Benito) Pipeline	13 CCID #2 (San Benito) Pipeline	14 CCID #2 (San Benito) Pipeline	15 HCID #1 (Edinburg) Pipeline	16 HCID #1 (Edinburg) Pipeline	17 HCID #2 (San Juan) Pipeline	
Total Discount Period (years)	50	50	50	50	50	50	50	50	
Cost Discount Rate -- Ag, $ (%)	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	6.1250%	
Discount Rate -- Water and Energy Volume (%)	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	4.0000%	
Cost of Water Saved									
NPV of Net Cost Stream ($)	$811,403	$936,099	$3,637,960	$2,339,578	$696,657	$863,339	$1,232,675	$1,074,075	$11,591,785
- annuity equivalent ($/yr)	$52,379	$60,429	$234,845	$151,029	$44,972	$55,732	$79,574	$69,336	$748,296
NPV of Capital Investment Costs ($)	$2,356,000	$1,397,786	$4,396,000	$2,646,000	$826,000	$1,333,299	$3,847,125	$1,580,300	$18,382,510
- annuity equivalent ($/yr)	$152,089	$90,233	$283,779	$170,810	$53,322	$86,070	$241,976	$102,015	$1,180,293
NPV of All Water Savings (ac-ft)	40,208	48,869	124,954	34,760	13,849	48,509	70,013	20,989	402,151
- annuity equivalent (ac-ft/yr)	1,872	2,275	5,817	1,618	645	2,258	3,259	977	18,720
NPV of Net Cost Stream per Ac-Ft of Water Savings	$20,180	$19,155	$29,114	$67,307	$50,302	$17,798	$17,606	$51,174	
Cost of Saving Water ($/ac-ft) [1]	$27.99	$26.56	$40.38	$93.34	$69.76	$24.68	$24.42	$70.97	$39.97

[1] i.e., Annuity equivalent, assuming perpetuity, zero salvage values, and replacement with identical technology.

Conclusions and Implications

Baseline, status-quo results, extrapolated from the 17 proposed project components previously evaluated by TAES/TCE (assuming their average costs represent what yet-to-be-determined projects/components will cost) indicate initial construction costs (to attain the 211,000 ac-ft of annual water savings estimated by Fipps in 2000) will be an estimated **$157.8 million**. As evidenced in **Tables 2** and **3**, however, the *costs-of-saving-water* across individual components can vary greatly.

In summary, the comprehensive 'net-impact' cost represented in the economic and financial results of the individual project components displayed in **Table 2** (and of other future proposed projects) should be considered by ID managers, policymakers, and other interested stakeholders if limited capital-investment funding is to be optimized. That is, some projects save water (or add to the region's supply) at what appears to be a very efficient cost, while others are more, and sometimes much more, expensive. As the LRGV region addresses the future water-supply imbalance, efforts to identify and financially support the most cost-effective projects should be a priority for all stakeholders.

Limitations and Caveats

The $157.8 million investment estimate reported herein is based on previously published estimates, using a logical extrapolation approach. This method of analysis was followed in the absence of more robust documented data being available to facilitate more detailed estimation procedures. In this section, several caveats are noted, qualifying the supposed accuracy of the $157.8 million estimate in recognition of several potential limitations in the available data.

Fipps' (2000) estimate of 211,000 ac-ft of potential delivery conveyance system water savings is broadly based, using county-level estimates of existing and potential delivery efficiencies. Notably absent are irrigation district-specific insights which identify the attributes of existing delivery system infrastructure on a smaller scale (e.g., miles and diameters of pipeline, miles and wetted perimeters of canals/laterals, number of turnouts, relift structures, soil types, etc.) and engineering-based water-savings estimate for each ID specific project type (e.g., canal/lateral linings, pipelines, etc.). The lack of such detailed data on potential water savings prohibits identification of a more accurate, and certainly more documented, estimate of needed investment for rehabilitation.

TAES/TCEs economic information is predicated on the accuracy of data collected and assimilated during the evaluation of individual project components. Among the principal factors considered for each component are the initial investment costs, the projected useful life, the changes in O&M, and the associated annual potential water savings. Limited preliminary post-installation evaluation of selected rehabilitation projects indicate the original estimated water savings may have been overstated for the scope of some proposed components. Such unanticipated underachievements of water savings may be associated with non-inclusion of additional improvements such as gate repair. If that is the case, the cost-of-saving-water could be substantially understated, as well as the estimated $157.8 million for initial required investment.

The supposition that the 17 project components previously evaluated by TAES/TCE are directly and proportionally representative of the scope of projects required to achieve the total 211,000 ac-ft of water savings estimated by Fipps (2000) could be challenged. For example, perhaps the existing proportion of lining canals versus replacing canals/laterals with pipelines in the 17 components evaluated by TAES/TCE is inconsistent with a similar proportion for the total valley-wide scope of rehabilitation. Further, perhaps some types of rehabilitation (e.g., gate structures) are not represented in the TAES/TCE information set, thereby potentially skewing the estimation procedure. Presuming there are 554,938 acres of irrigated agriculture in the LRGV (Texas Water Development Board) and that on average each 40 acres requires a gate structure costing $500 - $1,000. Therefore, another $7 - 14 million (i.e., 554,938 acres divided by 40 acres/gate equals 13,874 gates; multiplying by this value by $500 and $1,000 results in estimates of $7 - $14 million, respectively) of required rehabilitation investment would not be represented in the extrapolated $157.8 million estimate.

As a final review of the estimated investment, one other method of extrapolation is presented. A review of **Table 2** indicates and reports 53,602 ac-ft of annuity equivalent water savings for the 17 components which encompass rehabilitative efforts to improve 81.56 miles of waterway infrastructure. Given an estimated total 3,200 miles of pipelines, canals, and laterals in the LRGV ID system (Fipps; Rister et al. 2004), the implication is that rehabilitating 2.55% (i.e., 81.56 ÷ 3,200 = .0255) of the region's irrigation waterways will produce 25.4% of the potential savings estimated by Fipps (i.e., 53,602 ÷ 211,000 = .254). Although it is expected that early rehabilitation projects would be directed to the worst areas, intuitively, a comparison of these two proportions suggests they may be misaligned with one another. That is, fixing 2.55% of the waterways and realizing 25.4% of the potential water savings does seem somewhat extraordinary, and does provide cause for review. Though inconclusive, we can think of three plausible explanations for these results:

> Authors' Note:
>
> We apologize for the possibly confusing counter arguments provided in the indented and italicized text below, but we do wish to provide the reader an unabridged report which provides some amount of discussion about the inexactness of our providing a single dollar estimate of what the needed investment costs might be, since the data input is inexact by its very nature. That is, estimating construction costs, changes in operations and maintenance costs, how long will a project save water, how much water each year, etc. are all individually (and collectively) inexact. That is why we call the single dollar estimate an "estimate."

1) The input data are accurate. The 17 proposed project components (used in extrapolating a value for the total investment required) fix some very inefficient segments of the waterway system, and rehabilitating a small portion of the system does result in large water savings.

   If this is the case, the $157.8 million estimate could be low if future projects are not as effective at saving water, relatively speaking. Conversely, if future projects are more effective at saving water, then the estimate would be high - - given our assumption that ID managers (and their consulting engineers) would propose to fix their worst problems first, we would give little credence to this sub-argument, i.e., if the estimate is high. Given that only 2.55% of the waterway infrastructure is being impacted with the proposed components analyzed, however, the argument would tend to lean towards the $157.8 million estimate being reasonably accurate since there are many waterway segments which need to be fixed.

2) The estimated water savings used in analyzing individual project components are, across the board, excessively high, and are therefore the source of the potential inconsistency in comparing the 2.55% infrastructure fix versus the 25.4% of potential savings.

   Under this scenario, the $157.8 million value is probably low as the "actual" cost-effectiveness for future projects would be, albeit more accurate, less than the overstated water savings of projects used in making the extrapolated estimate.

3) The total potential savings estimate of 211,000 ac-ft by Fipps is an underestimate.

   If this is the case, please note there are no intentions to disparage any work done by Dr. Fipps, but only to reiterate comments about data input often being inexact in nature. If additional potential savings are identified in Fipps' 2005 work, the $157.8 million required investment estimate value is likely too low.

Future Opportunities and Needs

Based on available information related to costs of rehabilitation and water savings, an extrapolation of selected project components for the LRGV was conducted. Significant confidence in such estimates would be achieved through defining and quantifying the miles of canals where alternative projects (i.e., lining, pipeline, etc.) would be appropriate. Any refinement in size of sections to be rehabilitated further improves the estimate of total required investment costs.

In addition, accountability is especially important to agencies such as the USBR and TWDB. Therefore, selected seepage (losses) estimates both before and after construction and implementation of a rehabilitative project work to verify the anticipated water savings in the original project proposals.

In the work done and ongoing related to economics, the methodology to bring more detailed information has been incorporated into a spreadsheet as shown in **Tables 4-7**. Application of these spreadsheets with refined values on an option-specific basis is an effective process for more accurate values of total investment for rehabilitation as well as the cost per acre foot of water saved. Such refinement is recommended following completion of Fipps' 2005 work.

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Endnotes

1. In 2000, Fipps constructed a partial budget for a $2.1M hypothetical project assumed to contribute to improving the average ID efficiency from 71% to 90%. Considerations for the expected life of the project, its annual water savings, time value of money, changes in operations and maintenance costs, and other life-cycle cost attributes were not included, however. Appropriate methodology for accounting for these conditions and arriving at a comprehensive life-cycle cost of saving water via rehabilitation is documented in Rister et al. 2002.

2. Fipps is currently updating and enhancing his original estimates, with the preliminary-revised numbers anticipated to be published in late March, 2005 and final estimates by June, 2005.

3. Fipps also estimated potential on-farm water savings under scenarios of 'with' and 'without' improvements, and across differing water-supply conditions (i.e., drought and normal). The on-farm savings are not replicated or used in this report; instead, only the estimated savings from the water-delivery conveyance system under normal water-supply conditions are utilized.

4. Fipps defined a 'normal' year as the summed total of all individual irrigation districts' highest 5-years' (i.e., non-consecutive) average diversions for the twelve-year period 1986-1998.

5. Rister et al. 2004 is an example application of this methodology with respect to Hidalgo County Irrigation District No. 2 (San Juan)'s Alamo Main capital rehabilitation project. This report also has an current listing of related reports and applications of RGIDECON©.

6. Project costing is defined here as multiplying the expected quantities of all needed resources (e.g., pipe, gates, excavation work, etc.) by their expected costs, and then summing the sub-totals, as is typically done by engineers as part of design and project-planning work.

7. As mentioned, the analyses used as a basis for extrapolating the investment estimated herein were facilitated by RGIDECON©, a spreadsheet model with data input and calculations based on economic and financial principles consistent with *capital budgeting* (Rister et al. 2002).

8. The 17 project components are grouped by project type, with the individual and aggregate life-cycle costs-of-saving-water ($/ac-ft) also provided. Further, the data/results reflect those projects previously analyzed by TAES/TCE economists, and do not include other projects proposed to the USBR.

9. Note the analysis on Cameron County Irrigation District No. 2 (aka San Benito)'s Rio Grande pumping facility is ignored herein because of uniqueness and its being non-representative of the type of conveyance system improvements captured in Fipps' (2000) estimate.

10. Refer to Rister et al. 2002 for further discussion on annuity equivalents and their application towards the economic and financial costs of water conservation via capital-project rehabilitation.