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Texas Water
Resources Institute
make every drop count

Economic Methodology for South Texas Irrigation Projects – RGIDECON©

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Preface[1]

Recognizing the seriousness of the water crisis in South Texas, Congress enacted Public Law 106-576, entitled "The Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000 (Act)." In that Act, Congress authorized water conservation projects for irrigation districts relying on the Rio Grande River for supply of agricultural irrigation, and municipal and industrial water. Several phases of project planning, development, evaluation, prioritization, financing, and fund appropriation are necessary, however, before these projects may be constructed.

Based on language in the Act, the "Guidelines for Preparing and Reviewing Proposals for Water Conservation and Improvement Projects Under Public Law 016-576 (Guidelines)" require three economic measures as part of the evaluation of proposed projects:

- Number of acre-feet of water saved per dollar of construction costs;
- Number of British Thermal Units (BTUs) of energy saved per dollar of construction costs; and
- Dollars of annual economic savings per dollar of initial construction costs.

South Texas irrigation districts have an extensive system of engineered networks – including 24 major pumping stations and lifts, 800 miles of large water mains and canals, 1,700 miles of pipelines, and 700 miles of laterals that deliver water to agricultural fields and urban areas. Yet, many key components are more than 100 years old, outdated, and in need of repair. Texas Agricultural Experiment Station and Texas Cooperative Extension economists and engineers are collaborating with Rio Grande Basin irrigation district managers, their consulting engineers, the Bureau of Reclamation, and the Texas Water Development Board to perform economic and energy evaluation of the proposed projects.

Proposed capital improvement projects include, among others, (a) meters for monitoring in-system flows and improving management of system operations; (b) lining for open-delivery canals and pipelines to reduce leaks, improve flow rates, and increase head at diversion points; and (c) pumping plant replacement.

The economists have developed a spreadsheet model, Rio Grande Irrigation District Economics (RGIDECON©), to facilitate the analyses. The spreadsheet's calculations are attuned to economic and financial principles consistent with capital budgeting procedures — enabling a comparison of projects with different economic lives. As a result, RGIDECON© is capable of providing valuable information for prioritizing projects in the event of funding limitations. Results of the analyses could be compared with economic values of water to conduct cost-benefit analyses. Methodology is also included in the spreadsheet for appraising the economic costs associated with energy savings. There are energy savings both from pumping less water forthcoming from reducing leaks and from improving the efficiency of pumping plants.

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1 This information is a reproduction of excerpts from a guest column developed by Ed Rister and Ron Lacewell and edited by Rachel Alexander for the first issue of the Rio Grande Basin Initiative newsletter published in *Rio Grande Basin Initiative Outcomes, 1*(1) (Rister and Lacewell).

The economic water and energy savings analyses provide estimates of the economic costs per acre-foot of water savings and per BTU (kwh) of energy savings associated with one proposed capital improvement activity (referred to as a component). An aggregate assessment is also supplied when two or more activities (i.e., components) comprise a proposed capital improvement project for a single irrigation district. The RGIDECON© model also accommodates "what if" analyses for irrigation districts interested in evaluating additional, non-Act authorized capital improvement investments in their water delivery infrastructure.

The data required for analyzing the proposed capital improvement projects are assimilated from several sources. Extensive interactions with irrigation district managers and engineers are being used in combination with the Rio Grande Regional Water Planning Group Region M report and other studies to identify the information required for the economic investigations.

The RGIDECON© model applications will provide the basis for Texas Water Resources Institute reports documenting economic analysis of each authorized irrigation district project. An executive summary of the economic analysis of each authorized project will be provided to the irrigation districts for inclusion in their project report. The project reports will be submitted to the Bureau of Reclamation for evaluation prior to being approved for funding appropriations from Congress. The Bureau of Reclamation, in a letter dated July 24, 2002 (Walkoviak), indicated that RGIDECON© satisfies the legislation authorizing projects and that the Bureau will use the results for economic and energy evaluation.

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Acknowledgments

Many individuals have contributed to the methodology developed for the Rio Grande Basin Irrigation District economic analyses as described herein. We gratefully acknowledge and appreciate the input and assistance of the following:

- ***Wayne Halbert, George Carpenter, Sonia Kaniger, Bill Friend, Rick Smith, and Edd Fifer.*** These irrigation district managers have been and are a continual source of information, support, and inspiration as we work to develop an accurate, consistent, logical, efficient, and practical analytical approach for these investigations;

- ***Al Blair and Larry Smith.*** These private consulting engineers have substantiated and extended the insights of the irrigation district managers, thereby strengthening the rigor of our methodology and enhancing the integrity of the data;

- ***Guy Fipps and Eric Leigh.*** These agricultural engineers and our colleagues in the Department of Biological and Agricultural Engineering at Texas A&M University and in the Texas Cooperative Extension have provided an extensive amount of background information, contacts, and wisdom;

- ***Jose Amador and Ari Michelsen.*** These Resident Directors of the Agricultural Research and Extension Centers at Weslaco and El Paso, respectively, have been very supportive in identifying contacts, alerting us to critical issues, and arranging meetings, among other collaboration efforts;

- ***Bob Hamilton and Randy Christopherson.*** These economists affiliated with the Bureau of Reclamation have served as reviewers of our methodology. They have also identified appropriate means of satisfying the data requirements specified in the legislative-mandated Bureau of Reclamation Guidelines for Public Law 106-576 authorizing the projects being analyzed while also assuring principles of economics and finance are met;

- ***Ron Griffin.*** A Resource Economist in the Department of Agricultural Economics at Texas A&M University, Ron has provided insights regarding relevant resource issues, methods for appraising capital water-related projects, and observations on Texas water issues in general;

- ***John Penson and Danny Klinefelter.*** These agricultural economists specializing in finance in the Department of Agricultural Economics at Texas A&M University have served as mentors through our development of the methodology. They have been an excellent sounding board, reacting to an assortment of questions, ideas, and innovative applications of finance methods;

- ***Larry Walkoviak, Rick Clark, Mike Irlbeck, Thomas Michalewicz, and James Allard.*** These individuals are all affiliated with the Bureau of Reclamation in various management roles. They have been instrumental in fostering a collaborative environment in which the several agencies involved in this effort can mutually fulfill their varied responsibilities and conduct the related activities. They have taken the lead in bringing the Texas Water Development Board into planning and facilitating cooperation across State and Federal agencies;

- ***Danny Fox, Debbie Helstrom, Jeff Walker, and Nick Palacios.*** These engineers with the Texas Water Development Board (TWDB) have provided valuable feedback on the methodology and data as well as insights on accommodating the requirements imposed by the TWDB on the irrigation districts in association with their receipt and use of State Energy Conservation Office (SECO) funding for the development of their project proposals;

- ***Allan Jones and B. L. Harris.*** As the Director and Executive Director of the Texas Water Resources Institute, they provide leadership and oversight for the Rio Grande Basin Initiative funded through a grant from Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture;

- ***Michael Popp.*** An undergraduate in the Department of Agricultural Economics at Texas A&M University, Michael provided a critical review and several insightful, thought-provoking comments while reviewing a preliminary version of RGIDECON©;

- ***Jason Morris.*** A Student Technician in the Department of Agricultural Economics at Texas A&M University, Jason has provided daily support in the form of computer hardware and software assistance, Internet-based data searches, and other bolstering activities; and

- ***Michele Zinn.*** She is the glue that binds it all together! An Administrative Assistant in the Department of Agricultural Economics and in the Texas Agricultural Experiment Station at Texas A&M University, Michele assists in coordinating daily activities and travel, and provides editorial assistance during manuscript preparation.

Thanks to each and every individual noted above. Nonetheless, we, the authors of this manuscript, accept all responsibilities for any errors, omissions, and/or other oversights that are present in the manuscript and/or the economic spreadsheet model, RGIDECON©.

MER
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Economic Methodology for South Texas Irrigation Projects – RGIDECON©

Abstract

A mathematical discourse is provided, documenting the economic and financial methods used in RGIDECON©, an Excel spreadsheet capital investment evaluation model focused on irrigation district-level pumping and delivery systems. These methods and the spreadsheet are the basis for ascertaining several measures of performance for the capital improvement investments proposed by irrigation districts relying on the Rio Grande River for their supplies of agricultural irrigation, municipal, and industrial water. Both the approach developed by Texas Agricultural Experiment Station and Texas Cooperative Extension agricultural economists and the procedures used to calculate the required indicators mandated in Public Law 106-576 are presented. Attention is also directed to the process of selecting the discount rate to be used in the financial methods as well as toward the sources and protocol for identifying data to be used in the analyses for individual irrigation districts' proposed projects.

Economic Methodology for South Texas Irrigation Projects – RGIDECON©

Introduction

The following discussion pertains to assessment of the economic costs associated with projected water and energy savings forthcoming from capital improvement projects proposed by irrigation districts relying on the Rio Grande River for their supplies of agricultural irrigation and municipal and industrial water. The methods identified and discussed are those integrated into RGIDECON©, an Excel spreadsheet template developed by Texas Agricultural Experiment Station and Texas Cooperative Extension agricultural economists working with the Texas Water Resources Institute. Attention is accorded in these calculations to economic and financial principles consistent with capital budgeting procedures for evaluating projects of different economic lives (Barry et al.; Jones; Levy and Sarnat; Nelson et al.; Penson and Lins; Quirin; Robison and Barry; Smith 1987). That is, the analysis includes, but also goes beyond the Bureau of Reclamation's (Reclamation) announced Guidelines for this initiative, providing valuable information for implementing a method(s) of prioritization of projects. Such prioritization will be conducted under direction of the Bureau of Reclamation in a cooperative effort.

The methodology discussed herein and the RGIDECON© spreadsheet have been reviewed by several different individuals, representing an assorted array of different agencies, professions, and university subject-matter areas. The Bureau of Reclamation, in a letter dated July 24, 2002 (Walkoviak), indicated that RGIDECON© satisfies the legislation authorizing projects and that the Bureau will use the results for economic and energy evaluations (see Appendix).

Methodology similar to that presented here for water savings also is included in the spreadsheet for appraising the economic costs associated with energy savings (both on a BTU and kwh basis). That is, there are energy savings both from pumping less water forthcoming from reducing leaks and improving overall system efficiency and from improving the efficiency of pumping plants. A note on differences between the two approaches (i.e., calculating economic costs of water savings versus those of energy savings) is incorporated. Additional materials detailing the calculations used in identifying the measures required in the Bureau of Reclamation's announced Guidelines for this initiative are also presented.

The analysis stops short of performing a full cost-benefit analysis. Results of this analysis can be used, however, in comparisons to economic values of water to provide for implications of a cost-benefit analysis.

Objectives

There are three principal objectives to be met by the methodologies employed within the RGIDECON© spreadsheet:

- Assess the economic costs per acre-foot (ac-ft) of water savings and per BTU (kwh) of energy savings associated with one proposed capital improvement activity (referred to as a **component**) in the water delivery infrastructure of a single irrigation district relying on the Rio Grande River for its supply of agricultural irrigation, municipal, and industrial water;
- Aggregate the assessments of two or more components comprising a proposed capital improvement **project** for a single irrigation district relying on the Rio Grande River for its supply of agricultural irrigation and municipal and industrial water, thereby facilitating comparisons of proposed capital improvement projects across two or more irrigation districts; and
- Accommodate "what if" analyses for irrigation districts interested in evaluating additional, non-Act authorized capital improvement investments in their water delivery infrastructure.

Types of Capital Improvements Investments

Based on discussions with managers of three irrigation districts related to their proposed investments (Halbert, Carpenter, Kaniger), potential proposed capital improvement investments include, but are not limited to, the following:

a. Meters (for monitoring in-system flows) – one-year installation period plus 15 years productive period;

b. Lining of existing open-delivery canals – two-year installation period plus 30 years productive period;

c. Pipeline replacing open-delivery canal – two-year installation period plus 50 years productive period; and

d. Pumping plant replacement – installation period and productive period terms undefined at this time.

Additional types of capital improvement investments will be identified during subsequent investigations of irrigation districts' projects (e.g., Friend, R. Smith, Fifer).

Economic Costs Calculations for a Single Component

Four major components comprise the general cost calculations embodied in the economic and financial methodology used in evaluating Rio Grande Basin Irrigation Districts' proposed capital investments.:

(1) initial capital investment costs;

(2) changes in operating and maintenance costs;

(3) changes in energy costs; and

(4) salvage value of the capital investment at the end of its useful life.

For a single, mutually-exclusive, independent component (x) of a capital improvement project (P) over its (i.e., the component's) defined economic-planning period (Z), these general components may be used to calculate a net present value of economic costs as follows:

$$EC_{NPV}^{x,Z,P} = \sum_{j=0}^{Y^{x,P}} \left\langle \left\{ \left[I_j^{x,Z,P} * \left(1 + i_1\right)^j \right] \right\} \div \left\{ \left(1 + r\right)^j \right\} \right\rangle$$
$$+ \sum_{t=Y^{x,P}+1}^{N^{x,P}+Y^{x,P}} \left\langle \left\{ \left[\left(IOC_t^{x,Z,P} - DOC_t^{x,Z,P} \right) * \left(1 + i_1\right)^t \right] - \left[DEC_t^{x,Z,P} * \left(1 + i_2\right)^t \right] \right\} \div \left\{ \left(\left(1 + r\right)^t \right\} \right\rangle$$
$$- \left\langle \left\{ SV^{x,Z,P} \right\} \div \left\{ \left(1 + r\right)^Z \right\} \right\rangle,$$

where the elements are as defined in Table 1.

Calculation of NPV of Water Savings for a Single Investment Component

The economic and financial methodology used to measure the water savings associated with one component (x) of a capital improvement project (P) over its (i.e., the component's) defined economic-planning period (Z) is as follows:

$$WS_{NPV}^{x,Z,P} = \sum_{t=Y+1}^{N+Y} \left\langle \left\{ WS_t^{x,Z,P} \right\} \div \left\{ \left(1 + s\right)^t \right\} \right\rangle,$$

where the elements are as identified in Tables 1 and 2.

Calculation of NPV of Economic Costs per Acre-Foot of Water Savings for One Replacement Period

The above two measures (i.e., NPV of net economic costs and NPV of annual water savings) are reduced to a single measure by simply dividing the net present value of economic costs for a capital improvement component by the net present value of the water savings associated with that component over the time period comprised of installation and its productive use:

$$ECAF_{NPV}^{x,Z,P} = EC_{NPV}^{x,Z,P} \div WS_{NPV}^{x,Z,P}.$$

The interpretation of $ECAF_{NPV}^{x,Z,P}$ is that it is the current net economic cost for one ac-ft of water savings forthcoming from investment component x of project P which spans across a total time period of Z years, including both the installation period Y and productive period N.

Calculation of Annuity Equivalents of Economic Costs per Acre-Foot of Water Savings

The ability to compare the estimated costs per ac-ft of water savings across components having different economic lives is essential. Thus, the previous measure is converted to an annuity equivalent, assuming constant technology prevails into perpetuity along with a $0 salvage value of the capital improvement existing at the end of each replacement period. The essential elements of this calculation include the accounting for the annual stream of dollars necessary to maintain the annual water savings into perpetuity. The appropriate calculation to determine such an annuity equivalent is:

$$AEECAF_{AE}^{x,Z,P} = \left\| ECAF_{NPV}^{x,Z,P} \div \left\langle \left\{ 1 - \left(1 + r\right)^{Z} \right\} \div \left\{ r \right\} \right\rangle \right\| \div \left\| WS_{NPV}^{x,Z,P} \div \left\langle \left\{ 1 - \left(1 + s\right)^{Z} \right\} \div \left\{ s \right\} \right\rangle \right\|.$$

At first glance, the above expression may appear to be reducible to the same as that used to calculate $ECAF_{NPV}^{x,Z,P}$ by canceling the annuity equivalent operands. This is not the case, however, since r (6.125%) is the discount factor in the economic costs calculations while s (4.000%) is the discount factor applicable to the water savings; refer to the subsequent "Choice of Discount Rates" section for an explanation of why these two discount rates are different in this methodology. The interpretation of $AEECAF_{AE}^{x,Z,P}$ is that it represents the costs per year in current dollars of saving one ac-ft of water each year into perpetuity through a continual replacement series of component x of project P with all of the attributes previously indicated.

Aggregation of Multiple Components into a Composite Assessment for a Single Project

One single economic measure is desired to represent the overall performance of a project which may consist of more than one component. Such a measure must account for the differences in installation periods and productive periods across the different components and the related magnitudes of the capital investments and the associated forthcoming water savings. To that purpose, an aggregate annuity equivalent is calculated as follows:

$$AAE_{AG}^{P} = \left\langle \sum_{x=1}^{X_p} \left\{ AEECAF_{AE}^{x,Z,P} * Wt^{x,Z,P} \right\} \div \left\{ \sum_{x=1}^{X_p} Wt^{x,Z,P} \right\} \right\rangle,$$

where the elements are as identified in Table 3. This aggregated measure (i.e., AAE_{AG}^{P}) reflects a composite assessment of the costs per year (in current dollars) of saving one ac-ft of water achieved into perpetuity through continual replacement series of the multiple components comprising project P.

The desired attributes of the weights $Wt^{x,Z,P}$ are somewhat ambiguous (Penson) and open to interpretation. Consequently, three alternative sets of weights and resulting aggregate measures were utilized initially to allow for evaluation of the consistency / inconsistency of results, thereby facilitating greater robustness in the final evaluation process:

1) the respective $AEECAF_{AE}^{x,Z,P}$ for each component x are considered to be additive and divisible; thus, the measures are simply added using a weight of 1 for each component and the resulting sum is divided by the number of components comprising the total project P to calculate the aggregate measure, i.e., a simple average;

2) there is interest in emphasizing the relative magnitude of capital investment associated with the individual components; thus, the net present value of the initial investment stream is calculated for component x of project P and converted

into an annuity equivalent with the result serving as the respective $Wt^{x,Z,P}$ for each component x comprising project P:

$$Wt^{x,Z,P} = \left\| \sum_{j=0}^{Y} \left\langle \left\{ \left[I_j * (1+r)^j \right] \right\} \right\rangle \right\| \div \left\langle \left\{ 1 - (1+r)^Z \right\} \div \{r\} \right\rangle; and$$

3) there is interest in emphasizing the relative magnitude of water (or energy) savings associated with the individual components of project P; thus, the net present value of water (or energy) savings over component x's economic-planning period Z (i.e., $WS_{NPV}^{x,z,P}$) is converted into an annuity equivalent with the result serving as the respective $Wt^{x,Z,P}$ for each component comprising project P:

$$Wt^{x,Z,P} = WS_{NPV}^{x,Z,P} \div \left\langle \left\{ 1 - (1+s)^Z \right\} \div \{s\} \right\rangle.$$

Further experimentation during the development of these measures indicates, however, that the latter approach (i.e., #3) of weighting the individual components' annuity equivalents is consistent with a mathematically-consistent weighting scheme (Griffin), yielding the same value as realized when the $EC^{x,Z,P}{}_{NPV}$ and $WS_{NPV}^{x,Z,P}$ are individually summed and then divided, i.e., the same as

$$AAE_{AG}^{P} = \left\langle \sum_{x=1}^{X_p} EC_{NPV}^{x,Z,P} \right\rangle \div \left\langle \sum_{x=1}^{X_p} WS_{NPV}^{x,Z,P} \right\rangle.$$

Differences in Costs per Energy Unit Saved Calculations

There are interests in identifying mutually-exclusive estimates of the costs per unit of (a) water saved and (b) energy saved for the respective projects and their component(s). "Mutually-exclusive" refers to each respective estimate being calculated independent of the other. The measures are not intended to be additive nor used in any other means of composite measure – they are single measures representing different perspectives of the proposed projects and their component(s).

The process detailed above for calculating the costs per ac-ft of water saved is followed to a major extent when determining the costs per BTU (and kwh) of energy saved, with notable exceptions. In the prior equations documenting the cost of water savings calculations, a credit (i.e., reduction in costs) is allowed for the cost of saved energy. For the calculation of the cost of energy savings, the credit for saved energy is eliminated and, further, no credit is granted for the cost of water saved. Disallowance of any credit for water savings is assumed in recognition of (a) the incomplete cost-benefit nature of these analyses and (b) the potential broad range of possible values of water savings, depending on the assumed end use, e.g., agriculture, municipal, or industry.

Sensitivity Analyses

The previous discussion implicitly infers that all data are known with certainty and that the resulting calculated values are known with certainty, i.e., there are no risks associated with any of the water and/or energy saving realizations, with the capital cost estimates, or with the annual changes in operating and maintenance expenses. Clearly, seldom will current analyses unfold over time in a mirror image to the assumptions embedded in those analyses, no matter how detailed and extensive the process used to develop those estimates. While stopping well short of complete stochastic analyses of the several parameters contributing to the overall economics of the proposed projects, several sets of "what-if," two-way data tables (Walkenbach) are presented in the RGIDECON© spreadsheet sections for individual components of the respective proposed projects. These data tables provide a quick, but meaningful, perspective of the effects of changes in outcomes of selected pairs of parameters, while assuming all other parameters' values remain at the levels used in the base analysis.

The following sets of "what-if," two-way data tables constitute RGIDECON©'s sensitivity analyses of each project component:

- Net costs per ac-ft of water saved –
  - % reduction in Rio Grande diversions (i.e., water conserved) and expected useful life of the investment;
  - % reduction in Rio Grande diversions (i.e., water conserved) and initial capital investment cost;
  - % reduction in Rio Grande diversions (i.e., water conserved) and value of BTU savings (i.e., per unit cost of energy);
- Net costs per BTU and kwh of energy saved –
  - amount of energy expended per ac-ft of water saved and expected useful life of the investment;
  - amount of energy expended per ac-ft of water saved and initial capital investment cost; and
  - amount of energy expended per ac-ft of water saved and % reduction in Rio Grande diversions.

For each set of parameters considered in the sensitivity analyses, the benchmark level assumed in the base analysis is included plus several (i.e., 6-9) more values from the range of plausible possibilities[2] should the benchmark level not occur. The results are presented in tabular form. The tables are valuable in illustrating magnitudes of change in results associated with changes in basic parameters. Such results provide insight into the stability of analysis estimates and can be used by irrigation districts in evaluating alternatives for their district.

Choice of Discount Rates

The discount rate used for calculating net present values of the different cost streams represents a firm's required rate of return on capital or, as sometimes expressed, an opportunity cost on its capital. The discount rate is generally considered to contain three components: a risk-

[2] Such plausible ranges are determined in the course of dialogue between the economics analysis team and Irrigation District managers and engineers during the course of the data assimilation process.

free component for time preference, a risk premium, and an inflation premium[3] (Rister et al. 1999). The relationship between these three components is considered multiplicative (Leatham; Hamilton), i.e., the overall discount rate is determined by:

$$r = [(1 + s) * (1 + h) * (1 + i)] - 1.00,$$

where the terms are as identified in Table 4. Table 5 is a summary presentation of the various rates assumed or calculated in association with development of the methodology for evaluating Rio Grande Basin Irrigation Districts' proposed capital investments. Discussion of the basis for those respective rates follows.

One estimate of the r discount rate from the Districts' perspectives would be the cost at which they can borrow money (Hamilton). However, Griffin notes that because of the potential federal funding component of the projects, it could be appropriate to ignore the risk component of the standard discount rate as that is the usual approach for federal projects, i.e., h=0.00 in the equation above. Essentially, a state of perfect knowledge is assumed with respect to the values for all cost parameters and other factors affecting the output measures; that is, the analyses are conducted in a deterministic sense with no variation about the mean estimates considered. Hamilton notes that the Federal discount rate consists of two elements, time value of money and inflation, but that the rate is routinely used as a real rate, ignoring the inflationary component. After considering those views and consulting with Penson and Klinefelter, Texas A&M University agricultural economics specializing in finance, the 2002 Federal discount rate of 6.125% (Christopherson) was adopted for use in discounting all financial streams, i.e., r equals

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3 "Inflation" refers to a general rise in all factor prices. In the research of interest here, however, more attention and concern is directed toward relative increases in nominal prices for certain classes of inputs rather than such general "inflation." Thus, i is used here and in the respective analyses of South Texas irrigation districts' proposed capital renovation projects to represent relative nominal increases in input prices rather than a general increase in all prices.

0.06125 in RGIDECON© analyses conducted for South Texas irrigation districts. It is further assumed that this 6.125% rate will remain constant during the next 50 years.

Recognition of the potential for uneven annual flows of water and energy savings associated with different project components and different projects encourages normalizing such flows through calculation of the net present value of water and energy savings. In the absence of complete cost-benefit analysis and the associated valuation of water savings, it is acknowledged that there is no inflationary influence to be accounted for during the discounting process (Klinefelter), i.e., only the social time value (s) should be recognized in the discounting process. Accordingly, a lower rate than the 6.125% 2002 Federal discount rate is desired. Consultations with Griffin and Klinefelter contributed to adoption of the 4.000% rate used by Griffin and Chowdhury for the value of s in these analyses.

Using the equation noted above and assuming (a) r equals 0.06125, (b) h equals 0.00, and (c) s equals 0.04, the value of i can be solved algebraically – it equals 0.02043269 in this case,[4] i.e., annual increase in relative nominal prices is slightly above 2%. This rate was used to inflate 2002 nominal dollar cost estimates forward for years in the planning period beyond 2002. Rationale for assuming this rate is based both on the mathematical relationship presented above and analyses of several pertinent price index series and discussions with selected professionals.

In regard to "construction, operation, and maintenance class of inputs," analysis of 1992-2001 Producer Price Indices indicate a calculated rate of increase in nominal prices for 1992-2001 was 2.0%, and for 1996-2001 it was 1.2% (Tables 6 and 7) (U.S. Bureau of Labor Statistics

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4 Admittedly, excessive precision of accuracy is implied in this assumed value for i. Such accuracy of future projections is not claimed, however, but rather that this precise number is that which satisfies the multiplicative elements of the overall discount rate calculation, assuming the noted values for s and r.

2002a, 2002b).[5] The assumed 2.043269% rate appears reasonable for these types of costs, being somewhat consistent with the historic results and recognizing the competitiveness of Rio Grande Valley contractors (L. Smith, Carpenter).

The same 2.043269% rate is assumed applicable to energy costs. Analyses of ten years (1992-2001) of Producer Price Indices for miscellaneous electrical machinery, equipment, and supplies class of inputs result in a calculated rate of increase in nominal prices for 1992-2001 of 0.2%, and for 1996-2001 it was 0.0% (Table 8) (U.S. Bureau of Labor Statistics 2002c). This apparently low rate of change in nominal prices is re-enforced by discussions with Mjelde who notes the present overcapacity of Texas electric energy production in contrast to the more constraining situations in Western states. As suggested by Griffin, however, such a continued-low, almost non-existent rate is probably an incorrect assumption for the length of planning periods associated with the project components being investigated in the Rio Grande Basin at this time. Thus, the decision was made to use the same, slightly-higher rate applied to construction, operation, and maintenance repair costs of 2.043269%.

Methodology for Measures Desired by P.L. 106-576

Relying on language in the Act, the economic measures stated as required in the Act for the Rio Grande Basin Initiative are limited to three (p. 5):

1. Number of ac-ft of water saved per dollar of construction costs;
2. Number of BTUs of energy saved per dollar of construction costs; and
3. Dollars of annual economic savings per dollar of initial construction costs.

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5 Data also was retrieved and analyzed for the category "Inputs to Construction Industries" (Table 2). The results were identical, indicating similar data constitute these two categories in the Burea of Labor Statistics database.

Discussions with Bob Hamilton of the Denver Bureau of Reclamation office on April 9, 2002 indicated these measures are more typically stated in an inverse mode, i.e.,

1. Dollars of construction cost per ac-ft of water saved;
2. Dollars of construction cost per BTU (and kwh) of energy saved; and
3. Dollars of construction costs per dollar of annual economic savings.

This convention is adopted and used in the RGIDECON© model section reporting the measures designated in the P.L. 106-576 legislation.

The Guidelines do not specify the methods to be used in calculating these measures. Consistent with the approach used in the calculations previously outlined, the following protocol is followed in determining the respective components of these three measures:

- "Construction costs" are interpreted to include only the initial capital construction expenditures, i.e., subsequent operating and maintenance costs are excluded;[6]
- Construction costs accruing during the installation period are first compounded forward from current estimates to account for increases in nominal prices over time and then discounted and summed to a net present value on day one of the investment horizon;
- Annual water savings are summed after discounting the values for the individual years to the present;
- Annual energy savings are based on a three-step process: (1) current estimates of per unit energy costs are first compounded forward to account for increases in nominal prices over time; (2) such compounded, per-unit energy costs are next multiplied by the average amount of energy used per ac-ft of pumped water; and (3) all such projected savings are then discounted and summed to a net present value on day one of the decision;
- Energy-related values are calculated and reported on a per BTU basis; in addition, kwh values are calculated and reported, assuming 3,412 BTUs per kwh (Infoplease.com);

[6] Planning costs are also excluded from the economic and financial assessment of proposed projects' potential per Bureau of Economic convention for project analysis (Hamilton).

- "Economic savings" are determined to consist of the net marginal changes in operating and maintenance expenses associated with the proposed project components (i.e., sum of increases in annual operating and maintenance expenses, decreases in annual operating and maintenance expenses, and decreases in energy pumping expenses associated with less water being pumped and less energy to pump an ac-ft of water attributable to improved efficiency of pumping plants); such annual values are first compounded forward from current estimates to represent future costs, these compounded costs are then discounted back to the initial day of the investment horizon, and then all such discounted costs are summed to arrive at a net present value for component x of project P; and
- Aggregate project measures are developed using the amount of initial investment as the weighting method.

Data Assimilation Process

The data required for analyzing irrigation districts' proposed capital improvement projects are assimilated from several sources. Anticipated water savings are predicated on five-year (1997-2001) water usage levels identified in the Rio Grande Regional Water Planning Group Region M report[7], from the Rio Grande Watermaster's office (Rubinstein; Mejia), and irrigation district managers. Project-specific water savings are based on documented studies (Fipps), consultations with engineers (e.g., Blair; Fipps, Helstrom; L. Smith), and irrigation district managers (e.g., Carpenter, Friend, Halbert, Kaniger, R. Smith). Associated energy savings are linked to estimated water savings and per unit average costs of energy identified by the respective irrigation district managers (e.g., Carpenter, Friend, Halbert, Kaniger, R. Smith). Construction costs for individual projects and potential net changes in operating and maintenance costs are obtained via discussions with the respective irrigation district managers (e.g., Carpenter,

[7] For irrigation districts where irrigation has been impacted by allocation restriction(s), a more lengthy time series of water use is to be used to quantify representative water use.

Friend, Halbert, Kaniger, R. Smith), their consulting engineers (e.g., Blair, L. Smith, Allard), and Helstrom of the Texas Water Development Board.

Summary

Methods consistent with economics and finance theory are incorporated into an Excel spreadsheet, RGIDECON©, to facilitate capital investment budgeting analyses. The methods assure recognition of the social time value of money (and other resources), accounting for differences in assets' useful lives, and ability to integrate analyses of individual project components into one comprehensive project assessment. Cost projections are adjusted annually to account for nominal increases in prices. Discount rates include terms for both social time value and increases in relative nominal input prices, but ignore risk. Potential performance of proposed projects and their respective component(s) are measured in terms of costs of water and energy savings.

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TABLES

Table 1. Elements of Economic Costs Calculations, Economic Methodology for South Texas Irrigation Projects, October 2002.

Element	Definition
$EC_{NPV}^{x,Z,P}$	net present value of net economic costs for capital improvement component x of project P over the single economic-planning period Z
x	one component of a total project being evaluated; x may equal 1, 2, ..., 5 in RGIDECON©, with some irrigation districts' projects consisting of only one component while other irrigation districts' projects may include two or more components up to a maximum of five; such project components are considered to be independent; in the case of interdependent (i.e., complementary) activities, they are treated as one integrated component
Z	total economic-planning period for a one-time purchase and implementation of this component; is equal to the installation period (Y years) plus the length of the productive period (N years)
$I_j^{x,Z,P}$	initial capital investment costs occurring during year j of the installation period for capital improvement component x of project P over the single economic-planning period Z
$Y^{x,P}$	length of installation period (years) for capital improvement component x of project P
$N^{x,P}$	length of productive period (years) for capital improvement component x of project P
r	the discount rate (%) used to transform future cash flows into a 2002 dollar standard
i_1	compounding rate applicable to construction, operation, and maintenance class of inputs
$IOC_t^{x,Z,P}$	expected increase in operating and maintenance costs during year t of productive period N for capital improvement component x of project P over the single economic-planning period Z
$DOC_t^{x,Z,P}$	expected decrease in operating and maintenance costs during year t of productive period N for capital improvement component x of project P over the single economic-planning period Z
$DEC_t^{x,Z,P}$	expected decrease in energy costs resulting from less water being pumped and/or less energy to pump an ac-ft attributable to improved efficiency of pumping plants during year t of productive period N for capital improvement component x of project P over the single economic-planning period Z
i_2	compounding rate applicable to energy costs
$SV^{x,Z,P}$	salvage value of capital improvement component x of project P at end of year Z; assumed to be \$0 in all cases

Table 2. Elements of Calculations of NPV of Water Savings for a Single Investment Component, Economic Methodology for South Texas Irrigation Projects, October 2002.

Element	Definition
$WS_{NPV}^{x,Z,P}$	net present value of annual water savings for capital improvement component x of project P over the single economic-planning period Z
$WS_{t}^{x,Z,P}$	annual water savings (ac-ft) in year t for capital improvement component x of project P over the single economic-planning period Z
s	social time value discount rate (%)

Table 3. Elements of Calculations of Aggregation of Multiple Components into a Composite Assessment for a Single Project, Economic Methodology for South Texas Irrigation Projects, October 2002.

Element	Definition
AAE_{AG}^{P}	aggregated annuity equivalent of economic costs per ac-ft of water saved for project P for a single irrigation district
$Wt^{x,Z,P}$	the weight applied to the annuity equivalent for component x with an economic-planning period Z comprising one part of the total project P
X_P	the number of components comprising the total project P

Table 4. Terms Embodied in Discount Rate Calculations, Economic Methodology for South Texas Irrigation Projects, October 2002.

Element	Definition
r	comprehensive discount rate
s	rate representing social time value
h	rate representing risk (a.k.a. hazard for illustration here)
i	rate representing inflation, or as noted previously, relative nominal increases in prices for selected classes of inputs

Table 5. Interest Discount and Compound Rates, Economic Methodology for South Texas Irrigation Projects, October 2002.

Rate	Assumed Value
r	6.125%
s	4.000%
h	0.000%
i_1	2.043269%
i_2	2.043269%

Table 6. Producer Price Industry Data and Analyses Thereof, Inputs to Construction Industries, 1992-2002.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Calculated Annual Change
1992	115.0	115.9	116.4	116.6	116.8	116.8	116.7	116.8	117.3	117.2	117.4	117.9	116.7	
1993	119.0	120.5	121.8	122.2	121.6	121.1	120.9	121.1	121.8	122.0	122.5	122.8	121.4	104.0%
1994	123.6	123.7	124.0	123.8	123.9	124.7	124.8	125.4	125.8	126.0	126.8	126.9	125.0	103.0%
1995	127.6	127.9	128.6	129.1	129.3	129.2	129.5	129.7	130.0	129.6	129.2	129.2	129.1	103.3%
1996	129.4	129.4	129.8	130.3	131.3	131.5	131.2	131.6	132.3	132.0	132.6	132.5	131.2	101.6%
1997	132.9	133.4	133.6	134.0	134.3	134.2	134.2	134.2	134.1	133.7	133.8	133.5	133.8	102.0%
1998	133.2	133.3	133.3	133.6	133.6	133.5	133.8	133.9	133.8	133.5	133.3	133.1	133.5	99.8%
1999	133.6	133.9	134.5	135.1	135.7	136.6	137.5	137.7	137.2	136.6	136.9	137.3	136.1	101.9%
2000	138.0	138.7	139.4	139.3	138.9	139.5	139.1	138.7	139.2	139.0	138.8	138.5	138.9	102.1%
2001	138.6	139.0	138.8	139.2	140.6	140.6	139.5	139.5	139.7	138.4	137.9	137.3	139.1	100.1%
1992-2001 Average														**102.0%**
1996-2001 Average														**101.2%**

Source: U.S. Bureau of Labor Statistics, Inputs to Construction Industries, Producer Price Index Industry Data. Washington, DC.

http://data.bls.gov/labjava/outside.jsp?survey=pc Date retrieved: May 23, 2002a.

Table 7. Producer Price Industry Data and Analyses Thereof, Maintenance and Repair Construction, 1992-2002.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Calculated Annual Change
1992	115.0	115.9	116.4	116.6	116.8	116.8	116.7	116.8	117.3	117.2	117.4	117.9	116.7	
1993	119.0	120.5	121.8	122.2	121.6	121.1	120.9	121.1	121.8	122.0	122.5	122.8	121.4	104.0%
1994	123.6	123.7	124.0	123.8	123.9	124.7	124.8	125.4	125.8	126.0	126.8	126.9	125.0	103.0%
1995	127.6	127.9	128.6	129.1	129.3	129.2	129.5	129.7	130.0	129.6	129.2	129.2	129.1	103.3%
1996	129.4	129.4	129.8	130.3	131.3	131.5	131.2	131.6	132.3	132.0	132.6	132.5	131.2	101.6%
1997	132.9	133.4	133.6	134.0	134.3	134.2	134.2	134.2	134.1	133.7	133.8	133.5	133.8	102.0%
1998	133.2	133.3	133.3	133.6	133.6	133.5	133.8	133.9	133.8	133.5	133.3	133.1	133.5	99.8%
1999	133.6	133.9	134.5	135.1	135.7	136.6	137.5	137.7	137.2	136.6	136.9	137.3	136.1	101.9%
2000	138.0	138.7	139.4	139.3	138.9	139.5	139.1	138.7	139.2	139.0	138.8	138.5	138.9	102.1%
2001	138.6	139.0	138.8	139.2	140.6	140.6	139.5	139.5	139.7	138.4	137.9	137.3	139.1	100.1%
1992-2001 Average														**102.0%**
1996-2001 Average														**101.2%**

Source: U.S. Bureau of Labor Statistics, Maintenance and Repair Construction, Producer Price Index Industry Data. Washington, DC.

http://data.bls.gov/labjava/outside.jsp?survey=pc Date retrieved: May 23, 2002b.

Table 8. Producer Price Industry Data and Analyses Thereof, Miscellaneous Electrical Machinery, and Supplies, 1992-2002.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Calculated Annual Change
1992	110.7	110.8	110.8	111.1	110.7	110.7	110.8	111.1	111.2	111.3	111.0	110.7	110.9	
1993	110.8	110.6	110.6	110.6	110.4	110.4	110.2	110.2	110.1	110.2	110.5	110.3	110.4	99.5%
1994	110.4	110.2	110.5	110.1	110.7	110.4	110.6	111.1	111.2	111.3	111.0	111.1	110.7	100.3%
1995	111.4	111.8	111.7	111.5	111.9	112.0	112.0	111.9	112.1	112.1	112.2	112.3	111.9	101.1%
1996	112.6	112.8	112.8	112.9	112.9	112.8	112.9	112.8	112.8	112.4	112.8	112.8	112.8	100.8%
1997	112.8	113.1	113.0	113.1	113.0	113.1	113.0	113.0	113.0	112.9	112.8	112.8	113.0	100.2%
1998	112.6	112.4	112.4	112.1	112.3	112.3	112.2	112.3	112.2	112.4	112.7	112.6	112.4	99.5%
1999	112.6	112.9	112.8	112.7	112.6	112.6	112.3	112.5	112.5	112.2	112.4	112.5	112.5	100.1%
2000	112.7	112.7	112.8	112.8	112.9	112.8	112.0	111.9	111.8	112.0	112.0	112.4	112.4	99.9%
2001	112.5	112.8	113.1	112.7	112.7	112.9	113.2	113.2	113.2	113.2	113.4	113.4	113.0	100.5%
1992-2001 Average														**100.2%**
1996-2001 Average														**100.0%**

Source: U.S. Bureau of Labor Statistics, Miscellaneous electrical machinery, equipment, and supplies, Producer Price Index Industry Data.

Washington, DC. http://data.bls.gov/servlet/ SurveyOutputServlet?jrunsessionid=1023467123749199073 Date retrieved: June 7, 2002c.

APPENDIX

United States Department of the Interior
BUREAU OF RECLAMATION
Great Plains Region
OKLAHOMA - TEXAS AREA OFFICE
300 E. 8th Street, Suite G-169
Austin, Texas 78701-3225

IN REPLY
REFER TO:
TX-Clark
PRJ-8.00

JUL 24 2002

Dr. Ron Lacewell
Department of Agricultural Economics
Texas A&M University
College Station, TX 77843-2124

Subject: Economic Model for Use in Preparing Proposals for Water Conservation and Improvement Projects Under Public Law 106-576.

Dear Dr. Lacewell:

Having reviewed the formulas, calculations, and logic which support the "Economic Methodology for South Texas Irrigation Projects" (Model) developed by the Department of Agricultural Economics at Texas A&M University (TAMU), the Bureau of Reclamation (Reclamation) concludes that the Model adequately addresses the specific economic criteria contained in the *Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000* (P. L. 106-576). The results of the Model will fully satisfy the economic and conservation analyses required by the Act and it may be used by any irrigation district or other entity seeking to qualify a project for authorization and/or construction funding under P.L. 106-576.

We express our sincere appreciation to you, your colleagues, and to TAMU for this significant contribution to the efforts to improve the water supply in the Lower Rio Grande Valley.

If we may be of further assistance, please call me at (512) 916-5641.

Sincerely,

M L Martin

for Larry Walkoviak
Area Manager

A Century of Water for the West
1902-2002

---- NOTES ----