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ECONOMIC ASPECTS OF COST-SHARING ARRANGEMENTS FOR FEDERAL IRRIGATION PROJECTS: A CASE STUDY

by

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Research Project Technical Completion Report

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ABSTRACT

ECONOMICS OF COST-SHARING ARRANGEMENTS FOR
FEDERAL IRRIGATION PROJECTS: A CASE STUDY

The passage of the Reclamation Act of 1902 marked the beginning of the federal government's activities in planning and constructing irrigation projects. At the inception of the program, the philosophy was that all reclamation project costs should be repaid in full except interest on construction costs. However, early reclamation cost-sharing policy was not successful in that repayments to the government fell short of planned levels. This led to a series of changes in the repayment provisions, culminating with the Reclamation Act of 1939, which completely revised reclamation policy from total repayment of cost to repayment on an "ability to pay" basis as determined by the Bureau of Reclamation. Since that time, charges for Bureau-supplied irrigation water have not been required to reflect the cost of water supply. Consequently, there has been a growing concern with the degree to which reclamation irrigation projects are subsidized and the potential misallocation of public resources. Critics of current policy believe that it is highly unlikely that water users would agree to contract for reclamation projects if they were to bear full irrigation project cost.

The proposed Narrows Unit on the South Platte River in northeastern Colorado has been taken as a case study to test the above contention. A modeling approach, using farm budgeting and linear programming, is employed to measure ability to pay as compared with full cost and the USBR current charging procedures. Due to what the authors judge to be shortcomings in the USBR benefit estimation procedures, an alternative methodology is adopted.

Three cases are evaluated. We estimate average benefits (1976 price levels) accruing with the advent of the Narrows Project to be $44 per acre foot in the

case for which water is delivered to formerly non-irrigated lands. If the water were to supplement supplies on lands formerly inadequately irrigated, the estimated benefit is $32 per acre foot. For the third example, if lands had been adequately irrigated with groundwater, the net benefit would be about $8 per acre foot (equivalent to the cost savings from replacing wells and pumps).

The repayment capacity of the irrigation beneficiaries was computed, on the ability to pay criterion, by the Bureau of Reclamation to be $14.56 per acre foot. However, the expected cost of irrigation water is estimated to be $63.49 per acre foot of water received at farmers' headgates (also in 1976 prices) if water users were to repay all costs allocated to irrigation purposes, including interest at six and one-half percent.

The results show first, that water price charged under the ability to pay criterion reflects only a fraction of true cost. Second, water users could not profitably contract for Bureau-supplied irrigation water if they were to bear full irrigation project costs in any of the three instances studied.

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CHAPTER I

INTRODUCTION

Objective, Scope, Procedure, and Organization of the Study

The purpose of this study is to analyze the effects of cost-sharing and pricing arrangements on the economic feasibility of a typical project planned by the United States Bureau of Reclamation. Toward this end, the cost-sharing procedure practiced by the U.S. Bureau of Reclamation is first reviewed and compared with theoretical prescriptions. Next, a model is developed to estimate the value of supplemental water on a case study. Finally, the economic feasibility of the case study product to potential water users is examined assuming irrigators bear full project cost.

The proposed Narrows Unit in northeastern Colorado is taken as a case study. The Narrows Unit is a plan for development and conservation of water and land resources in the Colorado portion of the South Platte River Basin. It has been planned to serve multiple purposes, namely: supply supplemental irrigation water, provide flood control, increase recreational opportunities, and enhance fish and wildlife resources. This study, however, deals only with the analysis of direct irrigation benefits generated from the use of publicly supplied supplemental irrigation water.

To determine the economic benefits to farmers of Bureau-supplied irrigation water, three alternative "with" and "without" project situations are compared. These analyses were made under the following alternative irrigation methods:

a. Alternative Irrigation Method I: Providing irrigation water to lands formerly used for dryland wheat production.

b. Alternative Irrigation Method II: Providing supplemental irrigation water to lands currently irrigated, but possessing rights to an inadequate supply of surface water.

c. Alternative Irrigation Method III: Providing supplemental irrigation water to inadequately watered irrigated lands whose water supply is supplemented by groundwater.

This study is organized as follows: the remaining part of Chapter I deals first with a brief overall view of irrigation water development and then U.S. historical experience in financing and cost-sharing in reclamation irrigation projects are discussed.

In Chapter II, two alternative pricing methods are examined: 1) the principle of marginal-cost pricing, and 2) the U.S. Bureau of Reclamation pricing procedure. Chapter III describes the case study area and reviews data sources.

In Chapter IV, the value of the supplemental irrigation water supply is analyzed under the three alternative irrigation methods for the "with" and "without" project situations. The benefit estimates are then contrasted to the cost estimates to determine whether water users would find the reclamation project economically acceptable if they were to bear full project cost. Chapter V presents the summary and conclusions.

The Origins of Arid Land Reclamation in the United States

A great part of the western portion of the United States does not get enough moisture to support the desired agricultural production. Heim [1954] asserted, "Without irrigation, the west with the present state of technology could achieve only a low level of agricultural development." A. R. Golze [1961] explains that climate, increasing population, cattle industry, specialized crops, and relative isolation are the main elements that gave rise to the need for irrigation development in this region of the country.

Local private and public irrigation programs were common practice in the arid west before any reclamation program was considered by the federal government.

Irrigation programs were started by individual farmers and small groups of farmers. Later irrigation organizations in the form of cooperative irrigation companies and irrigation districts appeared on the scene. As many as seven of the sixteen western states had irrigation district laws enacted prior to the twentieth century [Huffman, 1953]. As an example, the first irrigation district legislation in the United States was enacted by the territory of Utah in 1865; California enacted irrigation district laws as early as 1887.

Prior to its direct particiaption in land reclamation programs, the federal government contributed much to water resource development. Federal incentives encourage the promotion of private irrigation development. The Homestead Act of 1862 became an effective device in the settlement of public lands. Under this Act, title to public lands was acquired by residence and the payment of merely nominal fees rather than by purchase [Teele, 1927]. The first federal legislation relating to irrigation was the Act of July 26, 1866 (amended after four years). It operated under state jurisdiction, where state rights were given to those who wanted to develop the land [Teele, 1927, pp. 61-62].

Another big step came with the passage of the Desert Land Act of 1877 which, Teele notes, "provided for the procuring of title to 640 acres (later reduced to 320) of arid land by conducting water upon it and the payment of $1.25 per acre." The main idea underlying this Act was to encourage settlers to develop the land. But since these arid lands lacked sufficient moisture for crops, their use for that purpose required development of irrigation water.

Yet another important step in federal aid to reclamation came before the end of the last century. The Carey Act of 1894 was intended to correct weaknesses of the Desert Land Act and provided for making the cost of reclamation a lien on the land. Under this Act, the responsibility to land development was vested in the states which in turn took the initiative to promote irrigation programs by selling land only to those who committed themselves to purchase water rights.

A point which needs to be stressed is that the early policy of the federal government was public acquisition and public distribution of land resources for farmers. Pure and simple, it encouraged settlement and arid land development. But the inability of private capital to finance irrigation programs finally led to the government's direct participation in irrigation reclamation programs.

It was in 1902 that irrigation water programs won public attention at national level. Heim says, "In 1902 after much political maneuvering, Congress passed its first law providing for direct federal participation in the construction and operation of reclamation projects." Since 1902, reclamation programs have developed both in scope and purpose. The focus of attention has shifted from small scale single-purpose to multi-purpose projects. James and Lee [1971] summarize as follows:

> The Bureau of Reclamation of the Department of Interior was established in 1902 to provide irrigation water for the economic development of arid areas. It built a number of small projects with mixed success in its early years and completed the first large-scale water project in the country with the construction of Hoover Dam in 1928. Today, the Bureau of Reclamation builds irrigation projects in the 19 states, including Hawaii and Alaska, west of the line from Texas to North Dakota. It also includes other project purposes and multi-purpose development. (p. 138)

Historical Experience in Financing and Cost-Sharing of Federal Irrigation Projects

Although the passage of the 1902 Reclamation Act came after a bitter congressional battle, it opened a new chapter in the history of irrigation water development in the United States. The underlying objectives for this program were threefold: to settle the vast arid regions of the West, to create new prosperous family farms, and to increase agricultural output for the rapidly growing population of the country.

Prior to the advent of the reclamation program, it was very difficult to secure satisfactory financing for irrigation programs from private capital. Even many large commercial irrigation companies failed in such programs and went bankrupt [Huffman, pp. 72-73]. Hence, it almost became impossible to raise funds for other similar ventures. In fact, it was the inability of private capital to finance irrigation projects coupled with the ever-increasing size of irrigation projects which gave impetus to federal action in promoting irrigation programs. With the passage of the Reclamation Act, the federal government established a reclamation fund for the construction of irrigation projects. Capital for the fund came from the sale of public lands. In return, the beneficiaries of such federally financed irrigation projects were required to sign contracts to repay construction costs in ten annual payments without interest on deferred payments [Teele, pp. 69-70]. Furthermore, annual operation and maintenance costs had to be paid in order that water be delivered.

The idea behind the need for full repayment of construction costs by the water users was to enable the government to maintain a revolving fund in order to promote other new irrigation projects. As Heim [1953] put it, full project cost repayment had two main purposes: first, its adoption would cause direct beneficiaries rather than the government to bear the costs of the irrigation system; and secondly, a repayment provision would offer protection to the Treasury.

But this early cost-sharing policy was not generally successful. Many water users failed to meet their repayment obligations. Several problems are cited by Davis and Hanke [1971, p. 126]. The costs of irrigation projects were often underestimated; so repayment burdens were heavier than originally anticipated. On the other hand, direct benefits from irrigation projects tended to be greatly overoptimistic. Full productivity was typically not achieved for several years after water was supplied and even then, yields were often not up to early projections. Farmers might have lacked experience with irrigation techniques. In any case, the fact remains that farmers experienced little or no returns during the early years of irrigation development. Finally, agricultural commodity prices fell drastically in 1921, and never fully recovered until World War II, nearly twenty years later. In addition to this, farmers were had hit by record high prices of land and suffered large debts in the 1920s [Heady, 1962, p. 27].

The failure of the early reclamation policy led to a number of attempts to change the repayment provisions. The most obvious need was for a lengthening of the repayment period. Consequently, with the passage of the Reclamation Extension Act of 1914, the repayment period was extended to twenty years which changes the repayment schedule. Accordingly, a new recipient of irrigation water had to pay 5 percent of his share of the construction charges at the time of application; the remainder was paid in 15 years, starting on the fifth year at 5 percent for each of the first 5 years and at 7 percent for the last 10 years [Golze, p. 244].

Even the Extension Act of 1914 was not fully successful in improving the financial condition of the water users because their financial position was worsened by the agricultural crisis of the 1920s. On the other hand, due to the ever-increasing construction costs on irrigation projects, the Department of the Interior was urging higher cost-sharing by the farmers. Meanwhile, the cry to relieve farmers from the increasing costs continued; representatives from the west fought strongly for this in the Congress. Finally, it was agreed that a committee be appointed by the Secretary of the Interior to study the whole situation. The recommendation of the Fact Finders Committee gave rise to the passage of the Fact Finders' Act of 1924 [Teele, p. 76]. Under this Act, annual payment of the construction charges per irrigable acre was to be computed at

5 percent of the average gross annual income on an acre basis for a period of ten calendar years. However the Fact Finders' Act also provided an indefinite period for repayment. In order to correct this weakness, the Omnibus Adjustment Act of 1927 was passed and provided a repayment period of forty years.

One of the most significant amendments to the Reclamation Acts came in 1939. This Act drastically revised the reclamation policy from repayment of costs to repayment based on ability-to-pay criterion. This remained the guiding principle of the Bureau of Reclamation pricing system through the 1970s. The 1939 Act states that the farmers' assigned share of the construction cost of irrigation projects must be paid back in a period of forty years with a ten-year grace period before payments had to be made. No provision is made for interest on construction costs. But, in addition to their appropriate share of construction charges, water users also are required to pay their share of the annual operation and maintenance costs which are determined on the basis of the amount of water delivered. Significantly, it also provided that irrigation costs above the water users' ability-to-pay would be repaid through assistance from surplus power and other simultaneous project revenues [U.S. Department of Interior, 1972, pp. x-xiii].

Thus, since 1902, reclamation policy has been amended several times. Repayment principles and procedures have been greatly changed. Until the passage of the 1939 Act, beneficiaries were expected to bear full irrigation project costs without interest on deferred payments, originally in a period of ten years and later within forty years. But, after the charges are completely paid off, water users would retain their land and the water rights became their own property.

As indicated above, the 1939 Act changed the rules of repayment to respond to the unfavorable conditions of the 1920s and 1930s. The concept of full repayment of irrigation costs with no interest was retained in the 1939 Act. But as Davis and Hanke [p. 115] put it, "full repayment by whom" is a very relevant point to consider. It is stated that water users should pay what they are able to pay and the remaining share should be paid back from other sources of revenue. The ability-to-pay of an average farm is determined by an economic analysis on a crop-income basis. The procedure of arriving at the ability-to-pay will be dealt with later. However, it is worth pointing out that the actual price charged is normally only 75 percent of the ability-to-pay, which is assumed to be a further incentive to irrigate [Davis and Hanke, p. 116]. The justification for attempting to reduce the repayment burden of the farmers is that irrigation was considered not only beneficial to the farmers but also to the nation as a whole [U.S. Department of Interior, p. x]. Such being the case, then, it is assumed to be unfair to let local water users bear the burden of projects whose benefits are more than local in scope.

The history of the requirements for repayment by water users reflects the conflicting desires of Congress. Golze (p. 248) asserts the argument reduces to whether a reclamation project should fully repay its costs and secondly, whether the repayment requirement be within the ability of beneficiaries to meet part of their obligation without any sacrifice of a reasonable standard of living. It is true that irrigation development has contributed much to the overall development of the western United States in particular and to the entire nation in general. However, the very fundamental issues of coming up with a generally agreed-upon system of sharing costs remain unsolved, even up to the present day.

CHAPTER II

METHODS OF CHARGING FOR PUBLICLY-SUPPLIED IRRIGATION WATER

In market economies, prices play an important role in determining how much of each commodity or service should be produced and how much should be consumed. Prices act as checks and balances on production and consumption by discouraging the excess consumption of a scarce good or service on the one hand and by inducing suppliers to produce more on the other hand.

The Principle of Marginal-Cost Pricing

Under a purely competitive market structure, prices are determined automatically through the forces of demand and supply. There is no need of government intervention to regulate prices because resources are automatically directed to their most valued uses. However, there are many cases where the market does not work properly [Bator, 1958]. Hence, prices cannot be determined automatically and so it is highly likely that there could be misallocation of resources. If such conditions prevail, then there arises the need for social intervention in determining prices so that resources may be efficiently utilized. Economists have argued that setting prices equal to marginal cost, as occurs in a competitive market system, will yield the most efficient allocation of resources.

Although there is no complete consensus on the practical use of the marginal-cost pricing rule, Davis and Hanke [p. 7-8] say that of all the pricing policies available, it is the most conducive to efficient resource allocation in the public services. The marginal-cost pricing rule states that resources are efficiently allocated when prices are equated to marginal opportunity cost. Failure to value goods and resources in terms of the opportunity cost causes resource misallocation.

Milliman shows the concept of marginal opportunity cost to be of special interest because it reflects the opportunities foregone elsewhere as resources are drawn away from alternative uses. The equality of price and marginal cost insures that rational consumers equate marginal benefits from the use of resources with the real alternatives foregone elsewhere.

The theoretical principle of marginal-cost pricing can be explained using Figure 1 which depicts the consumers demand (marginal benefit) function and the marginal cost of commodity supply, both dependent upon output. As shown in Figure 1, an efficient solution is attained when Oq_0 level of output is produced at OP_0 level of price. To prove this, let us consider the following two cases. First, consider output level which is less than Oq_0. Within the range of output where $q < q_0$, MB > MC for every additional unit of output; hence the rational user will continue expanding his consumption up to the point where MB = MC. Secondly, if more than Oq_0 level of output is produced, each additional unit of output adds more to cost than to benefit. Therefore, since MB < MC, the producer will cut production until MB = MC. When MB = MC, however, the value imputed to goods produced is the opportunity cost of the resources used to produce those goods, so P_0 is the appropriate price to change. Thus, when Oq_0 level of output is produced at OP_0 level of price, resource allocation is efficient. (See Davis and Hanke for a fuller development of the point.)

At this stage, it might be helpful to raise the question of financial and economic efficiency requirements that need to be satisfied. In Figure 1, since, by assumption, the industry is purely competitive, firms will enter (leave) the industry if there is pure profit (pure loss). It follows that the position of the long-run equilibrium will be consistent with "zero" profit or that P = AC as depicted in Figure 1. On the other hand, for a firm to attain its individual equilibrium, P = MC. Therefore, price must be equal to marginal

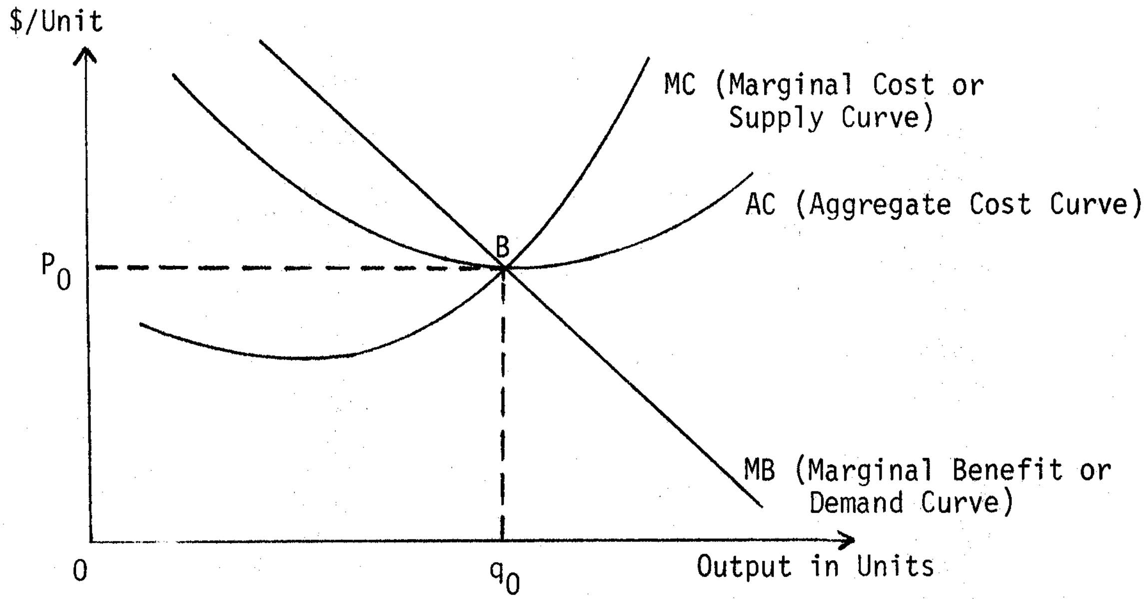

Figure 1. Selection of Price Under Pure Competition.

as well as average total cost. In Figure 1, this condition occurs at point B, where P = MC = AC. Hence, the financial requirement in which revenues cover costs is met when P = AC while economic efficiency requirement is satisfied as P = MC at point B as shown in Figure 1.

However, conditions are not always as simple as has been assumed in the model. One crucial problem regarding the practicality of the marginal-cost pricing rule in which water resource projects are typical examples is the problem of decreasing costs. Under the decreasing cost condition, the perfectly competitive model does not apply. Instead, the industry tends toward a monopoly solution, and the following analysis can be applied.

As already indicated, according to the principle of the marginal-cost pricing, resources are efficiently allocated when P = MC. But under the decreasing cost condition, revenues do not cover costs at the level of output where P = MC. As shown in Figure 2, OP_0 < AC at Oq_0 level of output where the economic efficiency requirement is satisfied. Instead, full cost is

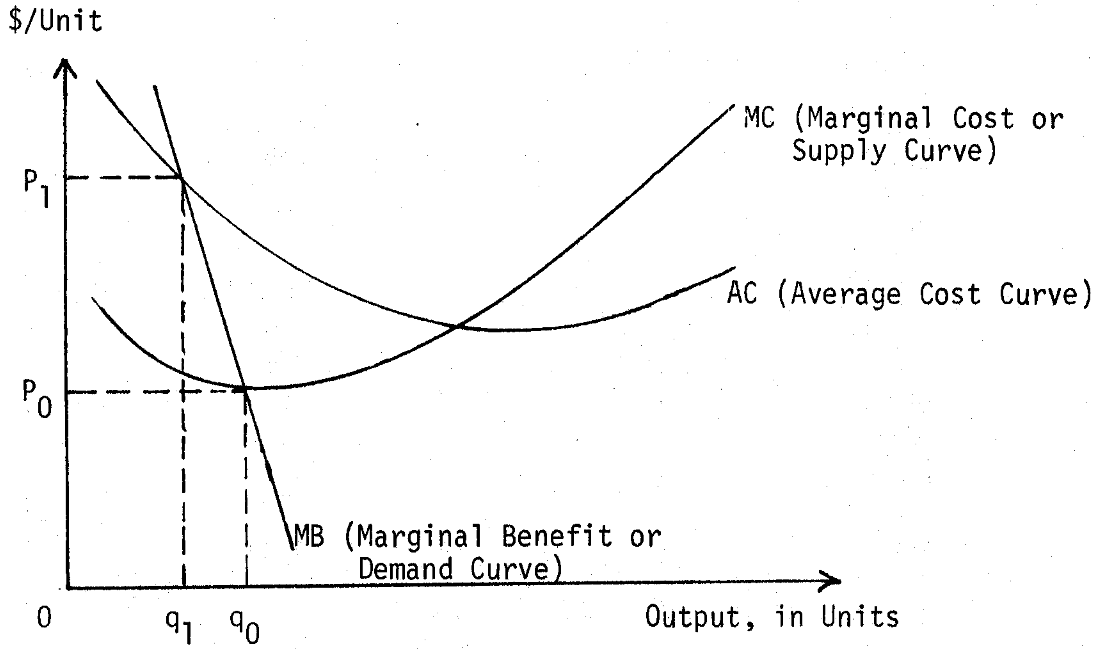

Figure 2. Selection of Price Under Decreasing Average Cost Conditions.

recovered at Oq_1 level of output which is less than the optimum level of output, Oq_0.

On the other hand, at Oq_1 level of output where P = AC, economic efficiency requirement is not met while the financial requirement is satisfied. Thus, at Oq_1, since MB > MC, resources are under-utilized and the optimum allocation is achieved only when output is Oq_0.

Even under the decreasing cost conditions, proponents of allocative efficiency suggest that the price should be set at the point where MC = MB. To remedy the problem of financial deficit, the government could provide a subsidy to compensate the financial loss through general tax revenues. However, many object to this solution on equity grounds, feeling that the beneficiary should pay the full cost of the service or commodity in question, if possible. A better solution is a two-part pricing system, where price is set at marginal cost, but a fixed levy is assessed on users to cover the deficit. This approach satisfies both the efficiency and financial criteria [James and Lee, 1971, p. 544].

The principle of marginal-cost pricing is a short-run as well as a long-run phenomenon. The short-run efficiency problem deals with the best use of existing facilities. Marginal-cost pricing is necessary for short-run efficiency in order to ration private goods where one individual's consumption may interfere with another person's consumption. Similarly, marginal-cost pricing is necessary for long-run efficiency so that price = MC to avoid distortion in investment decisions. Davis and Hanke [p. 40] summarize as follows:

> . . . if prices are set at less than marginal costs, there is a tendency to bias investment decisions toward overexpansion and premature investment. On the other hand, if prices exceed marginal cost, existing facilities are underutilized and future investments will tend to be made more slowly and in too small an increment. Therefore, the use of prices that are equated to marginal cost give the decision-maker the essential information necessary in estimating benefits. This is particularly important in helping him make long run investment decisions. Such a pricing policy would also facilitiate the efficient use of a project once it is established.

Regarding the marginal-cost pricing criterion, Milliman [1972] makes a very important point. Over time, changing patterns of income, population, and other elements of regional growth may shift the demand for a publicly supplied good or service such as water. This creates a rising opportunity cost. If project beneficiaries are not confronted with this opportunity cost, the publicly supplied good will tend to remain in its original use and larger economic benefits from its use in other sections will be foregone. Hence, an efficient pricing system for a publicly supplied commodity such as irrigation water should take into account opportunity costs of resources in addition to the operating costs. This implies that an optimal price will vary through time. (Note that a perfectly competitive market system smoothly adjusts to changes in opportunity costs. This suggests that an efficient pricing system for public intermediate goods should incorporate market processes, and not focus only on original construction costs.)

The Bureau of Reclamation Method of Calculating Irrigation Water Charges

Irrigation Water Charging Policy -- Under conditions where the market fails to function properly, it is difficult to assign prices that are appropriate for the efficient allocation of resources. This becomes a crucial problem when the alternative uses of scarce resources are compared. It is clear that water is a scarce resource in the western United States. Hence, the issue of how Bureau-supplied water is allocated to irrigation purposes and what prices are charged to irrigators is the theme of this section.

In considering benefits accruing to multi-purpose projects, the Bureau of Reclamation's first priority is always irrigation and all other purposes are secondary [Davis and Hanke, p. 122]. Giving priority to only one end use without relating prices to costs seems to be inconsistent with the concept of efficient allocation of resources. It violates the objective of efficient resource allocation. So long as the use of scarce resources is not determined based on economic values, it is hard for the user to see the possibility of lost opportunities due to misallocation of resources.

Regarding irrigation water supply, the cost-sharing policy of the Bureau of Reclamation is described as follows:

> It has long been the philosophy of the nation that all Reclamation project costs for the purpose of irrigation, power, and municipal and industrial water supply should be repaid in full . . . Repayment of all reimbursable project costs and operation and maintenance costs is a responsibility of the project beneficiaries . . . *Irrigation costs are interest free and are repaid by water users on the basis of their ability to pay as determined by an economic analysis of the particular project. Irrigation costs above the water users' ability to pay are repaid through financial assistance from surplus power revenues and other miscellaneous project revenues.* [U.S. Bureau of Reclamation, 1972, pp. ix-x. (Italics added)]

Hence, it is clear that ability-to-pay rather than any concept of resource costs is the criterion used for pricing Bureau-supplied irrigation water.

Repayment requirements for the farmer have been fully severed from any concept of cost.

The procedure for calculating ability-to-pay for water users will be described shortly. But, first it is worthwhile to explain irrigation benefits in general.

Direct and Indirect Benefits -- Benefits generated due to the advent of a new irrigation project are of two kinds. First, there are the direct irrigation benefits which are caused by additional production of farm products or by reduced costs of production. Secondly, there are those indirect or secondary benefits which comprise increased net income from the local trade affected by the project. They are caused by increased marketing of farm products and increased demand for goods and services consumed by farmers. Such indirect benefits are designed to reflect the impact of the project on the rest of the economy.

Regarding the direct irrigation benefits, gross income is computed as the sum of the annual receipts from sales of the farm products and the value to the farmer and his family of all products grown and consumed at the farm. Then payments for all farm inputs other than water are subtracted from gross farm income. The remaining part is net farm income. One point of great interest concerning the computation of the net farm income is that the opportunity cost of family labor is considered to be zero although a large portion of the net farm income is subtracted as a share of family living allowance after the net farm income is estimated. This procedure inflates the net farm income when the benefit aspect is considered but underestimates the payment capacity of water users. (This will be discussed further when the ability-to-pay approach is explained.)

The process of computing net farm income is carried out for both the "with" and "without" project situations. The change in the net farm income which is the difference in net farm income under the "with" and "without" project conditions is the overall benefit accruing as a result of the application of irrigation water.

Change in Net Income Approach to Benefit Estimation -- The Bureau's procedure for computing the change in net farm income due to the application of irrigation water supply is equivalent to the measure of the incremental value of the added water supply which, according to Young and Gray [1972], is conceptually suitable for comparison with the unit of incremental cost of providing the water.

The change in net income approach equates maximum willingness to pay to the change in net income for representative farms "with" a project as compared to "without." This can be illustrated symbolically as follows:

Let Z = net income and ΔZ = change in net income,

Y_j = output ($j = 1, 2, \ldots, m$),

X_i = inputs ($i = 1, 2, \ldots, n$),

P = price of output (j) and input (i) (assumed constant).

The objective is to compute change in net income, denoted as ΔZ, which is a measure of the maximum willingness to pay (i.e., benefits). Thus,

$$Z = (\sum_j P_{y_j} \cdot Y_j) - (\sum_i P_{x_i} \cdot X_i)$$

$$\text{and } \Delta Z = Z_1 - Z_0$$

where the subscripts 1 and 0 refer to the "with" and "without" project cases, respectively. Therefore, the change in net income is written as:

$$\Delta Z = \{(\sum_j Y_{1_j} \cdot P_{y_j}) - (\sum_i X_{1_i} \cdot P_{X_1})\} - \{(\sum_j Y_{0_j} \cdot P_{y_j}) - (\sum_n X_{0_i} \cdot P_{X_i})\}$$

$$j = 1, \ldots, m \qquad i = 1, \ldots, n$$

The change in net income approach holds true under the following assumptions. First, the total value of output (TVP) is assumed to be divided into shares such that each resource is paid according to its marginal value product (MVP) in such a way that TVP is completely exhausted in accordance to the well-known Euler's or adding-up theorem. Euler's theorem states that if $f(X_1, . . ., X_n)$ is a homogenous production function of degree m (where TVP exhibits constant returns to scale is a special case), then $f_1X_1 +, . . ., + f_nX_n = m \cdot f(X_1, . . ., X_n)$ [Nicholson, 1972].

The second assumption is that the market prices of all resource inputs, except the one whose value is to be computed, are equal to the return at the margin afforded by those resources, i.e., $MVP_{X_i} = P_{X_i}$. This holds true for a profit-maximizing entrepreneur's operation in a perfectly competitive economy.

<u>Ability-to-Pay Estimate for Payment of Irrigation Water Charges</u> -- It was pointed out above that the change in net farm income due to irrigation water supply is derived through comparisons of net farm incomes under the "with" and "without" project cases. Ability-to-pay is derived similarly, except that the change in net income calculations are restated with current rather than future (higher) crop yields, and further, a family living allowance is deducted. Thus, the ability-to-pay for irrigation water used to estimate the irrigation repayment capability, is that portion of the adjusted change in net farm income resulting from irrigation after an adequate family living allowance has been made for the farm family. Finally, the actual price charged to water users is normally only 75 percent of the calculated ability-to-pay. This further reduction is regarded as an incentive to irrigate, as already mentioned in Chapter I.

As indicated above, the Bureau of Reclamation uses a variation of the change in net income approach to arrive at the benefit derived from application of irrigation water. Furthermore, this variation is the basis for computing beneficiaries' ability-to-pay for the water they get. But there are at least two noteworthy areas where the Bureau makes certain adjustments in the calculations which we believe to be incorrect [Young, 1978]. As already indicated, the Bureau treats the opportunity cost of family labor to be zero. This helps to boost the benefit generated from irrigation water supply, since no such charges are deducted from net income. Secondly, benefits are computed on the assumption that farmers capture all gains from technological progress, since crop yields are projected to grow but production costs and prices do not adjust. It is the opinion of many informed specialists that farmers have not, in general, been the beneficiaries of technological gains in the U.S. Rather, the inelastic demand for most farm products leads to a fall in real prices which is as great or greater in the effect on net income than the increase in yield or cost reductions from technological change [Cochrane, 1958, pp. 34-50]. Note, however, when ability-to-pay, rather than benefits, are calculated, technological progress in crop yields is no longer included in the calculations. At the same time, the Bureau estimates a family living allowance which is also subtracted from the net farm income of the project. This underestimates water users' willingness-to-pay. In an attempt to indicate the magnitude of the share of family living allowance out of the net change in farm income, Eckstein [1958] shows that about 26 percent of all the direct benefit is taken away as the family living allowance component. The combined effect of all this and the provision of free interest rate leads to a farmer share of costs allocated to irrigation projects which is much lower than actual cost. North and Neely [1977] have shown that the actual cost share is typically less than 20 percent of full costs of irrigation water supply. This has great impact on whether public irrigation investments are efficient investments or not.

CHAPTER III

DESCRIPTION OF THE PROJECT AREA

Location, Climate, and Soils

The South Platte Valley is in the northeastern portion of Colorado, as shown in Figure 3. The upper stream half of the South Platte River originates along the Continental Divide at an elevation of nearly 14,000 feet. The river gets most of its water supply from snowmelt and from spring and summer rains. The basin slopes to the east and merges into the Colorado piedmont area where the proposed Narrows Project is to be located. The multi-purpose Narrows Project is a unit of the comprehensive Missouri River Basin Project; it will provide supplemental irrigation water, flood control, recreation, and fish and wildlife development as well as potential for future municipal and industrial water supplies. The Narrows Project area comprises approximately the downstream half of the South Platte River Basin in Colorado. As shown on the map (Figure 3) this region is located to the northeast of Denver. The South Platte has several tributaries that arise in the Rocky Mountains as perennial streams which contribute to the regular flow of the river. But its tributaries from the plains region are also important contributors to spring and summer runoff.

Broadly speaking, the South Platte River Basin has a temperate climate but with high daytime temperatures in the summer and a large range of temperatures over the whole year. This region receives light rainfall, averaging 15-16 inches per year, of which 70-80 percent falls in April through September. Precipitation also varies considerably from year to year. The relative humidity is frequently below 50 percent. Evaporation rates are high and these cause rapid cooling effect at this higher altitude. High velocity winds are also not unusual in some parts of the year.

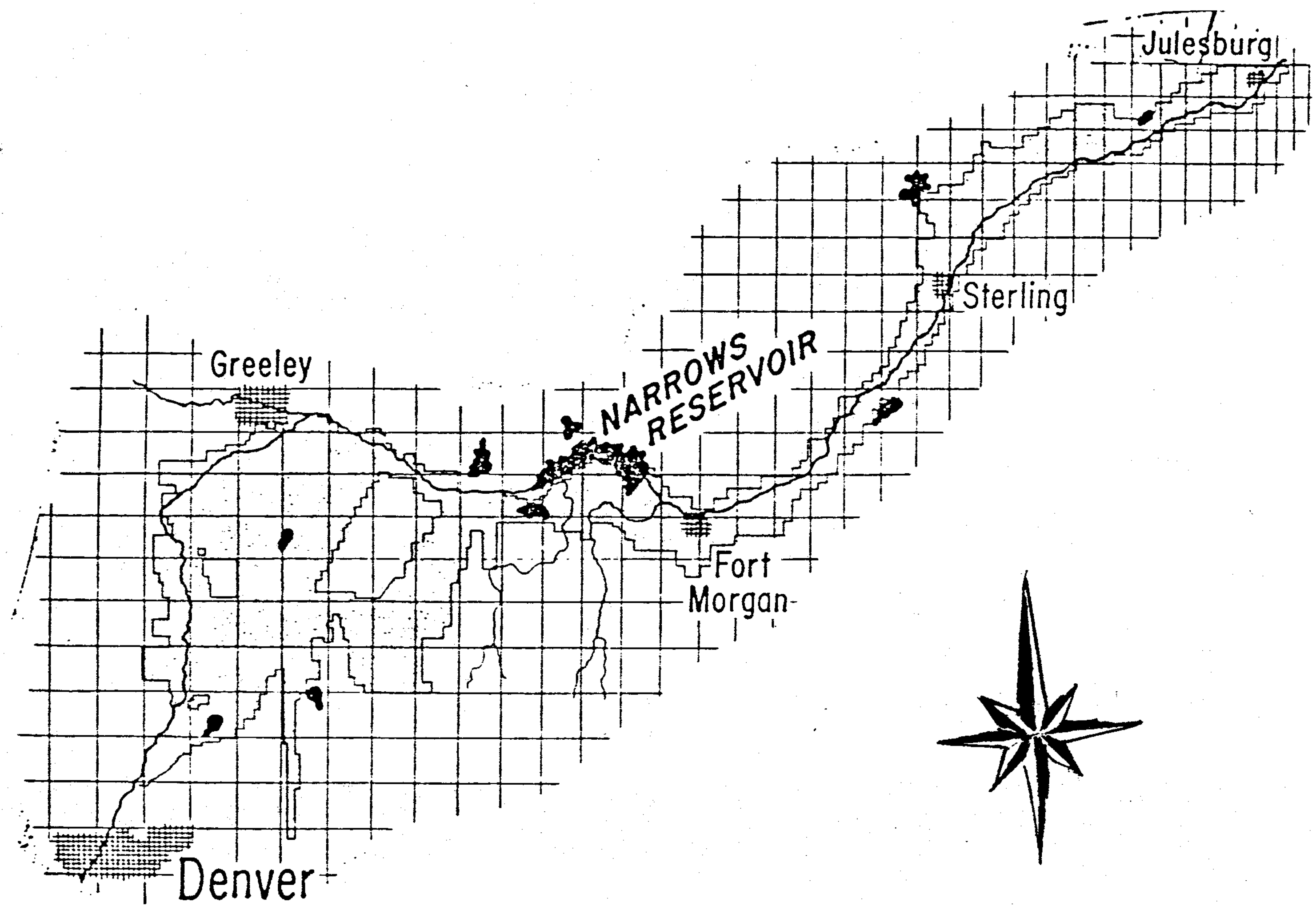

Figure 3. Map of Northeastern Colorado - South Platte Valley.

The soils of the northeastern plains of Colorado, in general, have developed under a temperate semi-arid climate. The native vegetation consists primarily of short grasses interspersed occasionally with low-growing shrubs.

The materials from which the major soil bodies have developed are alluvium, acolian deposits, and shales. The alluvium underlies all of the South Platte Valley. Normally, the alluvium is composed of a heterogeneous mixture of clay, silt, sand, and gravel and, on the whole, the soils of this region are said to be most productive for agriculture.

Irrigation History and the Case for Supplementing Water Supply

In view of the limited precipitation in the region, the residents in the South Platte Valley have turned to diversion of river water and pumping groundwater to enhance agricultural production. As with many other places in the western United States, irrigation diversions in the South Platte River Basin began in the late nineteenth century. Most of the early ditch systems in this region were constructed between 1870 and 1900. River flows were fully allocated by 1900 and very shortly a number of reservoirs were built to store spring runoff waters which would be used in the growing season. Later on, as irrigation programs continued to develop, legislation which authorized the formation of irrigation districts was passed and this encouraged farmers to cooperate in financing and constructing relatively better irrigation facilities.

The case for more water in this region is apparently obvious. The South Platte River Basin is normally semi-arid and relatively little crop production could occur without irrigation. In fact, it is often stated that water is the "life blood of progress" in this part of the state. But, the problem in the lower South Platte is a paradox. In many of the past 100 years, such as occurred in 1965, the flow of the river during the months of May and June was so great that extensive damages were sustained. On the other hand, in nearly every year the flow of the South Platte is so low in July, August, and September that serious water supply shortages are evident.

Such being the case, then, interest in water resource development had been high in the South Platte River Basin ever since the time of the first settlement, and a dam on the lower South Platte has been discussed since the turn of the century. The Narrows Unit was originally authorized by the Federal Flood Control Act of 1944, as a unit of the comprehensive Missouri River Basin Project. In 1958, a group of residents from the South Platte Valley appeared before the Colorado Water Conservation Board and requested the Board to reinitiate studies leading toward construction of channel storage in the South Platte River. The Bureau of Reclamation was given the responsibility of the study, leading to the selection of the Narrows site. However, the final authorization of the Narrows Project did not come until September 1964, after the people of the South Platte Valley once again showed their desire to develop their water resource. The formation of the Lower South Platte Water Conservancy District (LSPWCD) which stands ready to assume the financial responsibility of repaying the costs of the Narrows Project allocated on irrigation, reflected the firm intention to develop the water resource of this region. The LSPWCD comprises parts of Morgan, Washington, Logan, and Sedgwick counties and includes an aggregate land of 375,040 acres. Included are the municipalities of Fort Morgan, Brush, and Sterling, plus almost a dozen small towns.

Present Condition of Agricultural Economy

The South Platte Valley is essentially an agricultural region. It is a livestock feeding and processing area. It is also a producer of most of Colorado's major crops.

As mentioned above, because of the lack of sufficient rainfall, farmers irrigate, where possible, with surface water supplies. In addition to this, they resort to pumping groundwater for supplemental irrigation. Even so, many feel there is not an adequate supply of water to fully exploit the potential of this agricultural region. There remain areas which have inadequate surface water supply, but are not favored with a satisfactory groundwater source. Farmers in the South Platte Valley also suffer occasional severe droughts.

In the Valley, the only crops of economic significance grown without irrigation are winter wheat and native grasses. The principal irrigated crops are corn, alfalfa, sugar beets, and dry beans. Of these, forage, alfalfa, and corn for silage are fed to livestock, mainly on the farms where they are produced. Sugar beets, dry beans, and wheat are the major cash crops. Furthermore, alfalfa and corn harvested for grain are basic to the livestock enterprises on the farm or are sold off the farm to supplement nearby dryland farms and ranches, as well as to specialized commercialized feedlot operations [Conklin, 1975].

CHAPTER IV

IRRIGATION BENEFITS AND THE EFFECTS OF ALTERNATIVE CHARGING MECHANISMS

The purpose of this chapter is to report the estimated benefits gained by irrigators due to the provision of irrigation water from the proposed Narrows Project. Three alternative water supply situations are considered:

1. Alternative Irrigation Method I: Providing irrigation water to currently dryland wheat production.
2. Alternative Irrigation Method II: Providing supplemental irrigation water to currently irrigated lands with inadequate supplies of surface water.
3. Alternative Irrigation Method III: Providing supplemental irrigation water to currently irrigated lands with inadequate supplies of surface water supplemented by groundwater.

With the provision of irrigation water, dryland farmers presumed to crop on a wheat/fallow system are assumed to adopt currently predominant crop pattern for irrigated farming. Benefits to such farmers who convert dryland wheat production to fully irrigated crop patterns are computed on the basis of a flat 2.1 acre-foot/acre (ac. ft./ac.) supply of irrigation water.

Under Alternative Irrigation Methods II and III, farmers are assumed to continue using the predominant irrigated crop pattern. Measurable direct farm benefits are assumed to be generated from additional output of farm products and/or by reduced costs of production.

Benefits from Alternative Irrigation Method I

Under Alternative Irrigation Method I, farm budget analysis is the basic tool for estimating farm income. In evaluating the net benefits gained due to the provision of irrigation water, the development of farm business "with" and "without" the project is analyzed. The dryland wheat/fallow stands for the "without" project situation; in the "with" project situation, corn, beans, beets, alfalfa hay, and alfalfa establishment are produced as cash crops.

Regarding the "without" project situation, the cost of producing winter wheat is analyzed on the basis of a system of one acre fallow and one acre wheat [Agee, 1975]. Detailed costs for each operation performed on wheat production are shown in Appendix A and the summarized form is shown in Table 1. As indicated in Table 1, total production and opportunity cost is estimated to be $66.22 per acre. Based on current yield and price trends for northeastern Colorado, gross returns are estimated to be $110.20 per acre (29 bu./ac. at $3.80/bu.). Having computed the gross returns and total costs as indicated above, then net returns to land are $43.98 per acre ($110.20 - $66.22). Finally, the net returns expressed in dollars per acre of harvested land at 1975 price level is computed to be $23.97 per acre ($\frac{43.98}{2} \times 1.09$) where 1.09 is the inflation adjustment factor as indicated in Appendix B. The net return total is divided by two to get a true per acre return due to the additional one acre of fallow.

Table 1. Costs of Producing Dryland Wheat in Northeastern Colorado, 1975-76 (1200 acres fallow and 1200 acres wheat).

Operations	Variable Cost $ Per Acre	Fixed Cost $ Per Acre	Total Cost $ Per Acre
1. Fallow Activities	$9.16	$5.57	$14.73
2. Planting	6.56	1.84	8.40
3. Growing	7.39		7.39
4. Harvesting	12.28	0.17	12.45
5. Hauling	3.12	1.41	4.53
6. General Overhead Costs	6.74	1.47	8.21
7. Real Estate Overhead Costs	2.22	2.78	5.00
8. Management Cost, i.e., 5% of expected returns (29 bu./ac. at $3.80/bu.)	5.51		5.51
Total Costs	$52.98	$13.24	$66.22

Source: Adapted from Agee [1976].

Conklin's [1975] report provided the data base for the irrigation benefit analysis. His cash crop farm in the intermediate size category of 280 acres was selected for the analysis of the "with" project case. However, cost data for the five crops of corn, beans, beets, alfalfa hay, and alfalfa establishment have been adapted here with the following adjustments. First, since only surface water is dealt with, data for variable costs are identical to Conklin's, except that costs associated with pumping operations are deleted. Secondly, an interest charge of six and one-half percent of the $250 development cost to represent amortization of on-farm irrigation development costs is incorporated into the costs as shown in Table 2. Thirdly, 5 percent of the expected gross revenue is included as a charge to management, to avoid crediting this resource to water benefits. Finally, all costs are expressed in 1975 prices.

Table 3 depicts computation of returns to land. As far as the crop yield estimates are concerned, simple five year (1971-75) average crop yield figures projected as shown in Appendix B have been used. Similarly, to adjust for inflation, all crop prices are expressed in 1975 prices. These crop prices are computed on the basis of the USDA price index for all commodities farmers use in production as shown in Appendix B. Hence, we have the net return to land under the "with" project situation estimated to be $115.24 per acre as indicated in Table 3. The "adjustment factor" weights each crop according to the assumed cropping mix discussed earlier.

So far, net returns to land under the "with" and "without" project cases are estimated as $115.24 and $23.97 per acre, respectively. The difference between these two estimates is, then, the net return to the supplement irrigation water expressed on a per acre basis ($91.27 per acre). But, it has been assumed that water users' benefits would be computed on a flat 2.1 acre foot per acre water supply for irrigation. Therefore, net benefit gained due to

Table 2. Costs for Corn Grain, Pinto Beans, Sugar Beets, Alfalfa Establishment, and Alfalfa Hay (1975 Prices) on 280 Acre Cash Crop Farm.

Item	Cost Per Acre: Corn Grain	Pinto Beans	Sugar Beets	Alfalfa Establishment	Alfalfa Hay
Variable Cost	$111.94	$ 95.07	$209.03	$ 98.40	$ 83.45
Fixed Costs					
Overhead Charges	19.17	19.17	19.17	19.17	19.17
Machinery & Equipment Ownership	22.52	16.62	52.66	10.64	2.10
Interest on Machinery, Equipment	16.52	12.56	30.36	8.43	3.16
Total Fixed Costs	57.11	48.35	101.91	37.96	24.15
Development Cost (6 1/2% of $250)	16.25	16.25	16.25	16.25	16.25
Return to Management (5% of Gross Revenue)	15.16	20.02	31.95	6.83	8.88
Total Costs (1974 prices)	200.48	177.69	359.14	159.49	132.73
Total Costs (1975 prices)*	218.52	195.86	391.46	173.84	144.68

Source: Adapted with some adjustments from Conklin's [1975] cost data.

*1974 cost estimates are multiplied by 1.09 (inflation adjustment factor, Appendix B) to given 1975 cost estimates.

Table 3. Costs and Returns for Corn Grain, Pinto Beans, Sugar Beets, Alfalfa Establishment, and Alfalfa Hay (1975 Prices) on 280 Acre Cash Crop Farm.

	Value or Cost Per Acre					
Item	Corn Grain	Pinto Beans	Sugar Beets	Establish Alfalfa (with barley cover crop)	Alfalfa Hay	Net Return
A. Gross Returns from Product						
Unit	bu.	cwt.	tons	bu.	ton	
Price	$ 2.74	$ 22.54	$ 37.19	$ 2.75	$ 56.01	
Yield per Acre	107.16	17.76	17.18	50.00	3.17	
Value per Acre	$239.62	$400.31	$638.92	$137.50	$177.55	
Total	$303.62[a]	$400.31	$638.92	$137.50	$177.55	
B. All Costs	$218.52	$195.85	$391.46	$173.84	$144.68	
C. Residual (i.e., A-B)	$ 85.10	$204.45	$246.46	$-36.34	$ 32.87	
D. Adjustment Factor	130/280	40/280	50/280	15/280	15/280	
E. Adjusted Residuals	$ 38.51	$ 29.21	$ 44.19	$- 1.95	$ 5.28	$115.24

[a]Gross Returns include $10 per acre as the value of stalks for grazing.

the provision of the supplemental irrigation water supply will be $\frac{\$91.97}{2.1} = \$43.80$ per acre foot.

Alternative Irrigation Methods II and III

Based on Young and Bredehoeft's [1972] planning stage model, a linear programming model has been used to analyze benefits gained under Alternative Irrigation Methods II and III. The model serves to estimate maximum net returns accruing to the application of the supplemental irrigation water supply. Net returns are maximized both "with" and "without" the project as the available supplies of irrigation water and land are allocated to the production of corn, beans, beets, and alfalfa hay. The format of the model is presented in a linear programming tableau in Appendix C.

Actual data used in the model can be explained in the following manner. The objective function includes cost of both surface and groundwater supplies as well as estimates for net returns associated with the various alternative crop production activities as shown in Appendix C. Cost of the surface water supply is computed from a $2.50 per acre foot delivery cost plus labor cost associated with irrigation operations. Similarly, cost of the groundwater supply is based on a $4.50 per acre foot delivery cost and labor cost related to irrigation. Regarding the net return estimates, the detailed computation procedure is presented in Appendix D.

Four irrigation periods were defined for the linear programming analysis. Crop water use coefficients were computed for over 90 cropping activities reflecting various patterns and amounts of irrigation. Next crop productivity coefficients were computed for each of the activities using Blank's [1975] method for determining plant growth as a function of soil moisture. This allowed the linear programming model considerable flexibility in allocating water between the four crops and the four irrigation periods.

Table 4 gives examples of estimated net returns for sugar beet production under deficient water supply. The same procedure also applied to net return computation for the other three crops.

Benefits With Alternative Irrigation Method II

Based on historic water utilization practice in the north Sterling area, the farm headgate supply of water on 29,557 acres of irrigated land was estimated to be 1.36 acre feet per acre on the average. This is inadequate to support sustained agricultural crop production; water shortages are computed to be 0.76 acre foot per acre. Hence the Bureau's proposal for the Narrows Project is to furnish farmers in the project area with the desired supplemental irrigation water supply for a total of 2.1 acre feet per acre.

Water and Land Constraints -- Under Alternative Irrigation Method II, the application of 1.36 acre feet per acre is taken as the "without" project case; and the application of a 2.1 acre feet per acre stands for the "with" project situation. As already indicated above, the inadequately irrigated land of 29,557 acres is selected for the analysis. This available land is then distributed among the four crops on the basis of existing crop acreage in the project area.

Next the total required volume of irrigation water is estimated using the 29,557 acres of available land for crop production and the 1.36 and 2.1 acre feet per acre farm headgate water supply for the "without" and "with" project cases, respectively. Finally, the total available irrigation water is distributed between the four irrigation periods on the basis of existing crop acreage assuming "optimum" levels of irrigation.

Thus, as already indicated, the objective of the analysis under Alternative Irrigation Method II is to compute direct farm benefits generated from the additional supply of irrigation. The results will be dealt with in a later section of this chapter.

Table 4. Estimated Net Returns for Sugar Beet Production Under Various Schedules of Irrigation Water Supplies.

	Amount of Irrigation Water (acre inches) By Time Period for Alternative Schedules							
Alternative Irrigation Schedules	May 15 to June 15	June 16 to July 15	July 16 to Aug. 15	Aug. 16 to Sept. 15	Percent of Maximum Yield	Gross Returns	Costs	Net Returns
1	4.1	4.8	6.5	11.3	100	$638.92	$219.25	$419.97
2	4.1	4.8	6.5	0	92	587.97	219.25	368.72
3	4.1	0.9	8.1	11.3	99	632.60	219.25	412.35
4	4.1	4.8	5.7	4.2	95	606.94	219.25	387.69
5	4.1	0.9	0	4.2	87	555.99	219.25	336.74

Alternative Irrigation Method III

Here the purpose is to examine whether farmers who currently use both surface and groundwater could gain from reduced costs of production when they get Bureau-supplied supplemental irrigation water. A farm size of 280 acres is selected for this analysis. Similarly, it is assumed that: (1) each farm gets groundwater from two wells each with a capacity of pumping 4 acre feet of water daily, and (2) each farm gets 1 acre foot per acre surface water supply. Since these two sources of water supply do not consider any supplemental water from the Narrows Project, this situation is taken as the "without" project case. Regarding the "with" project case, in addition to the same available supply of groundwater, a 2.1 acre feet per acre supply of Narrows supplemental water is made available. Groundwater is assumed uniformly available during all irrigation periods at a rate of 8 acre feet per day. The supply of surface water is distributed among the four irrigation periods in the same optimizing manner mentioned above. Similarly, the same process of distributing the available land among the four crops outlined above is used here. Furthermore, the same crop production activities are used under both Alternative Irrigation Methods II and III as indicated in Appendix C.

Results of the Linear Programming Model

As already mentioned above, a linear programming model was used to determine benefits gained by water users from additional production of farm products and/or reduced cost of production. The results are shown in Tables 5 and 6. Table 5 shows the estimate of the value of supplement use of Bureau-supplied irrigation water to be $32.03 per acre foot. Since it is assumed that benefits measure willingness to pay, then, at least theoretically irrigators are willing to pay up to $32.03 per acre foot for the Bureau-supplied irrigation water in the Narrows Project area under Alternative II.

Table 5. Net Return to Increased Water Supply Under Alternative Irrigation Method II (29,557 acres).

	Amount of Water Actually Used (acre inches)		Net Change In Irrigation Water Used	Net Returns A	Net Returns B	Net Change In Return Due to Water Supply	Net Benefit Due To Supplemental Irrigation Water
Period	With Project	Without Project	Acre Inches	With Project	Without Project	A - B	$/acre foot
1	124,878	72,360					
2	196,406	159,192					
3	139,213	96,480					
4	287,737	154,368					
	748,236	482,400	268,836	$6,264,674	$5,555,138	$709,536	$32.03

Table 6. Net Return to Increased Water Supply Under Alternative Irrigation Method III (Representative 280 Acre Farm).

	Amount of Water Actually Used (acre inches)		Net Change In Irrigation Water Used	Net Returns A	Net Returns B	Net Change In Return Due to Water Supply	Net Benefit Due to Supplemental Irrigation Water
Period	With Project	Without Project	Acre Inches	With Project	Without Project	A - B	$/acre foot
Surface Water							
1	1,058	504					
2	1,860	1,108					
3	1,318	672					
4	2,257	1,075					
	6,497	3,360	3,136	$59,240	$57,204	$2,036	$7.80 or $0.65 per acre inch
Ground Water							
1	124	679					
2	0	752					
3	0	647					
4	467	1,651					
	575	3,948					

Table 6 also shows that water users can save $7.80 per acre foot by substituting Bureau-supplied irrigation water for most of the groundwater they use at present. This is lower than the previous case, since the measured increase in income is, in effect, the reduced pumping cost. However, such benefits have to be analyzed in light of the true cost of supplying the irrigation water supplied by the Bureau. This will be the subject of the following section.

Analysis of Benefits Gained From Alternative Charges for Bureau-Supplied Irrigation Water

The total estimated project cost of the Narrows Unit Project as of July 1975 is $139 million [U.S. Department of the Interior, 1976, p. 11]. Under federal laws, certain allocated costs of reclamation projects are nonreimbursable. Such nonreimbursable costs are absorbed as a desired federal investment. Certain other allocated costs are reimbursable by direct beneficiaries--some without interest, while others are interest bearing. Costs allocated to irrigation are reimbursable without interest.

Of the total Narrows Project cost of $139 million, reimbursable cost allocated to irrigation subject to repayment over a 50-year period amounts to $77.1 million, of which potential repayment by water sales is only $36.8 million. The remaining $40.3 million will be required from power revenues to repay the entire allocation.

The Interior Department [1976, p. 3, 22] estimated that the Narrows Project reservoir would furnish an average annual 133,000 acre feet of supplemental irrigation water at the dam. It is assumed that there would be a loss of 38 percent sustained in conveying the supply of irrigation water from the reservoir to the farm. Thus, the actual estimated supply of water at the farm headgate will be only 82,460 acre feet.

The \$77.1 million cost allocated to irrigation is broken down on an annual recovery cost basis as shown below. Basėd on recent trends of the interest rate used for economic analysis of public projects, a six and one-half percent interest rate is selected in computing the rate of annual capital recovery cost. First, the capital recovery factor (CRF) is computed:

$$CRF = \frac{i(1+i)^n}{(1+i)^n-1} = \frac{0.065(1+0.065)50}{(1+0.065)^{50}-1} = 0.0679$$

where i = interest rate and n = number of years.

Then, the annual capital recovery cost is estimated to be \$5.23509 million (77.1 x 0.0679). This needs to be expressed in terms of dollars per acre foot and is computed to be \$63.49 per acre foot $(\frac{\$5.23509 \text{ million}}{82{,}460 \text{ ac. ft.}})$.

The next step is to compare this estimated cost with the estimated benefit gained under the three alternative irrigation methods. Under Alternative Irrigation Method I, dryland wheat farmers are expected to achieve a return of \$43.80 per acre foot when they convert their farms to fully irrigated crop production. Under Alternative Irrigation Method II, irrigators would be able to gain \$32.03 per acre foot from using supplemental irrigation water from the Narrows Project. On the other hand, the cost associated with the supply of Narrows Project irrigation water is \$63.49 per acre foot as computed above if water users were to bear full cost allocated to irrigation purposes. Based on these estimates, then it seems that no rational water user would care to accept the supplemental irrigation water. Similarly, the benefit received by water users for replacing use of groundwater by Narrows supplemental irrigation water which amounts to \$7.80 per acre foot is not attractive enough for farmers to accept the Bureau-supplied supplemental irrigation water. Therefore, based on the direct benefits which would be generated from the

Narrows supplemental water, it is hard to justify the project.

The Bureau's recommended beneficiaries' payment capacity is $14.56 per acre foot [U.S. Department of the Interior, 1976, p. 16]. Obviously, this estimate of payment capacity hardly reflects the true cost of water supplied for irrigation purposes although the Bureau's price computation procedure may comply with the federal law and policy. Given that cost, most potential beneficiaries would find it attractive to enter into a water purchase contract.

CHAPTER V

SUMMARY AND CONCLUSIONS

Water is a most important single scarce resource for which, in many uses, there is no available substitute. It is an input factor among several competing uses. Hence, its marginal opportunity cost in one use should reflect its value foregone in other uses. At least, in principle for efficient resource allocation purposes, water should be allocated to its alternative end uses until the equality of its marginal benefits in all its uses is attained.

Since the inception of the reclamation program in 1902, the U.S. Bureau of Reclamation has been providing irrigation water for the economic development of the arid regions of the West. The program was successful in many aspects. It has boosted agricultural production in particular and the entire economy in general. However, it has been argued that such federally financed projects have been excessively subsidized. There are problems associated with recovering reclamation project costs too.

In the early days of the program, the cost-sharing policy was generally unsuccessful. Project costs were hardly ever recovered as originally anticipated. Even today, beneficiary charges for irrigation water are not commensurate with benefits gained. Generally speaking, the philosophy of the nation has been that all reclamation project costs should be repaid in full. But, irrigation project costs are interest free and are repaid on the basis of ability to pay. This ability to pay is determined from increased productivity of land under irrigation. However, one point which is quite clear is that the ability to pay as computed by the Bureau of Reclamation does not reflect the true cost of Bureau-supplied irrigation water. In short, such a pricing system completely divorces the price charged from project cost. Hence, the Bureau's pricing system is likely to invite inefficient use of irrigation water.

This study did not attempt to measure all the economic benefits and costs accrued to a reclamation project. This is so because what is defined as project benefits, for instance, comprise all identifiable gains in values, whether in goods, services, or intangible satisfaction, whether direct or indirect, and whether measurable in monetary or non-monetary terms. This is beyond the scope of our study. But, this study throws some light on the concern that the Bureau's procedure of estimating ability to pay is biased in favor of irrigation water users as against the taxpaying public.

The Narrows Project is taken as a case study to demonstrate the value of Bureau-supplied irrigation water and then to compare it to the actual cost of supplying the irrigation water as well as the ability to pay estimated by the Bureau of Reclamation. The annual cost of supplying Narrows irrigation water is computed to be $63.49 per acre foot should water users repay full cost allocation to irrigation. However, the actual irrigators' repayment capacity is set at $14.56 per acre foot as indicated by the Bureau of Reclamation.

In an attempt to compute the direct benefits gained due to the provision of the Narrows project, three alternative situations were considered. Under Alternative Irrigation Method I, it was assumed that dryland wheat farmers would get $43.80 per acre foot when they shift to fully irrigated type of crop production. Alternative Irrigation Method II was determined that irrigators who currently are confronted with inadequate water supply would gain $32.03 per acre foot when they get the Narrows Project supplemental water. Finally, under Alternative Irrigation Method III, farmers who currently supplement the inadequate supply of surface water by groundwater are assumed to reduce costs by $7.60 per acre foot when they substitute the use of groundwater by supplemental water from the Narrows Project.

Based on these results, cost of supplying the proposed irrigation water exceeds the direct benefits generated. Thus, it seems unlikely that water users would accept the Bureau-supplied irrigation water of the Narrows Project if they were to bear full cost allocated to irrigation. Furthermore, the results of this study seem to strengthen the argument that the Bureau's procedure of estimating water users' repayment capacity tends to result in charges which are much lower than the actual value of the irrigation water supplied.

Finally, it seems quite clear that the Bureau's procedure of estimating beneficiaries' ability to pay does divorce the pricing system from the cost associated with supplying irrigation water. Since the use of water for irrigation entails a cost in the form of foregone alternative uses of water, we recommend using cost-based pricing for water. This is particularly true under conditions where demand for the resource in question rises due to changing patterns of income, population, and other elements of regional growth. Thus, pricing mechanisms for Bureau-supplied irrigation water also should be arranged to vary accordingly.

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APPENDICES

Appendix A. Costs of Producing Winter Wheat, One Acre Fallow and One Acre Wheat, Northeastern Colorado, 1975-76 (1200 Acres Wheat, 1200 Acres Fallow, Average Production - 29 bushels per harvested acre).

Operation(s)	Tractor (hp)	Implement	Materials Description	Per Acre Physical Data: Truck Miles	Tractor Hours	Man Hours	Per Acre Case Costs: Materials & Custom $	Fuel, Lube, Repair $	All Labor $	All Per Acre Costs: Cash $	Fixed $	Total $
Fallow:												
Plow, moldboard	150	8-18's			0.167	0.167		1.39	1.34	2.73	1.73	4.46
Springtooth, 3 times	150	31'			0.300	0.300		1.94	2.40	4.34	2.22	6.56
Rodweed, 2 times	125	36'			0.142	0.142		0.95	1.14	2.09	1.62	3.71
Subtotal, fallow					0.609	0.609		4.28	4.88	9.16	5.57	14.73
Plant:												
Haul seed		2 ton	40 mi/235 bu	0.114[a]		0.029		0.02	0.23	0.25	0.04	0.29
Grain auger (0.003 hr/ac)		6"x41'						0.01		0.01	0.01	0.02
Clean & treat seed			23¢/cwt x .4 cwt				0.09			0.09		0.09
Plant seed	125	24 ft.	40 lb. seed		0.125	0.125	4.09	1.21	1.00	6.21	1.79	8.00
Subtotal, plant				0.114[a]	0.125	0.154	4.18	1.24	1.23	6.56	1.84	8.40
Grow:												
Spray weed, 1/2 of wheat	Custom	Air	3/4 lb. 2,4-D			0.003	1.70		0.02	1.72		1.72
Spray, armyworms, 1 of 5 years	Custom	Air	$3.25/ac			0.003	0.65		0.02	0.67		0.67
Crop insurance							5.00			5.00		5.00
Subtotal, grow						0.006	7.35		0.04	7.39		7.39
Harvest:												
Combine, $8 for 20 bu	Custom		10¢/bu for 9 bu				8.90			8.90		8.90
Haul wheat to bins	Custom		10¢/bu				2.90			2.90		2.90
Put in bins, 2 augers, 35 hrs ea		8"x41'				0.025		0.04	0.20	0.24	0.09	0.33
		6"x41'				0.025		0.04	0.20	0.24	0.08	0.32
Subtotal, harvest						0.050	11.80	0.08	0.40	12.28	0.17	12.45
Subtotal, fallow through harvest				0.114[a]	0.734	0.819	23.24	5.60	6.55	35.39	7.58	42.97
Haul to elevator:												
Load wheat, 2 augers, 30 hrs ea		8"x41' and 6"x41'				0.043		0.07	0.34	0.41	0.14	0.56
Haul, 3 hrs/load		2 ton	118 loads, 40 mi ea	3.347[a]		0.251		0.70	2.01	2.71	1.26	3.97
Subtotal, haul wheat				3.347[a]		0.294		0.77	2.35	3.12	1.41	4.53
Subtotal, fallow through haul to elevator				3.461[a]	0.734	1.113	23.24	6.37	8.90	38.51	8.99	47.50
General overhead:												
Pickup		1/2 ton	9,000 mi/yr	6.08[b]				0.69		0.69	0.97	1.66
Misc: labor @ 30% other @ 5% of above items				0.17[a] 0.30[b]	0.037	0.334	1.12	0.35	2.67	4.14	0.50	4.64
Interest on case costs @ 9% for 6 months							1.06	0.33	0.52	1.91		1.91
Subtotal, general overhead				0.17[a] 6.38[b]	0.037	0.334	2.18	1.37	3.19	6.74	1.47	8.21
Subtotal, fallow through general overhead				3.63[a] 6.38[b]	0.771	1.447	25.42	7.47	12.09	45.25	10.46	55.71

Real estate overhead: (for 2 acres)	Investment	Depreciation	Interest	Taxes	Insurance	Other Cash	Cash $	Fixed $	Total $
Land, 2 acres @ $250 @ 6%	$500			$1.26			1.26		1.26
Shop	5	$0.32	0.44	0.08	$0.15	$0.26	0.49	0.76	1.25
Grain storage	13	0.85	1.17	0.22		0.25	0.47	2.02	2.49
Subtotal, real estate overhead	$518	$1.17	1.61	$1.56	$0.15	$0.51	2.22	2.78	5.00
Management: at 5% of expected gross (29 bu/ac @ $3.80 = $110.20 x 0.05)							5.51		5.51
TOTAL PRODUCTION AND OPPORTUNITY COSTS							52.98	13.25	66.22

Source: Adapted with certain adjustments from Agee [1975].

[a]Truck mileage.
[b]Pickup mileage.

Appendix B-1. Prices Paid by Farmers, Index Numbers, 1971-75.

Year	Price Index for All Commodities Used in Production (1967=100)	1975 Price Adjusting Factor
1971	115	$\frac{188}{115} = 1.63$
1972	122	$\frac{188}{122} = 1.54$
1973	146	$\frac{188}{146} = 1.29$
1974	172	$\frac{188}{172} = 1.09$
1975	188	$\frac{188}{188} = 1.00$

Source: Adapted from 1) U.S. Department of Agriculture, Agricultural Prices, (Monthly Bulletin), Washington, D.C., January 30, 1976, and 2) U.S. Department of Agriculture, Agricultural Statistics, 1975, Washington, D.C.: Government Printing Office, 1975.

Appendix B-2. Calculation of Average Yield and Average Inflation-Adjusted Price for Five Crops, 1971-75.

	Grain Corn		Pinto Beans		Sugar Beets		Est. Alfalfa		Alfalfa Hay	
Year	Price $/bu.	Yield bu/ac	Price $/cwt	Yield cwt/ac	Price $/ton	Yield ton/ac	Price $/bu.	Yield bu/ac	Price $/ton	Yield ton/ac
1975	2.70	102.4	18.60	17.1	32.00	18.5	2.85	50.00	54.00	3.20
1974	3.02	110.0	28.00	18.8	50.30	16.2	2.79		52.00	3.10
1973	2.54	103.0	26.90	14.9	35.90	14.7	2.07		45.00	2.82
1972	1.61	119.3	8.60	18.2	17.70	18.3	1.77		40.00	3.44
1971	1.19	101.5	9.60	19.8	15.60	18.2	1.50		30.50	3.31
Simple Average		107.16		17.76		17.18		50.00		3.17
Inflation Adjustment										
1.00 1975	2.70		18.60		32.00		2.85		54.00	
1.09 1974	3.29		30.52		54.83		3.04		56.68	
1.29 1973	3.28		34.70		46.31		2.67		58.05	
1.54 1972	2.48		13.24		27.26		2.73		61.60	
1.63 1971	1.94		15.65		25.53		2.45		49.72	
Sum	13.69		112.71		185.83		13.74		280.05	
Adjusted Average	2.74		22.54		37.19		2.75		56.01	

Source: Adapted from Colorado Department of Agriculture, Colorado Agricultural Statistics, Denver, Colorado. (Annual Reports 1972-76)

Appendix C. Linear Programming Tableau.

Name		Constraint	Water Supplies							
			SW_5	SW_6	SW_7	SW_8	GW_{11}	GW_{12}	GW_{13}	GW_{14}
Net Returns	NETRV		-0.48	-0.48	-0.48	-0.48	-0.66	-0.66	-0.66	-0.66
Water Level 1	(W_1)	=	-1.0				-1.0			
Water Level 2	(W_2)	=		-1.0				-1.0		
Water Level 3	(W_3)	=			-1.0				-1.0	
Water Level 4	(W_4)	=				-1.0				-1.0
Surface Water 1	(SW_1)	<	1.0							
Surface Water 2	(SW_2)	<		1.0						
Surface Water 3	(SW_3)	<			1.0					
Surface Water 4	(SW_4)	<				1.0				
Groundwater 1	(GW_1)	<					1.0			
Groundwater 2	(GW_2)	<						1.0		
Groundwater 3	(GW_3)	<							1.0	
Groundwater 4	(GW_4)	<								1.0
All land	(land)	=								
Corn land	(corn)	<								
Pinto beans	(beans)	<								
Sugar beets	(beets)	<								
Alfalfa land	(alfa)	<								

Appendix C. Linear Programming Tableau (continued)

Name	C_{max}	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
NETRV	177.73	163.04	163.04	148.36	148.36	160.11	89.64	133.7	130.74	136.63	116.08	127.81	82.84
W_1	5.6	0	5.6	0	0	5.6	0	0	0	5.6	0	5.6	0
W_2	4.5	11.8	5.6	11.9	11.8	5.6	0	11.8	5.6	5.6	5.6	5.6	5.6
W_3	4.2	4.2	4.2	0	4.2	0	0	0	4.2	4.2	4.2	0	0
W_4	11.2	11.3	5.0	16.8	5.0	12.8	24.6	10.5	11.4	0	5.0	5.0	5.0
SW_1													
SW_2													
SW_3													
SW_4													
GW_1													
GW_2													
GW_3													
GW_4													
land	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
corn	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
beans													
beets													
alfa													

Appendix C. Linear Programming Tableau (continued).

	Beans	Sugar Beets					Alfalfa							Fallow
Name	PB_{max}	SB_{max}	SB_1	SB_2	SB_3	SB_4	A_{max}	A_1	A_2	A_3	A_4	A_5	A_6	
NETRV	300.84	419.97	368.72	413.45	387.69	336.74	92.72	89.39	92.72	92.72	89.36	85.44	78.72	-4.5
W_1	0	4.1	4.1	4.1	4.1	4.1	2.5	2.5	2.5	2.5	0	0	2.5	
W_2	8.7	4.8	4.8	0.9	4.8	0.9	12.6	4.0	12.5	12.6	12.6	8.7	0.4	
W_3	8.1	6.5	6.5	8.1	5.7	0	4.2	4.2	0	4.2	0	4.2	0	
W_4	6.6	11.3	0	11.3	4.2	4.2	2.7	2.7	2.7	0	2.7	0	2.7	
SW_1														
SW_2														
SW_3														
SW_4														
GW_1														
GW_2														
GW_3														
GW_4														
land	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
corn														
beans	1.0													
beets		1.0	1.0	1.0	1.0	1.0								
alfa							1.0	1.0	1.0	1.0	1.0	1.0	1.0	

Appendix D. Computation of Net Returns.

% of Maximum Yield		Yield Per Acre	Adjusted Prices	Gross Returns	Costs	Net Returns
				CORN		
C_{max}	(100%)	107.16 bu.	$2.74	$293.62	$115.89	$117.73
C_1	95%	101.80	"	278.93	"	163.04
C_2	95%	101.80	"	278.93	"	163.04
C_3	90%	96.44	"	264.55	"	148.36
C_4	90%	96.44	"	264.55	"	148.36
C_5	94%	100.73	"	276.00	"	160.11
C_6	70%	75.01	"	205.53	"	89.64
C_7	85%	91.09	"	249.59	"	113.70
C_8	84%	90.01	"	246.63	"	130.74
C_9	86%	92.16	"	252.52	"	136.63
C_{10}	79%	84.66	"	231.97	"	116.08
C_{11}	83%	88.94	"	243.70	"	127.81
C_{12}	67%	71.80	"	196.73	"	82.84
				BEANS		
PB_{max}	(100%)	17.76 cwt.	$22.54	$400.31	$98.99	$301.32
				BEETS		
SB_{max}	(100%)	17.18 tons	$37.19	$638.92	$219.25	$419.97
SB_1	92%	15.81	"	587.97	"	368.72
SB_2	99%	17.01	"	632.60	"	413.35
SB_3	95%	16.32	"	606.94	"	387.69
SB_4	87%	14.95	"	555.99	"	336.74
				ALFALFA		
A_{max}	(100%)	3.17 tons	$56.01	$177.55	$84.83	$92.72
Alf_1	98%	3.11	"	174.19	"	89.36
Alf_2	100%	3.17	"	177.55	"	92.72
Alf_3	100%	3.17	"	177.55	"	92.72
Alf_4	98%	3.11	"	174.19	"	89.36
Alf_5	96%	3.04	"	170.27	"	85.44
Alf_6	92%	2.92	"	163.55	"	78.72

Note: Cost figures are essentially Conklin's [1975] variable costs less costs associated to pumping operations and are inflation adjusted.