AN ABSTRACT OF THE THESIS OF

Darwin Blaine Nielsen for the Ph. D. in Agricultural Economics
(Name) (Degree) (Major)

Date thesis is presented 9/29/64

Title ECONOMICS OF FEDERAL RANGE USE AND IMPROVEMENTS

Abstract approved Redacted for privacy
(Major professor)

The BLM has the responsibility of managing millions of acres of federal land. Measured on an acreage basis, the most important use of this land is for livestock grazing. Each year large investments of public capital are made to improve these federal rangelands.

Administrators of these BLM rangelands are interested in application of analytical tools that would be useful in making decisions relative to the use and improvement of the federal rangeland.

This study was initiated and funded by the BLM to apply linear programming as a decision making aid. The three main objectives of the study were:

(1) Show the rates of return from public investment in various range improvement practices on a given management unit of federal rangeland as measured by the effect upon costs and returns to the individual ranchers.

(2) Compute the marginal value product of an animal unit month

of grazing for various seasons and given range conditions of the management unit under study.

(3) Evaluate the potential usefulness of programming models as an aid to decision making by public land administrators.

Linear programming models were developed to reflect the physical-biological and economic situation of the East Cow Creek allotment. Marginal value products (MVPs) of public capital were obtained from the solutions of these models. These MVPs were discounted over the life of the investment.

Internal rates of return were computed for all relevant levels of public investment in range improvements. These internal rates of return ranged from 31.0 percent to 3.25 percent for spraying and from 13.0 percent to 1.0 percent for reseeding to crested wheatgrass.

As many as 23 different levels of public investment were considered for some of the models. At each level of public investment considered, a complete new solution was obtained. Weighted average MVPs for the federal grazing were computed for the most relevant levels of public investment. At essentially zero public investment the weighted average MVPs were from $7.90 to $5.09, depending on the assumptions of the model. These weighted average MVPs were from $3.00 to $3.76 at the optimum level of investment determined for each model.

Several uses of these MVPs were presented and discussed. One of the big advantages of using linear programming models to estimate these MVPs is that all measurable factors effecting them are considered simultaneously.

Several assumptions were built into these linear programming models, thus causing each one to be different from the others. Despite these differences in the models, there were certain consistencies in the results from which some general conclusions can be drawn:

(1) Returns on public investment in range improvement practices as measured through livestock production are high enough to justify investment in such practices. However, at levels of public investment where the commensurate properties of the ranchers are being used near their capacity, these returns are soon pushed down to zero.

(2) Spraying the federal rangeland for brush control returns more per dollar invested in range improvements than a dollar invested in reseeding to crested wheatgrass.

(3) A high degree of interdependence exists between private and public decision-making. Returns on public investments in range improvements are dependent on the investment of private funds to improve the commensurate properties. The amount of private investment required is indicated in the solutions of the linear programming models.

It is concluded from the results of this study that the linear programming models have great potential usefulness as an aid to decision making by public land administrators.

ECONOMICS OF FEDERAL RANGE USE AND IMPROVEMENT

by

DARWIN BLAINE NIELSEN

A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

DOCTOR OF PHILOSOPHY

June 1965

APPROVED:

Redacted for privacy

Associate Professor of Agricultural Economics

In Charge of Major

Redacted for privacy

Head of Department of Agricultural Economics

Redacted for privacy

Dean of Graduate School

Date thesis is presented

Typed by Lucinda Nyberg

ACKNOWLEDGMENT

I wish to express my appreciation to the Department of Agricultural Economics and to the Bureau of Land Management for making it possible for me to continue doing research on range and ranch problems.

My sincere thanks goes to Dr. W. G. Brown for his help and encouragement while directing this research. His many witticisms and bits of philosophical wisdom seem to come at just the proper time.

Appreciation is extended to Range Management, especially to Dr. D. H. Gates and T. R. Bunch who supplied the physical-biological coefficients for this study. The cooperative research study with them proved to be very rewarding and enjoyable. I am sure that answering the questions of "an economist" seemed like an endless task.

Dr. R. D. Lloyd, Bureau of Land Management Economist, is acknowledged for his personal interest in the research project.

Special thanks is given to the cooperating ranchers of the East Cow Creek allotment for cooperation in getting the economic input-output data for the study. Thanks is also extended to the personnel of the Vale office of the Bureau of Land Management for their help.

I am especially grateful to Zoe, my wife, for her support and help throughout my graduate studies and for typing a rough draft of this thesis.

TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

ECONOMICS OF FEDERAL RANGE USE AND IMPROVEMENT

CHAPTER I

INTRODUCTION

The gross area of the United States, including Alaska and Hawaii, is about 2.3 billion acres. Various federal agencies hold title to about 771 million acres or about 34 percent of this gross area (42, p. 1). These federal owned lands represent an important part of the nation's natural resources.

The Bureau of Land Management (BLM) has the responsibility of managing 465 million acres or 60 percent of these lands (42, p. 1). Over one-half of the BLM land is located in the state of Alaska. Of these 465 million acres, 178.8 million acres are classified and administered as grazing lands. Under the provisions of section three of the Taylor Grazing Act the BLM administers 160 million acres in 58 grazing districts. Over 18,020 operators held 19,226 licenses or permits to graze 7,112,642 head of livestock on the federal range in 1962 (42, p. 142). This amounts to 12,000,057 animal unit months (AUMs).[1]

[1] An Animal Unit Month is the amount of forage which is necessary for the complete sustenance of a 1,000 pound cow for a period of one month; also a unit of measurement of grazing privileges within grazing districts which represents the privilege of grazing one animal unit for one month.

Big game animals consume an estimated 1.7 million AUMs of forage from these lands each year in addition to the domestic livestock use. The BLM uses an animal unit as a standardized unit of measurement which is equivalent to one cow or one horse or five sheep or five goats, all over six months of age.

There are large numbers of isolated tracts of land which are outside these grazing districts. These isolated tracts of land are leased for grazing purposes under section 15 of the Taylor Grazing Act and amount to approximately 18.8 million acres. Thus, a total of 178.8 million acres of grazing land are under the control of the BLM.

The lands administered by the BLM are located in the 11 Western States and Alaska. There are 31,969,038 acres of federal owned land in the state of Oregon or about 52 percent of the total land area of the state. The BLM has title to about one-half of this or 15,414,641 acres (42, p. 12-18). Taken on an acreage basis the most important use of this land is for grazing. Livestock are grazed on approximately 12.5 million acres in eastern Oregon and 500,000 acres in western Oregon. "This federal grazing land supplements the production of the privately-owned ranches in those areas. Without this supplemental acreage, operations would often be reduced below an economic level (43, p. 12)." A total of 1,136,056 AUMs of grazing were furnished by these lands in the five eastern Oregon grazing districts in 1961.

The above statistics on land ownership indicate the importance of the federal owned lands to the national economy and also to the economy of Oregon. They become extremely important to the economy of many local areas in the country and state. It is therefore in the public interest that these lands be "properly" managed. "Properly" managed will in this study be denoted as that management which leads to the most efficient allocation of resources from society's point of view.

The BLM conducts other programs in addition to the administration of the above mentioned grazing districts. Programs for soil and moisture conservation to rehabilitate millions of acres of seriously eroded rangeland are conducted under the National Soil Conservation Act. A range improvement program authorized by the Taylor Grazing Act provides range use facilities to aid range management and utilization. The National Halogeton Control Act provides authority for the control of poisonous and noxious weeds on the federal rangeland. "During the 1963 fiscal year, major accomplishments under these programs included land use planning resource surveys on 4,164,000 acres, conservation plans on 6,996,000 acres, brush control on 317,966 acres, range seeding on 126,650 acres, 3,780 miles of fencing, chemical weed control on 8,427 acres, water developments consisting of 686 wells, 655 reservoirs, 259 springs and 1,490,498 linear feet of pipelines, 62 water control structures, soil stabilization on 7,970 acres with checks, 6,866 acres of water spreading, and contouring on 22,526 acres (42, p. 153)." A good share of these improvement practices have taken place in Oregon. For example, in 1963 a total of 113,171 acres were sprayed for brush control, 27,629 acres were reseeded, 181 miles of fence were put in, 91 reservoirs were constructed, 32 springs were developed, 585 wells were dug, and 196,829 linear feet of pipeline were laid. It is apparent that large sums of public capital have been and probably will continue to be invested in these rangelands.

Of course, finances are not available now and probably never will be available to improve all of the BLM rangeland that has the physical potential for improvement. Thus some criterion is needed to help the public land management decision-maker decide when, where, how much, or if the range should be improved.

Some Comments On The Criterion Problem

The criterion presently used by the BLM for making decisions relative to range improvement is not very clear. Limited observation from talking to these decision-makers indicates that some criterion reflecting the need of the resource is used, i. e., rangeland which is in the most run-down condition should be improved first.

A criterion based on the "worst-first" principle is valid and acceptable only under the assumption that unlimited amounts of public capital would be available for range improvements regardless of the magnitude of the economic return or even if the economic return is positive. With unlimited capital all rangeland capable of being improved could be improved, thus the most economical way to improve all of it might well be to start with the worst (most run-down) rangeland and improve it first. However, as stated above, it is more realistic to consider public capital as a limited factor.

Before presenting a detailed description of the specific problems to be considered in this study, a few words concerning the general economic criteria for conservation and rangeland improvement practices are in order. Heady presented a paper in 1951 on the general criterion problem for soil conservation programs. "Two important economic problems related to public conservation programs are: (1) What is the optimum over-all level of conservation, and hence what total quantity of resources should society invest here? (2) How should given funds be allocated if maximum efficiency is to be guaranteed (17, p. 47)?" Since some range improvements are conservation practices and a good many of them are justified on political grounds under the National Soil Conservation Act, these questions are important to this research. Under our present political-economic system, economic studies probably have more influence in determining the optimum allocation of funds after these funds have been ear-marked for a specific purpose such as range improvements.

Potential conservation funds can be used for intensifying and increasing production on soils which may or may not be subject to permanent deterioration by erosion. In some areas a range improvement practice such as reseeding or spraying may stabilize the soil, stop erosion, and increase forage production on the site. Soil stability could be improved by the introduction of deep rooted perennial grasses or by the increased vigor and size of the resident perennials brought about by spraying. However, in other areas these improvements may increase forage production but have little if any positive effect on soil erosion retardation. Some researchers are of the opinion that the disturbance of the soil caused by reseeding may increase the amount of erosion, both in the long- and short-run.

Range improvements and range conservation are not necessarily synonymous terms. However, the underlying economic principles upon which the criteria are based are essentially the same. It should be remembered that the optimum allocation of investment in soil conservation does not imply an optimum allocation of range improvement investment.

A necessary condition for an economically optimum investment in range improvements is that funds allocated for this purpose be used for practices that do improve the productivity of the range. Some question arises on this point when range improvement funds are spent for cattle guard construction and access road development beyond some given level. This necessary condition does not insure optimum range improvement from a given investment. Nothing has been said about allocation of funds among range improvement practices, which range sites should be improved first, or the level of investment that should be made in these improvements.

To attain the necessary and sufficient conditions for optimum range improvement, present funds should be allocated to improvement practices and to range sites according to their marginal productivity. If the marginal return to spraying is greater than the marginal return to reseeding, then spraying should be undertaken first. Rangeland should be sprayed as long as its marginal return is greater than the marginal return for reseeding. Given two range sites with different productive potentials, the marginal return would be the greatest on the one with the highest productivity potential; thus, this site should be improved first. This criterion is not in accord with the "worst-first" principle mentioned above.

Castle commented on this point in a letter written to the Washington D. C. staff of the BLM (4). He was discussing criteria for conservation investment, but again the underlying principles apply to range improvements. The application to range improvements is apparent in the following:

> In determining priorities the following factors, taken in combination, are relevant:
>
> 1. Select for immediate attention those areas where erosion and depletion are just beginning. Thereafter, give intensive treatment in inverse relation to the extent of the depletion.

2. The most potentially productive sites should be favored over less potentially productive sites for treatment. Because no one knows precisely man's future needs, subjective appraisal will be required for such action.

3. Attention should be given to minimum treatment that will tend to stabilize the situation on highly fragile and badly eroded lands. An example of such a treatment would be fencing for nonuse; inexpensive treatment measures should be sought for lands in this category (4).

The economic criterion discussed in this thesis can be used at any level of decision-making, i. e., on the national level to allocate funds among departments; on the department level to allocate funds among bureaus; on the bureau level to allocate funds among grazing districts; on the district level to allocate funds to grazing allotments; on allotments to allocate funds to different improvements and to different range sites. For optimum allocation of limited funds the criterion should be used at all levels of decision-making. With the above general background of the criteria problem the next section moves into the specific problems and purposes of this study.

Problem and Purposes of the Study

This research was initiated for three main purposes. The first of these purposes was to determine the rate of return on public investment in range improvement practices as measured through domestic livestock use, the most profitable range improvement practice, and the optimum level of improvement. Reseeding, spraying, and meadow fertilization are the improvements considered. The amount of public capital assumed available is varied and a new solution is obtained for each level of available public capital. Purpose number two was to determine the marginal value products (MVPs) for the different grazing seasons on the management unit under study as measured through domestic livestock use. The last purpose was to evaluate the potential usefulness of programming models as an aid to decision making by public land administrators.

To adequately test the analytical tools used the study was conducted for a particular type range-livestock situation where several ranchers use a BLM grazing allotment collectively. The BLM produces range forage for various grazing seasons on the federal rangeland, the ranchers furnish feed for the other seasons plus the livestock to utilize the forage produced on both the federal and private lands. In most cases these two groups, the ranchers and the BLM, are dependent on each other for the use and management of the range resources at their disposal. Because of the interdependence of one group on the other, the returns on public investment in range improvements are tied directly to privately owned resources and the economic situation in which the ranchers find themselves.

To accomplish the first purpose listed above brings up the problem of developing a method of analysis that will take into account the interdependence of the public and private owned resources. The method of analysis should also reflect the economic environment of the ranchers, at least at a given point in time.

The problem encountered in trying to bring about the second purpose of this study is in many ways similar to the first problem, i. e., both public and private resources, as well as the economic situation, must all be considered at the same time. One might go so far as to say that the second problem has to be solved before or simultaneously with the first problem discussed. This is because the MVP of an AUM of grazing is an essential variable in determining the best range improvement practice and the amount of range improvement that should be undertaken. The method of analysis used in this study solves both of these problems simultaneously while considering the interdependence of the public and private resources.

A general resource valuation process and its importance is presented in the following chapter. A framework for making an economic evaluation of range forage is also presented. The use and importance of the MVP of a grazing season is explained and discussed with reference to the above mentioned resource valuation process and framework.

Methods of determining the MVPs of the various factors of production and optimum range improvement are considered in Chapter three. The advantages and disadvantages of budgeting, linear programming, and regression analysis are also discussed in some detail. Reasons for choosing linear programming are presented and discussed.

The early part of Chapter four gives a description of the management unit and the general range area around the study site. Physical-biological procedures used by the cooperating range management personnel are described. Methods of determining the economic input-output coefficients are explained in the last part of Chapter four.

Linear programming models developed especially for this project are presented and discussed in Chapter five. The logic and underlying assumptions of these models are examined and analyzed as to their effect on the results obtained. From 10 to 20 different solutions are computed for each model, one for each level of public capital assumed. Starting essentially from zero, public capital is increased until its MVP is less than one dollar. When the MVP of public capital is less than one dollar this means that the return per dollar invested does not cover all of the investment cost. Only a few of these solutions where significant changes occur in land use, in the MVP of public capital, or in the investment required by one of the ranchers are analyzed in any detail. The changes in land use patterns as more range improvements are made are traced out over the different levels of public investment. Internal rates of return are computed for almost every level of public investment. These internal rates of return can serve as choice indicators for the public land management decision-maker. The initial solution which starts with essentially zero public capital is tested to see if the sum of the MVPs of each factor times the quantity of the factors used equals the total adjusted income to the ranchers.

Other uses and implications of the results of this study are discussed in Chapter six. For example, the weighted average MVPs of public grazing can be used to estimate the productive value of the rangeland. These MVPs can also be used as an estimate of the value of increased grazing to be used in benefit-cost analysis.

CHAPTER II

RESOURCE VALUATION PROCESS

Resource valuation is fundamentally a problem of allocating the total product resulting from a production process to the factors which are involved. The returns attributed to the various factors are used in the determination of the most efficient allocation of resources. Since efficient allocation of resources is generally taken as one of the goals of this economic system, the economist is very much interested in finding the return to each factor of production.

"Resource prices serve the function of allocating resources among different uses and different geographic areas. Resources are correctly allocated when they make their maximum contribution to net national product (25, p. 323-324)."

If pure competition in product markets and resource markets prevails, resources will be automatically allocated to maximize net national product. Misallocation of resources occurs when the MVP of a factor differs in different employments. Resources will be transferred from lower to higher MVP uses until they are all equal under pure competition. At this point the MVPs will be equal in all uses and the price of the factor will be the same as its MVP (25, p. 323-324).

There are a number of factors in the real world which prevent the most efficient allocation of resources from occurring.

Misallocation of resources can come about even with the free operation of the price system as a guide. Monopoly in product markets, monopsony in resource markets, certain non-price impediments, and interferences with the price mechanism are four causes of misallocation of resources. The problem area in this study has elements of at least the last two causes of misallocation of resources.

Institutional factors and interferences with the price mechanism act as barriers to the proper allocation of federal range resources. For example, grazing privileges were granted on some basis other than the most efficient use of the resource. Also the fees charged for using these resources have never been set to reflect the MVP of the grazing.

Ranchers were given grazing allotments based on the following four considerations. First consideration was given to applicants whose property, in land or water, within a grazing district was sufficient to care for their livestock during periods of unfavorable range conditions and who had used this property for such purposes for three years out of the five preceeding January 1, 1935. Second consideration was given to those ranchers who could demonstrate prior use but did not own commensurate property. The last consideration was given to a group designated as "other qualified applicants". Most of the successful applicants fell in the first group. However, some former users could not qualify for grazing permits (34, p. 228-229).

The first grazing fees were set up to cover the cost of administration plus some range improvements. Fees were originally set at $ .05 per AUM in 1936. The fees were distributed in the following manner, 25 percent for range improvements and maintenance, 25 percent general fund treasury, and 50 percent to the state in which the land was located. On May 1, 1947 the fees were set at $ .08 per AUM, $ .06 went for grazing fee and $ .02 for range improvements (34, p. 267-276).

In August 1954, the National Advisory Board Council agreed to a fee system based on the combined prices of cattle and sheep in the 11 Western States. Since 1954 the fee has been increased above the combined (average) price of cattle and sheep but this change had very little if anything to do directly with the MVP of an AUM of grazing. Federal land grazing permits supposedly have no value in and of themselves since they are privileges and not rights. However, because the fees do not equal the MVPs of these seasonal AUMs of grazing, the difference has been capitalized into the value of the comensurate private properties and/or the grazing permits. It is not uncommon for these permits to be sold for substantial sums of money. Before being allowed to transfer these permits the purchaser has to show control of enough private property to carry the livestock while not on the Federal range. Many ranchers have permits that are too small for an economical unit under present conditions.

Because of these institutional barriers and the insecurity of the grazing permits, reallocation of resources toward a more efficient use is stifled. Ranchers find it too expensive and/or too risky because of the insecure tenure of these grazing permits to try to increase the size of their operation. The BLM sets up grazing allotments, individual and community, which act as further blocks to proper allocation of resources. For example, suppose allotment X has excessive amounts of forage due to range improvements while allotments Y and Z are short of feed. Ranchers in allotment X go to great lengths to prevent ranchers having permits in allotments Y and Z from being allowed to graze allotment X. This type action is quite rational and to a large degree justifiable if the range in allotment X is better because of the actions of the ranchers using it and especially if they have invested a good deal of private capital in this public resource. It can be seen that there are areas where the most efficient allocation of resources is not taking place.

Before going further into the resource valuation process a framework is needed to help explain and establish the logic behind an economic evaluation of range forage. Johnson and Hardin have developed a general forage evaluation framework (21, p. 1-20). Many of the concepts they developed can be applied to an economic evaluation of forage produced on federal and private rangeland. However, when a public land agency is the decision-making unit some difficulty arises in making a direct application of these concepts.

One important use of forage value estimates was mentioned above in the discussion of resource allocation. There are other places where these value estimates can be used. A value of range forage is needed to compare with the costs of new seeding practices or the costs of seeding new grass species. The value of the range forage is important to the public and/or the private decision-maker when deciding to improve or not to improve a block of rangeland. As competition for use of federal lands increases, the value of forage used by animals, both domestic and wild, is important for making an allocation of the resource between uses. Every few years the problem of setting new grazing fees comes up. A value of the range forage could be used as a reference point even if the goal is not to maximize returns to the public agency. Finally, this forage value would be useful as an annual return figure to be capitalized when appraising the productive value of federal rangeland.

What is range forage worth? This question can be answered in several ways, depending on the point of view of the interested party. Some want to set the value of the forage equal to the value of the animal turn-off from the range (animal turn-off would be weight gain of the cows, calves, steers, etc.). Others say range forage is worth as much as the cheapest alternative feed that will produce the same animal product as the range forage. Still others claim the range forage is worth an amount equal to its contribution to total ranch income. It is quite likely that these forage values will not all be equal, so care must be taken to avoid being confused by these different values.

Johnson and Hardin applied the economic theory of input pricing to forage evaluation. They came up with three ways of pricing forage as a feed input for livestock: (a) purchase (acquisition) price, (b) sale (salvage) value, and (c) MVP (use value) (21, p. 5-6).

a - Purchase price or acquisition cost: This would be the cost of establishing a range seeding by the most economical means. For a rancher grazing federal lands it could be the cost of getting an AUM of feed from some other source such as buying hay or leasing private range.

b - Salvage value: This price is probably low in the case of the federal lands considered in this study. The only alternative uses available for these lands are for soil erosion control, wildlife habitat, and some recreation. A rancher might have an off-ranch sales opportunity however.

c - Marginal value product: This price of range forage on a given ranch or the weighted average MVP for several ranchers on a community allotment is what the forage is worth at the margin in producing livestock and livestock products. The MVP or use value depends on the ranch organizations, the production relationships, the market situation during a particular period, and on the amount of forage available.

The MVP may be greater than the acquisition price, less than the salvage value or somewhere in between. The relationship between the MVP and the two market values is important in decision making. This relationship is presented graphically in Figure 1.

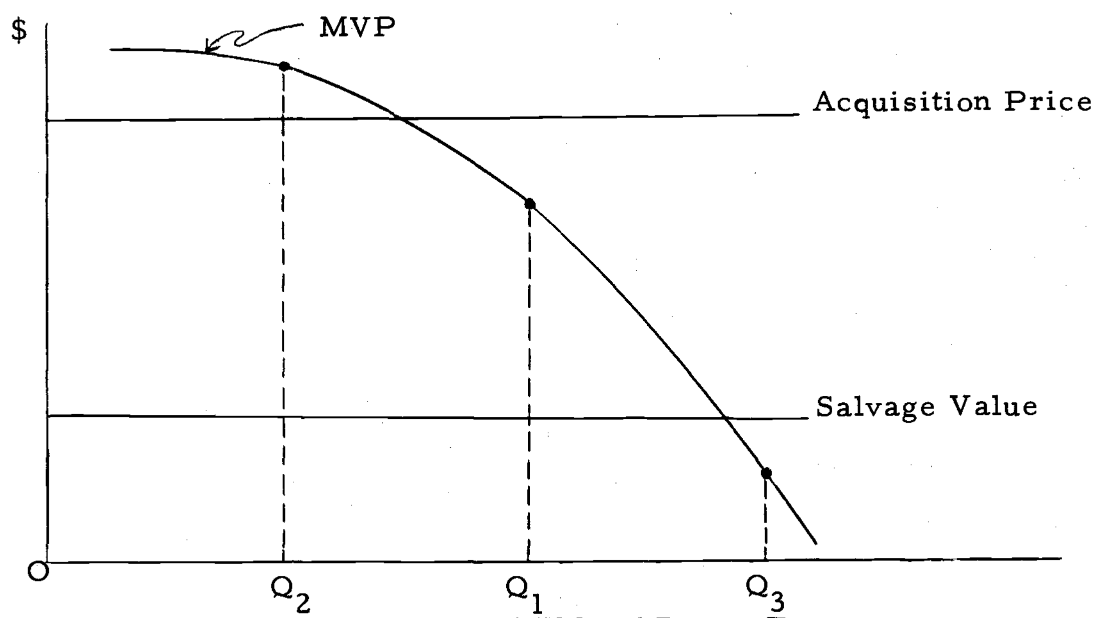

Figure 1. Relation of acquisition and salvage value to marginal value product of range forage.

When quantity OQ_2 AUMs of range forage is used its MVP is greater than its acquisition cost so more AUMs of range forage should be purchased. As more AUMs of range forage are added, the MVP falls until it is less than the acquisition price but greater than the salvage value. The MVP at quantity OQ_1 is within this interval between salvage value and acquisition price. When the MVP of an AUM of range forage lies between the acquisition price and the salvage value there is no incentive for off-ranch forage transfers. However, if the MVP were below the salvage value, as it is at quantity OQ_3, the decision-maker should sell AUMs of range forage until the MVP is above the salvage value. He would be better off to sell the forage because its salvage value would be greater than its return when used in the ranch organization.

The above analysis suggests that the value of range forage be:

(1) Not less than the highest net value realizable by the salvage value.

(2) Not more than the cost of acquiring by the most economical means available additional forage units or their equivalent (acquisition price).

(3) Equal to its MVP if its MVP falls between the limits of (1) and (2) above (21, p. 19).

Estimating the MVP of range forage is an important task of the researcher using this framework. Several analytical tools are available for estimating the MVP of range forage. Some of these tools are discussed in the following chapter.

CHAPTER III

METHODS OF DETERMINING MVPs OF FACTORS OF PRODUCTION

Budgeting or residual imputation, linear programming, and multiple regression analysis are the methods often used to determine these returns. Each one of these methods has its own advantages, disadvantages, and limitations.

Budgeting

The oldest of these methods is budgeting which was introduced in economics over 75 years ago. A budget is defined as an estimation of possible changes in costs and returns in a given time period when there is a contemplated change in the use of production resources (10, p. 33). This technique is a powerful tool that can be used as a decision-making aid in the allocation of scarce resources. Trial estimates of expected costs and returns can be made before committing resources to a new plan. Budgeting is based on theories relating to equilibrium of the firm. Budgets can be made for the entire ranch organization and/or partial budgets can be used to estimate MVPs for changes in the use of a resource. The similarities and differences of budgeting and other methods will be discussed in a later section.

Linear Programming

Linear programming originated largely during World War II as a method of finding minimum distance routes for the limited shipping facilities available (18, p. 1). It was later developed into a tool that could be used in maximization and minimization problems in agricultural economics. Using this technique a unique value-weighted solution to a set of simultaneous linear equations in which the number of unknowns may exceed the number of equations and in which no variate has a negative value can be obtained (29, p. 4).

The general linear programming problem can be written as follows:

maximize the linear function

$$F = C_1X_1 + C_2X_2 + \cdot \cdot \cdot + C_nX_n$$

subject to

$$A_{11}X_1 + A_{12}X_2 + \cdot \cdot \cdot + A_{1n}X_n \leq b_1$$

$$A_{21}X_1 + A_{22}X_2 + \cdot \cdot \cdot + A_{2n}X_n \leq b_2$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$

$$A_{m1}X_1 + A_{m2}X_2 + \cdot \cdot \cdot + A_{mn}X_n \leq b_m$$

$$X_i \geq 0, \ (i = 1, \ . \ . \ . \ , n).$$

where the A_{ij}s, B_is and C_js are known constants.

It is necessary to make the following four assumptions when using linear programming: linearity, divisibility, additivity, and finiteness (11, p. 1238-1245).

Linearity

This means that the input factors are combined in fixed proportions at all levels of output and that the amount of resource used to produce a unit of a particular output is the same regardless of the output. This would appear to disregard all economies and diseconomies of scale but a linear programming model which is properly developed can be made to reflect these conditions for a particular situation. By changing the restrictions or the amount of one of the inputs, a non-linear function can be approximated; these linear segments can be as narrow as the researcher desires. For example, consider the situation in Figure 2.

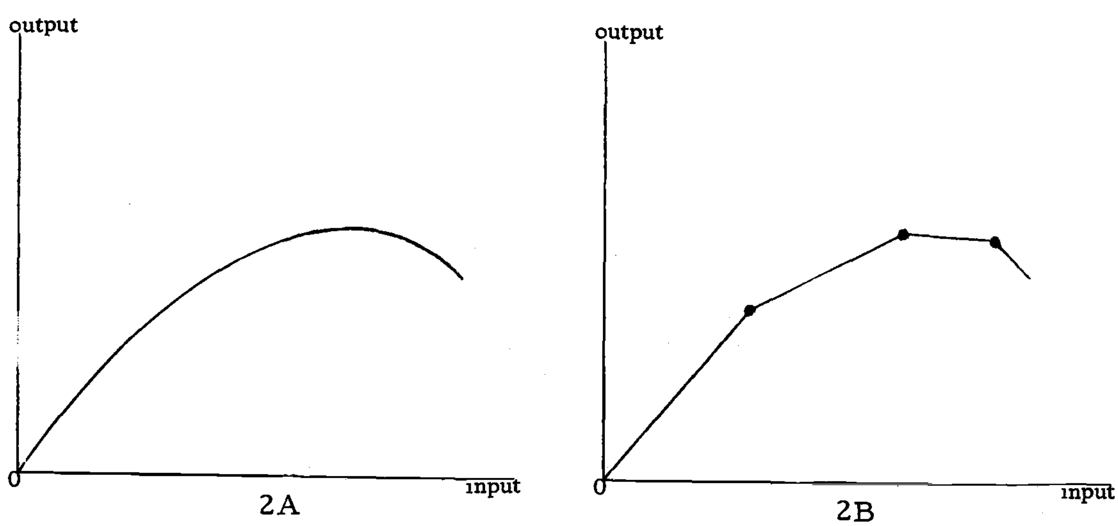

Figure 2. Linearized approximation to a continuous production function.

Figure 2a represents a production function with diminishing returns, Figure 2b is an approximation of it using linear programming. Thus the assumption of linearity does not restrict the use of this technique for many problems.

Divisibility

It is assumed that factors can be used and products produced in quantities which are fractional units. For example, a program of activities may be specified which uses 102.7 acres of reseedable range, 100.8 dollars of capital and 59.6 AUMs of April grazing to aid in the production of 105.6 cows. This assumption is not serious since rounding to the nearest unit can be done without having any serious effect on the decision-making process. Integer programs have been developed to overcome this problem but will not be used in this study.

Additivity

This assumption states that the total amount of resources used by several different enterprises must be equal to the sum of the resources used by each of the individual enterprises. No interaction exists between the resource requirements when products are produced jointly. In cases where there is an interaction factor, such as an alfalfa-corn rotation system, the interaction can be handled by adding new activities for distinct combinations of alfalfa and corn. This assumption is not restrictive in the problem to be analyzed in this research.

Finiteness

It simply means there is some limit to the number of activities and resource limitations which need to be considered in a problem. Selection of the most significant activities and resource limitations is an important function of the researcher. As larger problems are analyzed using linear programming, a decision has to be made as to the amount of detail required and the interpretability of the results. This assumption does not usually limit the use of this type analysis, especially when high speed computers are used in solving the problem.

None of the above assumptions seriously restrict the use of linear programming for the purposes intended in this study. It has many advantages over other methods that will be discussed below.

Comparison of Linear Programming and Budgeting

Linear programming and budgeting are basically the same procedures and under given circumstances would yield identical solutions. When the budgeting approach is used all but one of the factors must be valued prior to obtaining a solution. The solution of the partial budgets will yield the MVP for changes in the use of this one factor.

A concept used in economics known as "Euler's theorem" states that if each factor is paid the value of its marginal product (MVP), the value of the total product will just be exhausted under conditions of constant returns to scale (19, p. 64-65). When the MVP of each factor equals its price in all uses the most efficient allocation of resources is accomplished. The implicit assumption made in budgeting is that the prices of the other factors are equal to their MVPs and therefore the computed MVP for the factor of interest is correct (16, p. 763-793). The MVPs computed by the linear programming procedure are not dependent on this assumption and can be compared to their individual prices. If the factor prices equal the MVPs for each factor then identical solutions would be obtained from linear programming and budgeting, assuming the optimum plan was budgeted.

Another limitation or disadvantage of budgeting is that one never knows if the optimum plan has been considered. It could be that plan A is shown to be better than plan B but a plan C, not considered, may be better than plan A. A great deal depends on the experience and knowledge of the analyst in deciding on which plans to budget. Some budgets probably come very close to the optimum plan. The optimum plan, given the proper activities and constraints, can always be determined by linear programming. Algebraic signs of a set of residual values in the computational procedure indicate when the optimum allocation is reached within the alternatives outlined in the model. For large complex problems, being assured of obtaining the optimum plan is very important, thus making linear programming more advantageous than budgeting.

Linear programming routines have been developed for most of the electronic computers which makes possible handling problems with many alternative activities and resource restrictions. In a large portion of the cases it is cheaper to use the computers for solving linear programming problems than to work out budgets. Linear programming offers the only feasible procedure for analysing the problem in this study.

Multiple Regression Analysis

This type of analysis has the advantage of solving a system of simultaneous equations to obtain the returns to various factors. But there are some disadvantages that limit its use in estimating returns to various range improvement practices. Biases are introduced by the non-optimum aggregation of inputs and the non-optimum aggregation of outputs which puts doubt on the validity of the MVP estimates (37, p. 664-675). Also because of funds, computational facilities, non-measurability, etc. variables are excluded, approximations are accepted, aggregations are made, and various other errors of omission and commission are made. These are called specification errors (37, p. 664-675). These errors further bias the estimations. At the present time this method does not seem to be a feasible alternative to linear programming.

For the purposes of this study, linear programming offers the best procedure for estimating the MVPs of different range input factors. The MVPs are determined simultaneously, thus reflecting the value of the factor to the entire ranch operation. For example, the MVP of an AUM of April grazing takes into account all of the other inputs that are used in producing the livestock and livestock products. This is more logical than an animal turn-off value which only considers one grazing season, one type of range, and does not consider the other factors required to keep the animals through the entire year. The MVP of an April AUM of grazing has an upper limit equal to its purchase price or the price of the cheapest alternative feed that will produce the same net value product.

Linear programming is used as a decision-making tool to aid in the decision as to what range improvements should be undertaken. It also indicates how many acres of land can profitably be improved under the assumptions built into the model. Valuable information can also be gained for determining the optimum season to use the different types of rangeland. The close interrelationships between public and private decision-making are shown by the linear programming models to be presented later.

CHAPTER IV

INPUT DATA FOR THE MODELS

Physical and Biological Coefficients

A management allotment, centered about a block of federal rangeland grazed in common by nine cattle permittees, was selected. This selection was made on the basis of the number of ranch units in the allotment and on the representativeness of the ranches and range area.

The East Cow Creek Allotment of the Vale District of the BLM was selected. This allotment is located just north and west of the town of Jordan Valley in Malheur County, Oregon. The rangeland and types of cattle operations are quite typical of the high desert range country.

This area is essentially a plateau with some east and southeast oriented low ridges. The elevation varies from 4,000 - 4,800 feet above sea level. There are areas of the allotment which are too steep to plow while others are too rocky to plow. Some areas are covered by comparatively recent lava flows which are practically void of vegetation.

The semi-arid climate of the study area is characterized by warm, very dry summers, and cold winters. Danner, located near the center of the study area, has a 20-year mean annual precipitation of 11.26 inches. Most of the moisture occurs as snow between the months of

November and March. A secondary rainy period, however, usually occurs in May or June. The 20-year mean monthly precipitation shows that May is the wettest month of the year. Mean monthly temperature exceeds 40° F. for the period April through October. Average annual runoff from the area is less than an inch (7, p. 3-12).

A joint study was set up between the Department of Agricultural Economics and the Department of Range Management. BLM personnel at the federal, state, and local levels and the ranchers involved agreed to cooperate in the study. The Department of Range Management furnished the physical-biological yield coefficients to be used in the linear programming models.

These data are based on information collected during the summer of 1963 and on the personal experience and judgement of the Range Management staff. Other research information was used to support these data where applicable. It is recognized that one year's data are not sufficient to make precise estimates of these coefficients. On the other hand, if linear programming is going to be of practical value as a decision-making tool for deciding on range improvement practices, these estimates should be precise enough to give reasonable results. It would be interesting to have these data collected over a period of years, thus increasing the reliability of the estimates, then re-run the programs to see how accurate the original estimates really were. If both runs gave results that were reasonably close to being the same, much more confidence could be placed in the coefficients estimated on limited information. By "reasonably close" it is meant that the same general decisions would be made in either case.

Early in the spring of 1963, 34 plots (17 paired plots) were set up in and around the East Cow Creek Allotment. One plot of each pair was on native unimproved rangeland and the other plot was on improved range. The plots in each pair were located quite close together on sites as much alike as possible. These plots were fenced to prevent grazing by livestock.

Forage clippings were made to determine the differences in yields between the improved and unimproved plots. Four 9.6 square foot sections were clipped in each of the 34 plots. Soil holes were dug on each site so that a description of the soil could be made. In addition, an ecological classification was determined for each site. By using this type of information it was possible to tie potential production to various range sites.

Range Management also provided estimates of the amounts of rangeland, federal and private, which fell into the following categories: reseedable, sprayable, and other range. "Other range" was broken down into other "good" (range too good to be reseeded or sprayed) and other "poor" (range too poor for reseeding or spraying because of topography, soil, and perennial grass understory).

In order for a block of land to be classified as reseedable it had to have the following characteristics: (1) soil well enough developed to support a stand of crested wheatgrass (Agropyron cristatum); (2) topography and vegetative cover such that it could be physically prepared for seeding, i.e., not too steep, no brush species or trees that could not be plowed over, and a minimal amount of rock out-croppings; (3) the perennial grass understory so depleted that spraying would not be feasible and; (4) in large enough blocks to be practical for seeding and management. Sprayable range would be range-land with a fair to good understory of perennial grasses, with the potential of increasing in growth and vigor given a reduction in competition from the brush species and a rest from grazing. Again, sprayable tracts should be large enough for economical spraying and management.

Aerial photos of the entire allotment, including the private land of the permittees, were obtained. These photos were used by trained range technicians to delineate various range types. A technician would go out on a given segment of the allotment, locate this segment on the aerial photos, and make pencil delineations of the various range types on the photos. Next a visual inspection would be made of the types delineated in order to determine the dominant brush species, the dominant specie of understory grass, and an estimate of the herbage production per acre. The three technicians worked as a group until their estimates of production and composition were uniform. At periodic intervals of time they would clip forage and weigh it to determine if their estimates of production were still reasonably accurate. A code giving the above information was also noted on the photos for each of the delineated range types. This mapping procedure was carried out for the entire allotment and the commensurate properties.

Big sagebrush (Artemisia tridentata), low sagebrush (Artemisia arbuscula), and rabbit brush (Chrysothamnus sp.) were the dominant brush species encountered on this allotment. Cheatgrass (Bromus tectorum) and blue bunch wheatgrass (Agropyron spicatum) were the dominant grasses with some sandberg bluegrass (Poa secunda) and Idaho fescue (Festuca idahoensis) in some areas. Herbage production classes were: (a) less than 100 pounds per acre; (b) 100-200 pounds per acre; and (c) over 200 pounds per acre.

In making this resource inventory, an emperical ecological classification was made and rather broad delineations were used. In so doing, it is recognized that there are some inclusions and that each delineation is not necessarily a homogeneous unit. However, they were mapped on the basis of sound ecological principles. Within each of these delineations the breakdown of range productivity was somewhat arbitrary. It was felt that by breaking production down into the three yield categories that a more precise treatment of actual range conditions could be presented.

When all rangeland on a particular photo was classified and outlined, the codes and outline were traced on acetate overlays. These acetate overlays were used in the computation of the actual acres in each of the delineations. A square inch grid system with the appropriate conversion factor was used to determine the acreages that fell into reseedable, sprayable, other "good", and other "poor" rangeland categories.

With the acreages computed and the estimated yields of the various classes of rangeland it was possible to convert to acres per AUM or carrying capacity. Eight hundred pounds of air dried forage was used as the feed requirement per AUM. These conversions were made assuming the following percentage utilization figures: (1) 75 percent of the available cheatgrass would be used; (2) 50 percent of the blue bunch wheatgrass available would be used; (3) 66 percent of the crested wheatgrass available would be used; (4) rangeland used only during the month of April would have a 50 percent carry over to be used the next April.

All of the forage yield data were adjusted using the "yield index" set up by Sneva and Hyder (39, p. 1-11). Several sources of weather data in the immediate vicinity of the allotment were used in order to give a better index number.

For the purposes intended in this study the above outlined method of obtaining a resource inventory and yield estimates appears to be sufficiently accurate. This was also an efficient means of getting these data. It should be kept in mind that these data were obtained by technicians trained in range resource management and based on their experience and judgement. The particular input coefficients derived from these data will be discussed in more detail in the section describing the construction of the linear programming model. It should also be noted that these coefficients do not necessarily reflect the management that is being used on this allotment but they are based on what these professional range managers believe the management ought to be. It is important to keep this in mind when considering the results of the study.

Economic Input - Output Coefficients

A meeting was held with the five ranchers who control 90 percent of the grazing permits on the East Cow Creek Allotment. The research project was explained to them and they agreed to cooperate by giving information relative to costs and returns for their individual ranch businesses. Ranch budget data were collected for the calendar year 1962. A personal interview was made with each rancher in late December 1962 and early January 1963. It was hoped that this would reduce memory bias. These data were summarized and a net return per unit of breeding herd was calculated for each ranch.

Net return per unit of breeding herd is the gross return per unit of breeding herd minus the variable costs. The assumption is made that the variable inputs are receiving a price equal to their MVPs. Returns to the fixed factors are maximized by the procedures build into linear programming. An alternative assumption might be made, i. e., if there is any surplus it will be distributed to the fixed factors. In this study all costs were deducted except the costs of the fixed factors being considered in the linear programming model, such as private rangeland, private meadow, public rangeland, and public capital.

Five ranch operations accounted for about 90 percent of the use on this allotment. Because of complicated tenure arrangements and lack of computer capacity, only four of these operations are considered. However, they account for over 80 percent of the use on the allotment.

The net return calculated for these ranches varied from ranch to ranch. Some of the variation was due to the type of operation, such as cow - calf - yearling or cow - calf. Efficiency due to size was another factor causing variation. Management was probably the most important factor causing variation. However, no attempt was made to adjust for differences in management, and each ranch was taken as it operated in 1962. These ranch budgets are presented in Appendix A.

Costs of Reseeding

Many publications have been put out dealing with the costs of reseeding rangeland. These costs differ from area to area because of the physical characteristics of the sites and other related factors. Changes come about through time as improved equipment is developed for plowing and seeding. In some areas competition among those contracting to perform this service has reduced the cost substantially.

Seed costs are quite high for some grass varieties until seed producing areas are developed. The cost of crested wheatgrass seed has decreased substantially in the past few years. Whitmar wheatgrass seed is high in price compared to crested wheatgrass seed. But if the demand for whitmar wheatgrass increases, a source of supply could well be developed that would cause a drastic reduction in its price.

Management in the proper use of seeding equipment and in site selection is another very important factor in determining the cost and success of a range reseeding project.

Lloyd in 1960 reported an average initial investment of $8.92 per acre for reseeding some 54,000 acres of BLM rangeland in Utah. He also found related fencing investment to be $ .96 per acre on the average, with an annual charge of $ .08 per acre for maintenance (27, p. 3-9). A study of Colorado sagebrush ranges by Gardner in

1961 shows an average cost per acre of reseeding of $7.73 (13, p. 2). Caton and Beringer in 1960 found the average cost per acre of reseeding to be $7.52 on southern Idaho rangelands (5, p. 14). Pingrey and Dortignac in 1957 found reseeding costs to vary from $6.00 - $9.00 per acre in a New Mexico study (36, p. 1). In a report published in 1962, McCorkle and Caton list clearing and seeding costs at $11.25 per acre (30, p. 40). They also used $ .60 per acre as a cost for fencing of the seedings.

The seeding cost per acre used in this study is based on projected reseeding costs in the East Cow Creek Allotment and adjacent areas. These cost estimates were obtained from the BLM staff of the Vale grazing district in 1963 (Table I).

TABLE I. RESEEDING COST ESTIMATES FOR CRESTED WHEATGRASS[a]

Initial Costs:	
Plowing and Drilling	$9.71 per acre
Fencing	.99 per acre
Water Developments	2.20 per acre
Non-use	.63 per acre
	$13.53
Annual Costs:	
Fence Maintenance	$ .08
Water Maintenance and Use	.10
	$ .18
20 Year Life of the Seeding:	

$$\frac{\$13.53}{20} = \$\ .68 + \$\ .18 = \$\ .86 \text{ per acre per year}$$

[a]Based on 6 reseeding projects planned for the next few years (see Appendix B).

It was assumed that the BLM staff had a better basis for estimating these costs than could have been obtained from secondary sources. Thousands of acres of BLM rangeland have been reseeded in the Vale district so they have a large number of cases on which to base their estimates.

The initial investment for plowing and drilling ($9.71) seems rather high compared to the studies cited above. However, the assumption is being made that at this cost a 95 - 100 percent brush kill will be forthcoming and that proper care will be exercised to insure correct seeding rate and seed cover. It is further assumed that a seeding will last 20 years without more investment. Length of seeding life is somewhat arbitrary at best. It depends on many factors, some of which can be influenced by management while others cannot be influenced by management.

Gardner footnotes some information from the Intermountain Forest and Range Experiment Station where crested wheatgrass stands are still vigorous after 20 years (13, p. 6). He goes on to use 30 year life in his study. McCorkle and Caton required a complete reseeding program every 10 years (30, p. 40).

Some reseeded rangeland in the vicinity of the study area has very little sagebrush encroachment after five to eight years, while other seedings have considerable sagebrush invasion in three to five years. Based on information available and the judgement of the cooperating researchers trained in range management the 20-year life figure was decided upon.

Costs were computed for two years' non-use on the seedings. The number of AUMs of grazing for a two year period (based on unimproved carrying capacity) foregone were valued at $3.00 per AUM. The $3.00 per AUM is based on private grazing fees reported in Utah in 1961 (33, p. 4).

Costs of Spraying

All of the spraying considered in this study is aerial spraying for the control of sagebrush and rabbit brush. Krenz reported total aerial spraying costs ranging from $2.70 to $4.00 per acre in Wyoming during 1960 (22, p. 9-10). He also stated that the costs of chemicals had decreased about $ .40 per acre by 1962 when the publication came out. This would put the costs at $2.30 to $3.60 per acre. In the Krenz study two pounds of 2,4D ester per acre in diesel oil at a total volume of two gallons per acre was recommended.

McCorkle and Caton report aerial spraying costs of $3.00 per acre (30, p. 40). One-half of this amount was for materials the other half for application. The chemical used was 1.5 pounds of 2,4D in five gallons of water plus .025 gallons of liquid detergent per acre.

Again, as with seeding costs, the spraying costs used in this study are based on projected spraying costs for the East Cow Creek Allotment and adjacent areas. The spraying costs are summarized in Table II.

TABLE II. AERIAL SPRAYING COST ESTIMATES[a]

Initial Cost:	
Spraying (including materials and application)	$3.42 per acre
Fencing	.28 per acre
Water Developments	.67 per acre
Non-use	.33 per acre
	$4.70
Annual Costs:	
Fence Maintenance	$ .03
Water Development Maintenance and Use	.02
	$ .05

12 Year Life of the Spraying

$$\frac{\$4.70}{12} = \$\ .39 + .05 = \$\ .44 \text{ per acre}$$

[a]See Appendix C.

Non-use in the case of spraying is for deferrement until after the grasses mature for two years. This would amount to a loss of about one-half the use each year or one year's non-use. The perennial grasses are given a chance to increase in vigor during this two year period.

The initial cost of spraying is somewhat higher than some of the more recent estimates from the Vale office of the BLM. At the cost used in this study it is assumed that a high percentage brush kill will be forthcoming and the spraying will last at least 12 years before having to respray for brush invasion.

Costs for fencing and water development are substantially less for spraying projects than for reseeding projects. In the area of interest it requires less fencing and water development to get the level of range management desired.

Based on ranchers' estimates, Krenz used a 13 year life for sprayings (22, p. 14). McCorkle and Caton reported spraying every four to six years depending on the range improvement plan (30, p. 40).

Given the costs used it was thought by the researchers involved that a spraying should last at least 12 years in the study area, i. e., a good enough kill of the brush species should be forthcoming from this much investment to last 12 years.

Cost of Meadow Fertilization

Nelson and Castle found application of up to 100 pounds of nitrogen fertilizer per acre economical, the specific amount depending on the price of beef cattle (32).

A study was conducted in Nevada on the economics of meadow improvement in 1960. This study considered more improvements than fertilization so it was not possible to isolate the effects of fertilizer (12).

Willhite listed the following meadow hay yield responses to the application of nitrogen:

Oregon:

0 pounds of nitrogen per acre	1. 8 tons of hay per acre
50 pounds of nitrogen per acre	2. 6 tons of hay per acre
0 pounds of nitrogen per acre	1. 6 tons of hay per acre
60 pounds of nitrogen per acre	2. 4 tons of hay per acre

Idaho:

0 pounds of nitrogen per acre	1. 7 tons of hay per acre
50 pounds of nitrogen per acre	2. 4 tons of hay per acre
80 pounds of nitrogen per acre	3. 0 tons of hay per acre

He went on to say; "About three-fourths of the high elevation meadow land in the west is producing forage at only about one-fourth of its economic capacity. The remainder is producing about one-half what it should (44, p. 5-8)."

Time and research funds did not allow the carrying out of experiments on the meadows of the cooperating ranches; therefore, estimates of the potential yields given some application of nitrogen on these meadows had to be gained from other sources. The most logical place to get this data was from the Squaw Butte - Harney Branch Experiment Station. This station is located about 130 miles from the study area. The physical data for the Nelson - Castle article cited above was collected at Squaw Butte.

Cooper, an Agronomist at Squaw Butte, found the average increase in yield from the application of 60 pounds of nitrogen to be three-fourths of a ton per acre (6 , p. 2). From this data it was decided to use an application of 60 pounds of nitrogen per acre with an expected increase in yield of .75 tons per acre. The ranchers in the study area have never fertilized any of their meadows and estimate the yield to be one ton per acre on their unimproved meadows.

In order to get 60 pounds of nitrogen it would require the application of about 180 pounds of ammonium nitrate or 300 pounds of ammonium sulfate per acre. The 1963 prices of ammonium nitrate and ammonium sulfate were around $90 per ton and $60 per ton respectively. Thus the cost of fertilizer would be between $8.10 to $9.00 per acre. The cost of application has to be added on to these figures. For this study an annual cost of $8.60 per acre for 60 pounds of applied nitrogen is used. It is assumed that this will increase the yield of meadow hay from one ton per acre to 1.75 tons per acre.

CHAPTER V

LINEAR PROGRAMMING MODELS

The linear programming models used in this study were developed to determine the optimum allocation of resources on this allotment under various assumed conditions. Brown (1961) developed a linear programming model to estimate rates of return from investments in range improvements (3). Only one rancher was considered in this study and only a few grazing seasons. The relationships between public and private investment are not brought out. Much of the underlying logic used in Brown's paper is used in this study. Another range improvement study using linear programming was made by Barr in 1960. He found native grass reseeding to be economically feasible at the 21-24 percent capital rate (1 , p. 125-126). He analyzed some of the alternatives open to ranchers in Oklahoma. Brush control activities came into the solution with ACP cost sharing at the 11-14 percent rate, without ACP cost sharing at the 6-9 percent rate. A bermuda grass establishment activity came into the solution with ACP cost sharing at the 16-19 percent level when used for hay and at the 6-9 percent level with ACP cost sharing when used for grazing. Barr's linear programming models are very well constructed and logically complete; however, his situation was not concerned with investment in federal range resources or different grazing seasons. About the only similarity between the models developed by Barr and the ones used in this study is that they both deal with range improvements in some form.

Model I

The first model developed for this study is presented in Table III. The economic and physical coefficients used were discussed in Chapter four. One of the important assumptions made in this model is that the number of AUMs of federal grazing taken by each rancher will remain in a fixed ratio one to another. For example, if Rancher I is getting ten percent of the available AUMs initially, he will get ten percent of the total AUMs regardless of how many additional AUMs are produced by range improvements.

Only four of the nine ranches in the allotment are considered. However, these four ranches account for 82 percent of the use on the federal land in this allotment. A problem of limited computer space had to be faced in constructing the model. Therefore, an attempt was made to maximize the use of the available memory space. As mentioned in the introduction, at least one rancher was omitted because of complicated tenure arrangements which made it impossible to separate out costs associated with his own ranch operation (this ranch accounted for about eight percent of the total use on the allotment). To account for the 82 percent restriction, the federal

TABLE III. LINEAR PROGRAMMING MODEL I WHERE EACH RANCHER'S RELATIVE SHARE OF USE ON THE

		Resources	Unit	B_is P_o	Apr. 1 May 1 P_1	May 1 July 1 P_2	May 1 Aug. 1 P_3
	1	Reseeded range	Acres	3,874.0	-	-	-
	2	Reseedable range	Acres	9,499.0	9.5	7.7	8.0
	3	Sprayable range	Acres	4,517.0	-	-	-
	4	Other (good) range	Acres	1,034.0	-	-	-
	5	Other (poor) range	Acres	22,117.0	-	-	-
	6	Public capital	$	10.0	-	-	-
	7	Meadow	Acres	270.0	-	-	-
	8	Capital	$	.0001	-	-	-
	9	Apr. 1 - May 1 grazing	AUMs	.0002	-.0629	-	-
	10	May 1 - June 1 grazing	AUMs	.00003	-	-.03145	-.0210
	11	June 1 - July 1 grazing	AUMs	.0004	-	-.03145	-.0210
R I	12	July 1 - Aug. 1 grazing	AUMs	.0005	-	-	-.0210
	13	Aug. 1 - Oct. 1 grazing	AUMs	.0006	-	-	-
	14	Oct. 1 - Nov. 20 grazing	AUMs	270.5	-	-	-
	15	Hay	Tons	.00001	-	-	-
	16	Meadow	Acres	923.0	-	-	-
	17	Capital	$	.00022	-	-	-
	18	Apr. 1 - May 1 grazing	AUMs	.0003	-.6112	-	-
	19	May 1 - June 1 grazing	AUMs	.00044	-	-.3056	-.2037
	20	June 1 - July 1 grazing	AUMs	.00055	-	-.3056	-.2037
R II	21	July 1 - Aug. 1 grazing	AUMs	.00066	-	-	-.2037
	22	Aug. 1 - Oct. 1 grazing	AUMs	.0007	-	-	-
	23	Oct. 1 - Nov. 20 grazing	AUMs	474.0	-	-	-
	24	Hay	Tons	.005	-	-	-
	25	Meadow	Acres	80.0	-	-	-
	26	Capital	$	.00023	-	-	-
	27	Apr. 1 - May 1 grazing	AUMs	.00011	-.2437	-	-
	28	May 1 - June 1 grazing	AUMs	.0011	-	-.12185	-.0812
	29	June 1 - July 1 grazing	AUMs	.011	-	-.12185	-.0812
R III	30	July 1 - Aug. 1 grazing	AUMs	.0012	-	-	-.0812
	31	Aug. 1 - Oct. 1 grazing	AUMs	.00012	-	-	-
	32	Oct. 1 - Nov. 20 grazing	AUMs	209.0	-	-	-
	33	Alfalfa	Acres	343.0	-	-	-
	34	Hay	Tons	.00015	-	-	-
	35	Meadow	Acres	175.0	-	-	-
	36	Capital	$	.00016	-	-	-
	37	Apr. 1 - May 1 grazing	AUMs	.002	-.0822	-	-
	38	May 1 - June 1 grazing	AUMs	.0021	-	-.0411	-.0274
	39	June 1 - July 1 grazing	AUMs	.00021	-	-.0411	-.0274
R IV	40	July 1 - Aug. 1 grazing	AUMs	.00024	-	-	-.0274
	41	Aug. 1 - Oct. 1 grazing	AUMs	.00033	-	-	-
	42	Oct. 1 - Nov. 20 grazing	AUMs	72.0	-	-	-
	43	Hay	Tons	.00019	-	-	-
	44	Rancher I - Aftermath	AUMs	180.0	-	-	-
	45	Rancher II - Aftermath	AUMs	615.0	-	-	-
	46	Rancher III - Aftermath	AUMs	1,082.0	-	-	-
	47	Rancher IV - Aftermath	AUMs	117.0	-	-	-

FEDERAL RANGE IS HELD IN A FIXED RATIO

June 1 July 1 P_4	July 1 Aug. 1 P_5	Aug. 1 Oct. 1 P_6	Apr. 1 May 1 P_7	June 1 July 1 P_8	July 1 Aug. 1 P_9	Aug. 1 Oct. 1 P_{10}	Apr. 1 May 1 P_{11}	June 1 July 1 P_{12}	July 1 Aug. 1 P_{13}
-	-	-	-	-	-	-	-	-	-
7.0	10.0	11.0	-	-	-	-	-	-	-
-	-	-	6.0	10.6	5.0	5.5	-	-	-
-	-	-	-	-	-	-	6.02	10.61	5.01
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	0.0629	-	-	-	-.0629	-	-
-	-	-	-	-	-	-	-	-	-
-.0629	-	-	-	-.0629	-	-	-	-.0629	-
-	-.0629	-	-	-	-.0629	-	-	-	-.0629
-	-	-.0629	-	-	-	-.0629	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-.6112	-	-	-	-.6112	-	-
-	-	-	-	-	-	-	-	-	-
-.6112	-	-	-	-.6112	-	-	-	-.6112	-
-	-.6112	-	-	-	-.6112	-	-	-	-.6112
-	-	-.6112	-	-	-	-.6112	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-.2437	-	-	-	-.2437	-	-
-	-	-	-	-	-	-	-	-	-
-.2437	-	-	-	-.2437	-	-	-	-.2437	-
-	-.2437	-	-	-	-.2437	-	-	-	-.2437
-	-	-.2437	-	-	-	-.2437	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-.0822	-	-	-	-.0822	-	-
-	-	-	-	-	-	-	-	-	-
-.0822	-	-	-	-.0822	-	-	-	-.0822	-
-	-.0822	-	-	-	-.0822	-	-	-	-.0822
-	-	-.0822	-	-	-	-.0822	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Aug. 1 Oct. 1 P_{14}	Apr. 1 May 1 P_{15}	May 1 July 1 P_{16}	May 1 Aug. 1 P_{17}	June 1 July 1 P_{18}	July 1 Aug. 1 P_{19}	Aug. 1 Oct. 1 P_{20}	May 1 July 1 P_{21}	June 1 July 1 P_{22}	July 1 Aug. 1 P_{23}
-	-	-	-	-	-	-	7.0	2.0	2.3
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
5.51	-	-	-	-	-	-	-	-	-
-	9.51	7.71	8.01	7.01	10.01	11.01	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-.0629	-	-	-	-	-	-	-	-
-	-	-.03145	-.0210	-	-	-	-.03145	-	-
-	-	-.03145	-.0210	-.0629	-	-	-.03145	-.0629	-
-	-	-	-.0210	-	-.0629	-	-	-	-.0629
-.0629	-	-	-	-	-	-.0629	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-.6112	-	-	-	-	-	-	-	-
-	-	-.3056	-.2037	-	-	-	-.3056	-	-
-	-	-.3056	-.2037	-.6112	-	-	-.3056	-.6112	-
-	-	-	-.2037	-	-.6112	-	-	-	-.6112
-.6112	-	-	-	-	-	-.6112	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-.2437	-	-	-	-	-	-	-	-
-	-	-.12185	-.0812	-	-	-	-.12185	-	-
-	-	-.12185	-.0812	-.2437	-	-	-.12185	-.2437	-
-	-	-	-.0812	-	-.2437	-	-	-	-.2437
-.2437	-	-	-	-	-	-.2437	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-.0822	-	-	-	-	-	-	-	-
-	-	-.0411	-.0274	-	-	-	-.0411	-	-
-	-	-.0411	-.0274	-.0822	-	-	-.0411	-.0822	-
-	-	-	-.0274	-	-.0822	-	-	-	-.0822
-.0822	-	-	-	-	-	-.0822	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

Aug. 1 Oct. 1 P_{24}	May 1 June 1 P_{25}	June 1 July 1 P_{26}	July 1 Aug. 1 P_{27}	Aug. 1 Oct. 1 P_{28}	Apr. 1 May 1 P_{29}	June 1 July 1 P_{30}	July 1 Aug. 1 P_{31}	Aug. 1 Oct. 1 P_{32}	Hay P_{33}
2.6	-	-	-	-	-	-	-	-	-
-	6.01	2.01	2.31	2.61	-	-	-	-	-
-	-	-	-	-	3.0	5.3	2.5	2.8	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	5.17	1.73	1.99	2.24	1.32	2.33	1.11	1.23	-
-	-	-	-	-	-	-	-	-	1.0
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-.0629	-	-	-	-
-	-.0629	-	-	-	-	-	-	-	-
-	-	-.0629	-	-	-	-.0629	-	-	-
-	-	-	-.0629	-	-	-	-.0629	-	-
-.0629	-	-	-	-.0629	-	-	-	-.0629	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-1.0
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-.6112	-	-	-	-
-	-.6112	-	-	-	-	-	-	-	-
-	-	-.6112	-	-	-	-.6112	-	-	-
-	-	-	-.6112	-	-	-	-.6112	-	-
-.6112	-	-	-	-.6112	-	-	-	-.6112	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-.2437	-	-	-	-
-	-.2437	-	-	-	-	-	-	-	-
-	-	-.2437	-	-	-	-.2437	-	-	-
-	-	-	-.2437	-	-	-	-.2437	-	-
-.2437	-	-	-	-.2437	-	-	-	-.2437	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-.0822	-	-	-	-
-	-.0811	-	-	-	-	-	-	-	-
-	-	-.0822	-	-	-	-.0822	-	-	-
-	-	-	-.0822	-	-	-	-.0822	-	-
-.0822	-	-	-	-.0822	-	-	-	-.0822	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

60# N P_{34}	Hay P_{35}	60# N P_{36}	Meadow Hay P_{37}	60# N P_{38}	Alfalfa Hay P_{39}	Hay P_{40}	60# N P_{41}	Oct. 1 Nov. 20 P_{42}	Oct. 1 Nov. 20 P_{43}
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
1.0	-	-	-	-	-	-	-	-	-
8.60	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-3.16	-
-1.75	-	-	-	-	-	-	-	-	-
-	1.0	1.0	-	-	-	-	-	-	-
-	-	8.6	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-2.75
-	-1.0	-1.75	-	-	-	-	-	-	-
-	-	-	1.0	1.0	-	-	-	-	-
-	-	-	-	8.60	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	1.0	-	-	-	-
-	-	-	-1.0	-1.75	-2.0	-	-	-	-
-	-	-	-	-	-	1.0	1.0	-	-
-	-	-	-	-	-	-	8.60	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-1.0	-1.75	-	-
-	-	-	-	-	-	-	-	3.16	-
-	-	-	-	-	-	-	-	-	2.75
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-

		R I 78.00	R II 72.50	R III 58.00	R IV 41.00	R I 68.00	R II 62.50	R III 48.00
Oct. 1 Nov. 20 P_{44}	Oct. 1 Nov. 20 P_{45}	Cow-calf Yearling P_{46}	Cow-calf Yearling P_{47}	Cow - calf P_{48}	Cow - calf P_{49}	Cow-calf Yearling P_{50}	Cow-calf Yearling P_{51}	Cow - calf P_{52}
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	1.9	-	-	-	1.9	-	-
-	-	1.9	-	-	-	1.9	-	-
-	-	1.9	-	-	-	1.9	-	-
-	-	1.9	-	-	-	1.9	-	-
-	-	2.28	-	-	-	3.8	-	-
-	-	3.16	-	-	-	3.16	-	-
-	-	1.94	-	-	-	1.94	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	1.65	-	-	-	1.65	-
-	-	-	1.65	-	-	-	1.65	-
-	-	-	1.65	-	-	-	1.65	-
-	-	-	1.65	-	-	-	1.65	-
-	-	-	1.98	-	-	-	3.30	-
-	-	-	2.75	-	-	-	2.75	-
-	-	-	2.0	-	-	-	2.0	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	1.2	-	-	-	1.2
-	-	-	-	1.2	-	-	-	1.2
-	-	-	-	1.2	-	-	-	1.2
-	-	-	-	1.2	-	-	-	1.2
-	-	-	-	1.44	-	-	-	2.4
-2.00	-	-	-	2.00	-	-	-	2.00
-	-	-	-	-	-	-	-	-
-	-	-	-	1.8	-	-	-	1.8
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	1.3	-	-	-
-	-	-	-	-	1.3	-	-	-
-	-	-	-	-	1.3	-	-	-
-	-	-	-	-	1.3	-	-	-
-	-	-	-	-	1.56	-	-	-
-	-2.17	-	-	-	2.17	-	-	-
-	-	-	-	-	1.75	-	-	-
-	-	1.52	-	-	-	-	-	-
-	-	-	1.32	-	-	-	-	-
2.00	-	-	-	.96	-	-	-	-
-	2.17	-	-	-	1.04	-	-	-

R IV	R II	R IV				
31.00			-1.10	-1.10	-1.10	-1.10
Cow - calf	Hay fed Oct. - Nov.	Hay fed Oct. - Nov.	Private capital @ $1.10			
P_{53}	P_{54}	P_{55}	P_{56}	P_{57}	P_{58}	P_{59}
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-1.0	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	1.0	-	-	-	-	-
-	8.60	-	-	-1.0	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-4.38	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-1.0	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	1.0	-	-	-	-
-	-	8.60	-	-	-	-1.0
1.3	-	-	-	-	-	-
1.3	-	-	-	-	-	-
1.3	-	-	-	-	-	-
1.3	-	-	-	-	-	-
2.6	-	-	-	-	-	-
2.17	-	-4.38	-	-	-	-
1.75	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

range resources listed in the first five rows of column P_o in Table III have been reduced to 82 percent of the original acreages estimated by Range Management.

At the time these data were collected, there were about 4,724 acres of crested wheatgrass seeded on the allotment. This crested wheatgrass seeding is included in this model but is excluded in some of the models to be discussed later.

Quantities of available resources are listed in column P_o with the units of measurement in the column labeled "unit". Many of the rows in column P_o are zero but to prevent cycling of the program solution they were distorted slightly by adding figures such as .001, .00044, etc. The figures in rows 14, 23, 32, and 42 of column P_o give the number of AUMs of grazing available on each of the ranchers' private rangeland. It was assumed that all of this range would be used during the period from October 1 to November 20. The number of AUMs of aftermath grazing furnished by each rancher's meadow are given in rows 44, 45, 46, and 47. This is not the best way to handle the private range resources but it allows these resources to be attributed their share of the total adjusted income in the final solution. The number of AUMs of aftermath grazing was arrived at by using 1.5 acres per AUM for native meadow and three AUMs per acre for irrigated alfalfa where no second cutting is made. For example:

$$180 \text{ AUMs (row 44)} = \frac{270 \text{ acres of meadow (row 7)}}{1.5 \text{ acres of meadow per AUM}}$$

The fixed quantities, such as acres of federal range, acres of meadow for each rancher, AUMs of grazing for each rancher during the time the livestock are on the private range, and public capital act as constraints in Model I, i. e., the amount used of any factor cannot exceed the amount available as listed in column P_o.

Different seasons of use on the various classifications of federal rangeland are considered by Activities P_1 - P_{24}. The positive quantities in the federal range resource rows of column P_1 - P_{24} are the acres required per AUM. These quantities vary due to the different types of rangeland and different seasons of use.

The negative figures in these columns perform two functions in Model I. First, they are the means by which the fixed proportionality assumption is incorporated into the model. Considering the negative figures in column P_1, the -. 0629 in row 9 means that Rancher I gets 6. 29 percent of the AUM; the -. 6112 in row 18 means that Rancher II gets 61. 12 percent of the AUM; the -. 2437 in row 27 means that Rancher III gets 24. 37 percent of the AUM; and the -. 0822 in row 37 means that Rancher IV gets 8. 22 percent of the AUM produced on 9. 5 acres of reseedable rangeland grazed only during the month of

April.[2] Second, they can be manipulated in such a way as to allow the grazing season used in a column to differ from the grazing seasons used in the rows. For example, the grazing season in column P_2 is May 1 - July 1; there is no May 1 - July 1 grazing season in the rows, but there is a May 1 - June 1 and a June 1 - July 1. Therefore, this AUM produced on 7.7 acres of reseedable range will produce one-half an AUM for May 1 - June 1 and one-half an AUM for June 1 - July 1 if used May 1 - July 1 as indicated by column P_2. Since the AUM is already being divided among the four ranchers (in a fixed ratio), each rancher's share is split between the May 1 - June 1 and the June 1 - July 1 rows. That is, Rancher I gets 3.145 percent of the AUM in May and 3.145 percent of it in June. The same reasoning holds for the other ranchers. No matter how these negative quantities are split up they should sum to one, thus using the entire AUM. The same sort of explanation holds for all of the negative figures in column P_1 - P_{32}.

Activities representing all seasons of use are not presented for

---

[2] Dry forage from the year before is generally the only forage available during the month of April. Land grazed in April is not grazed after May 1 and the current year's growth is left for use the next year. According to Robert J. Raliegh, Squaw Butte Range Experiment Station, this dry feed is just about as nutritious as the meadow hay. Use of the range has the advantage of getting the cattle off the meadows during this wet month. Disease problems in the calves can be reduced by getting the cows out of the concentration on the meadows and scattered on the range.

each type of rangeland. For instance, there is no activity for May 1 - June 1 grazing on sprayed range. These were purposely omitted because it was believed that grazing this particular type of range at that time of year was not good range management, no matter how many acres per AUM were allowed.

Reseeding to crested wheatgrass and spraying on federal rangeland are allowed to enter through Activities P_{25} - P_{32}. The annual cost of reseeding is \$ .86 per acre and the annual cost of spraying is \$ .44 per acre as shown in Chapter two. Since an AUM is the unit of measure in these columns the improvement cost must be based on an AUM. The quantities in row 6 are annual costs per AUM for improvements. The cost per AUM is found by multiplying the cost per acre for spraying or reseeding by the acres required per AUM. Considering Activity P_{29} where sprayed range is used during April, three acres are required per AUM times \$ .44 equals \$1.32 spraying cost per AUM.

Hay production on the ranchers' meadows and meadow improvement by the application of 60 pounds of nitrogen fertilizer are considered in Activities P_{33} - P_{41}. The negative quantities in these columns represent tons of hay per acre. Yields increase from 1.0 ton to 1.75 tons per acre with the application of 60 pounds of nitrogen.

Activities P_{42} - P_{45} are included in Model I to allow more flexibility in the use of the private range resources. Aftermath grazing from the meadows not used from August 1 - October 1 can be transferred and used October 1 - November 20. The figure 2.75 in row 45, column P_{43} shows that 2.75 AUMs of aftermath grazing are required to produce 2.75 AUMs of October 1 - November 20 grazing for Rancher II (row 23). A similar activity is included for each of the other ranchers.

So far, only activities that produce feed for livestock have been considered. Use by livestock enters the model in Activities P_{46} - P_{53}. These activities have prices listed above their respective columns which correspond to the adjusted income figures which were discussed in Chapter four and presented in Appendix A. Each rancher has two livestock activities but the prices are different by ten dollars. The highest price is the same as the one computed in the appendix. The reason for the other price for each rancher will be explained below.

Feed requirements per unit of breeding herd are represented by the numbers in the respective columns for each ranch operation. For example, consider Rancher I in column P_{46}. The 1.9 in the rows corresponding to April, May, June, and July grazing means that for each unit of breeding herd 1.9 AUMs of feed are required for each of the four months. Ordinarily, one would expect this to be equal to 1.0, not 1.9. Since other livestock are an integral part of the ranch operation and must be fed, this figure is adjusted up to include yearlings, bulls, and other livestock using the ranch and range resources. For the two month period August 1 - October 1 this figure would usually be just double 1.9 or 3.8, but these ranchers bring at least their salable livestock off the dry federal range and put them on aftermath grazing. It is assumed that 40 percent of the livestock will be put on the aftermath. Sixty percent of 3.8 is 2.28, the feed requirement in row 13, column P_{46}. The other 40 percent, 1.52 is listed in row 44.

Now an explanation can be made for the two prices on the livestock activities. It was assumed that if the salable livestock are put on the aftermath, they will gain about a pound per day more than the cattle left on the dry federal range. During the two month period this would amount to about a 50-60 pound differential between the two alternatives. Figuring on the conservative side, a straight ten dollar difference was used for all ranchers. The only difference in the feed requirements between the two activities for the same rancher is that August 1 - October 1 grazing is double the single months and no aftermath is required for this grazing period for the low price livestock activity.

Getting back to the feed requirements per unit of breeding herd for Rancher I, the 3.16 (1.9 X 1.66 months) means that this many AUMs of grazing are required from the private land for the period October 1 - November 20. Hay feeding starts on November 20 and continues until April 1. It requires 1.94 tons of hay to feed a breeding unit on Ranch I over the winter as shown in row 15 of column P_{46}. The same logical patterns follow for the other ranchers but they will not be discussed further. Differences in type of ranch operation, i. e., cow - calf - yearling or cow - calf, accounted for most of the difference in feed requirements per month on these ranches. Ranchers I and II had cow - calf - yearling outfits while Ranchers III and IV had cow - calf outfits.

Because Rancher II gets such a large portion of the federal grazing, his meadow and private rangeland soon become the limiting factors for the entire system. (Remember that the AUMs of grazing for each rancher are held in a fixed ratio.) Rancher IV has so few acres of private land that they soon become exhausted, even with his small percentage of use on the federal range. For the above reasons, Activities P_{54} and P_{55} were included in Model I. These activities allow Ranchers II and IV to feed hay from improved meadows to their cattle, October 1 - November 20. Each acre of improved meadow produce 3,500 pounds of hay. Assuming 800 pounds of forage required per AUM, 4.38 AUMs would be forthcoming from an acre of improved meadow at an annual cost of $8.60.

Capital buying activities for each of the four ranchers are considered in the last four activities of Table III. The cost of capital is set at $1.10. This means that a dollar invested annually in meadow improvements must return $1.10 per year or a ten percent return on investment. Public capital is handled differently in this model. An equation for public capital is represented by row 6 and the amount available can be varied. The annual return on public capital is determined by the solution of the model.

Solution of the Model

A linear programming routine developed by James Boles was used to solve this model on the IBM 1620 computer (2 , p. 1-183). It takes about 2. 5 hours of computer time to get the initial solution. Once the solution is in the memory of the computer, parametric programming can be used to change the quantity of one of the resources in column P_o (usually referred to in programming as the right hand side). The parametric changer can be set up in such a way that it will increase the amount of a resource just enough to cause some change in the basic solution of the model. A change in the basic solution occurs when the variable that is altered causes a new variable to come into the solution.

Parametric programming was used to increase the amount of public capital. For this model thirteen parametric changes were needed to get the MVP of public capital below one dollar. Investment beyond this point was assumed irrational since the cost of public capital would not be fully recovered. After each parametric change a complete new solution is obtained so that the effects of increasing public capital can be traced out. A great deal of computer time is also saved, if a solution is desired at several levels of public capital, because the entire program does not have to be re-run at every desired level of public investment.

Results Obtained From the Solutions. As pointed out, the results obtained from programming are a function of the assumptions and data, as reflected in the coefficients. Only a limited number of activities representing alternative ways of using the range resources can be considered. Each solution indicates the optimum way to use both public and private resources, given the assumptions, input-output coefficients, and alternatives explained above for this model. Knowing the optimum way to use these resources is important. However, additional information is gained from the solution of a linear programming model which is equally valuable.

MVPs of the Limiting Factors. The MVPs for all limiting factors of production are mathematically computed in the solution of a linear programming model (MVPs are usually called shadow prices in the programming literature). With these MVPs several of the following questions can be answered: How would the total adjusted income to the allotment be affected if (1) another dollar of public capital was made available, (2) another AUM of grazing for some season was made available, or (3) another acre of some resource was made available? How many dollars of public capital would have to be made available before spraying or reseeding would come into the solution? How much does the last dollar invested in some particular range improvement return to the system? The MVPs shed light on many other questions that are important in making public and private land policy decisions. These questions will be discussed in detail in a later chapter on policy implications.

Some of the results obtained from the solutions of Model I are presented in Table IV. Only seven of the thirteen solutions obtained are summarized in Table IV. At the $10, essentially zero, level of public investment one more dollar of public capital would return $2. 27 or a 127 percent net annual return. As more public capital is made available the return becomes less. An annual investment of $6, 760 is the largest investment that will yield a positive return over the cost of the capital.

The MVP of public capital at any given level of investment is applicable for each dollar invested up to the next higher investment level determined by the parametric program. For example, with an annual investment of $5, 370 the MVP is $1. 24. According to the parametric program $1. 24 would be returned for each dollar invested up to an annual investment of $6, 257. The fact that the MVP computed for any level of public investment applies to each dollar up to the next higher investment level is very important in later sections of this

TABLE IV. RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE INPROVEMENTS, ASSUMING THAT THE RANCHERS UTILIZE THE INCREASED FORAGE IN THE SAME RATIO AS PRESENT USE[a]

Levels of Public Investment	$10	$365	$1985	$5370	$6257	$6737	$6760
MVP Public Capital	2.27	1.77	1.36	1.24	1.21	1.21	.85
MVP Apr. Grazing	5.59	4.78	4.67	4.23	4.25	4.23	4.48
MVP May Grazing	8.99	7.75	7.56	6.83	6.85	6.85	7.25
MVP June Grazing	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MVP July Grazing	5.03	3.94	3.85	3.47	3.42	3.43	2.79
MVP Aug. - Sept. Grazing	5.70	4.85	4.41	4.15	4.02	3.84	3.12
Av. MVP Public Grazing	5.09	4.28	4.11	3.76	3.72	3.68	3.50
MVP Aug. - Oct. Grazing Pvt.	3.28	9.60	8.87	8.29	8.09	8.00	7.37
MVP Oct. - Nov. Grazing Pvt.	3.28	3.26	3.33	3.68	3.66	3.63	3.93
MVP Hay Pvt.	7.29	7.26	7.57	8.77	8.70	8.64	9.34
RI Private Investment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RII Private Investment	3519.43	3909.07	5295.00	7920.00	7920.00	7920.00	7920.00
RIII Private Investment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RIV Private Investment	122.63	134.83	182.10	582.13	749.45	837.90	842.32
Acres Sprayed	23	832	4517	4517	4517	4517	4517
Acres Seeded	0	0	0	3942	4975	5534	5562

[a]The present range resource included 3874 acres of reseeded crested wheatgrass.

thesis.

The MVPs of the various months of grazing are summarized for the four ranchers in Table IV. These figures do not represent the MVP of any particular rancher but the weighted average MVP for that grazing period in the allotment. The sums of the AUMs required for the four ranchers for a particular season are used as weights. To clarify this weighting procedure, consider the following example from the initial solution ($10 capital level):

	AUMs		MVP for April grazing		
Rancher I	77.88	x	$41.05	=	$3,196.97
Rancher II	756.75	x	4.91	=	$3,723.26
Rancher III	301.73	x	0.0	=	0.0
Rancher IV	101.78	x	0.0	=	0.0
Totals	1,238.15				$6,920.23

The weighted average MVP for April grazing $= \frac{\$6,920.23}{1,238.15} = \$5.59$ per AUM.

The same procedure is used for each one of the grazing periods. To get the weighted average MVP for season-long grazing, the following method is used:

	AUMs		MVPs		
April grazing	1,238.15	x	$5.59	=	$ 6,921.26
May grazing	1,238.15	x	$8.99	=	11,130.97
June grazing	1,238.15	x	$0.0	=	0.0
July grazing	1,238.15	x	$5.03	=	6,227.89
Aug. and Sept. grazing	1,485.78	x	$5.70	=	8,468.94
Totals	6,438.38				$32,749.06

The weighted average MVP for public grazing $= \frac{\$32,749.06}{6,438.38} = \$5.09$

per AUM. The above figures are taken from the first column of Table IV.

As more public capital is invested and more public grazing becomes available the average MVP for public grazing gets continuously lower. For Model I it goes from $5.09 down to $3.50 per AUM. There is a concept in economic theory known as the law of diminishing returns that characterizes this situation.

Private Investment Required. Because of the proportionality assumption made in Model I, Rancher II is required to make a large private investment at each level of public investment. In every case it is higher than the public investment. Rancher IV soon has to invest in meadow improvements because he has so few private resources available. From these figures it can be seen that private investment is essential to profitable use of increased forage brought about by public investment in range improvements on federal rangeland. Results from an earlier model gave indications that the price of private capital could be substantially higher before it would be unprofitable to invest. These results showed very little decrease in the amount of private investment when the price was raised from $1.10 to $1.50.

Application of the Forage Evaluation Framework

The next logical step in analyzing this problem is to put the information obtained from this model into the framework developed in Chapter two. Once the information is placed in this framework, the decision-maker can decide which value of the forage is applicable. In theory it sounds very simple to do this. However, many problems arise when one tries to decide on the acquisition price and the salvage value. Should the problem be looked at from society's point of view, from the public land manager's point of view, or from the individual rancher's point of view?

Answers to many of these questions are beyond the scope of this study. Nevertheless, it would be well to bring some of the specific questions that need answering into the open for analysis. Consider the problem as seen by an individual rancher with respect to the federal grazing. A situation like this might arise when comparing the differences in the MVPs of federal grazing and the federal grazing fees. Are these comparisons always valid regardless of the magnitude of the MVPs? The economic evaluation of forage framework can help to answer the above question. Each rancher would have to set this framework up for his own case. Some of the questions he would have to answer are: Is the cost of an AUM of feed from meadow hay the figure that should be used for an acquisition price? It could be argued that this is not the right figure since livestock do better and are more healthy out on the open range. Others might say this is the wrong figure because most ranchers really do not have this alternative open to them because of lack of feed yards and other physical facilities or the risk of having to purchase hay is too high. From the information obtained concerning the nutritive quality of most flood meadow hay it would appear that flood meadow hay is not an equal substitute for most seasonal AUMs of grazing. Alfalfa hay may offer a better alternative than meadow hay.

Another possibility that might be considered as an alternative is the lease fee charged for private grazing. One rancher in this study reported paying $. 15 per head per day for fall grazing. This would be $4. 50 per AUM. Is this the figure that should be used? Care must be exercised before accepting private lease fee alternatives to be sure that the products compared are the same. Does the private lease fee include payment for more services than just grazing? Are death losses, percent calf crop, weaning weights, etc. significantly different for the two alternatives? Only a few of the problems that must be considered have been mentioned here.

Suppose some assumptions are made about the comparability of the alternatives. How divergent are the estimates of the acquisition price under the different assumptions? Assume $20 per ton hay is a comparable alternative: $20 x 0. 4 = $8. 00. The 0. 4 is calculated assuming 800 pounds of forage per AUM: $\frac{800}{2000} = 0.4$. Private lease fees have been found to range from $3. 00 to $5. 00 per AUM (33, p. 4). From the above discussion it is quite clear that each rancher would have to examine the alternatives open to him carefully and then decide what his acquisition price is.

A rancher considering which value of federal grazing is the relevant one for him would need to have an estimate of his acquisition price and the MVPs for federal grazing. It would appear that the salvage value for an individual rancher would be the cost of using the federal forage. This would include grazing fees, grazing association fees in some cases, costs of hiring a rider or doing the riding himself, and other costs necessary for using the federal range. If the MVP of grazing dropped below the cost of using the federal range, the rancher would have the alternative of not taking any federal grazing. With an estimate of the acquisition price and salvage value a relevant range can be determined over which the MVPs could be directly compared to the lease fees. This relevant range would be where the MVPs are less than the acquisition price but greater than the salvage value.

If the analysis is applied to a rancher's private rangeland he would be facing a somewhat different situation. The acquisition price could be the same as when considering federal grazing or it might equal the cost of getting additional grazing from range improvements. The salvage value would be equal to the price at which the rancher could sell an AUM of grazing. The entire ranch operation has to be considered in setting the salvage value, i. e., all grazing seasons are required if the ranch keeps livestock year-long and the salvage value could not be based on the sales opportunity for grazing at some critical season.

When analyzed from the point of view of the public land manager or society the MVP (use value) appears to be the appropriate value of the forage to use. In this model at least, the MVP of public capital is in part a function of the MVP of federal grazing. The MVP of public capital is very important in making decisions concerning public investment in range improvements.

Determination of Land-Use Patterns

Mention was made earlier that the linear programming solution gave the optimum seasonal use pattern for the rangeland, given the activities and constraints of the model. It is also interesting to see how the seasonal use of each type of rangeland is changed as more improvements are made. These changes are presented in Table V.

All 9,499 acres of unimproved reseedable rangeland are grazed during the period May 1 - July 1 at the first three investment levels. Unimproved reseedable range continues to be used during this period at higher levels of investment but the acreage is reduced as it is reseeded to crested wheatgrass. At the highest two levels of investment a few acres of it are used during April.

Sprayable range is used in August and September but it is soon all sprayed. Other "good" range is also used in August and

TABLE V. SEASONAL USE PATTERNS FOR EACH TYPE FEDERAL RANGELAND FOR MODEL I.

Investment Level	$10	$365	$1985	$5370	$6257	$6737	$6760
Season of use for each Range type							
Reseedable Range							
May 1 - July 1	9,499	9,499	9,499	5,557	4,524	3,831	3,862
Apr. 1 - May 1	0	0	0	0	0	134	75
Sprayable Range							
Aug. 1 - Oct. 1	4,494	3,685	0	0	0	0	0
Other Good							
Aug. 1 - Oct. 1	1,034	1,034	1,034	1,034	1,034	49	0
Apr. 1 - July 1	0	0	0	0	0	985	1,034
Other Poor							
Apr. 1 - May 1	11,775	12,065	10,243	3,505	1,305	0	0
May 1 - July 1	8,219	10,052	11,874	18,612	20,812	22,117	22,117
May 1 - Aug. 1	2,123	0	0	0	0	0	0
Reseeded							
July 1 - Aug. 1	2,644	2,918	3,190	3,607	3,781	3,874	3,874
Aug. 1 - Oct. 1	1,230	956	684	267	93	0	0
New Seedings							
Aug. 1 - Oct. 1	0	0	0	3,942	4,975	5,534	5,557
July 1 - Aug. 1	0	0	0	0	0	0	5
Sprayings							
Apr. 1 - May 1	0	0	928	3,596	4,517	4,517	4,517
Aug. 1 - Oct. 1	23	832	3,588	921	0	0	0

September until April grazing becomes a bottle neck; then it is used in April.

Other "poor" range is grazed April, May, June, and July at the $10 level of investment. As more range improvements come in, its use is shifted away from July and April grazing and it all ends up being grazed in May and June.

Most of the crested wheatgrass already seeded at the time of the study is used in July. At the lower levels of investment it is used in August and September. As new crested wheatgrass seedings come in they are also used in August and September. This seems like a poor time to use crested wheatgrass but, given the assumptions of this model, this is its most profitable use.[3]

Sprayed range is used the same as other "good"; it starts out being used in August and September but as more improvements are made its use is shifted to April grazing.

Another advantage of using a linear programming model as a method of finding the optimum way to use the range resources is its

---

[3] In this model other "poor" range and reseedable range were allowed to furnish grazing for May 1 - July 1 but not for May 1 - June 1 and June 1 - July 1 separately. As a result, it would not be profitable for crested wheatgrass to provide the June 1 - July 1 grazing since May 1 - June 1 grazing could not be supplied from any other source. A new model was developed to handle this problem. The results showed some changes in the land use pattern but very little change in the MVPs of the factors. These changes will be discussed later in the section on Model III.

capacity to consider the biological and economic aspects of range management simultaneously. The biological aspects are reflected in the activities selected to represent alternative ways of using the range and in the coefficients required for these activities. Given these alternatives or activities, the economic optimum use is made of the resources. The economic optimum use is realized when the total adjusted income to the allotment is maximized. Achievement of proper management as defined earlier in this thesis is dependent on consideration of economic and biological factors.

Federal Range Improvement Decisions

So far, the discussion has failed to come to grips with the primary objective of determining a rate of return on public investment in range improvements that can be used in decision-making. Once such a rate of return has been determined, one is in a position to say something about the most profitable range improvement practices and the optimum level of improvement.

The MVPs of public capital listed in Table IV are directly applicable only if the decision-maker is willing to completely ignore time. Range improvements require an investment in time period t_o, whereas the returns come in over the annual time periods t_1 to t_n. (For the case under discussion n would equal 12 for spraying and 20 for reseeding.) If time is ignored, this implies that a dollar return at any time in the future is worth as much as a dollar today. Most decision-makers are not willing to ignore time, so a process called "discounting" is used to equate future returns to the present. The difference between the worth of a dollar today and a dollar in some time period t_i depends on the interest rate the decision-maker will accept.

Several interest rates could be assumed for the decision-maker. The level of investment could be determined for each rate of interest where costs of improvements are equal to the discounted annual returns from the improvements. The problem here is that one would never know the appropriate interest rate for any given decision-maker. A better way of handling this problem would be to compute the rate of interest that would make the present value of costs and returns equal for each level of public investment. The interest rate that equates the present value of costs and returns is known as the internal rate of return. Gardner presented a paper in 1963 where he discusses the internal rate of return and range improvement decisions (14, p. 87-109).

There has been much discussion in the literature concerning the proper method that should be used for project evaluation. Gardner claims the internal rate of return is superior. LeBaron argues, in a discussion of Gardner's paper, that the internal rate of return is not necessarily the best method for ranking projects or for deciding on the scale of a project (22, p. 117-127). He shows where projects can be ranked differently using the internal rate of return and the maximization of present worth methods. Other authors have discussed the problems of selecting a criterion for making investment decisions: McKean (31, p. 25-49), Lorie and Savage (26, p. 229-239), Solomon (40, p. 124-129), Eckstein (9 , p. 47-109), and Lutz (28, p. 83). Each one of these add a little more to the over-all analysis of the problem but none of them deal with a problem just like the one encountered in this study.

In some ways the problem of this study is simpler than the problems discussed by the above authors. However, serious study of the investment principles is needed to decide which principles apply to the problem at hand. The specific task of this study with regard to investment criteria is to take the MVPs of public capital, discount them over time, and give some choice indicator for the public land management decision-maker to use in deciding the appropriate level of public investment. It is believed that the internal rate of return will best meet this need.

The assumption was made earlier that public funds are limited for range improvements, i. e. , all physically possible range improvements will not be undertaken. The relative profitability of spraying versus reseeding has already been determined by the linear programming solution, which eliminates many of the problems of ranking projects. Using the MVPs for the different levels of investment, an internal rate of return can be computed at each level.

Gardner makes the following statement concerning the use of the internal rate of return in deciding on the level of investment (14, p. 102). "The internal rate of return decision criterion asserts that the firm should utilize the investment opportunity if the internal rate of return, i_o, exceeds the internal rate of return from all other alternative uses of the investment funds. Alternatives external as well as internal to the firm must be considered. . . . The internal rate of return must not only be greater than the best alternative use of funds by the firm but must also exceed the firm's cost of borrowing."

One must be careful about making direct comparisons of the internal rate of return and the market rate of interest. Gardner says; "It is especially important to note that the internal rate of return is logically equavalent in every respect to the annual compound rate of interest employed in money markets (14, p. 95)." Although the internal rate of return may be logically equivalent to the annual compound rate of interest used in the money markets, this does not necessarily mean that direct comparisons between the two can be made for investment decisions. Direct comparisons would be valid only if one was sure that a "perfect market" situation existed in the money market.

Joel Dean, discussing some of the advantages of the internal rate of return in an article in Harvard Business Review, says:

". . . decisions can be made quickly and safely on the basis of the relationship between indicated return and the value of money to the company (8 , p. 129-130)." The relationship between the internal rate of return and the value of money to the company is considered by Dean, not the relationship between the internal rate of return and the interest rate determined in the money market. For the purposes of this study where public funds are being invested in range improvements it is important to use the opportunity cost of public capital and not the market rate of interest as a standard to be compared with the internal rate of return. The internal rates of return are estimated in Table VI for each level of public investment considered in Model I; the decision-maker can equate his own opportunity rate of interest with them.

Before going any further a few more points made by Gardner are applicable to this study and should be mentioned (14, p. 87-109). The point is made that much of the difference in rates of return reported for range improvement studies is due to the author's concept of rate of return. Since this concept is used by decision-makers as a tool to indicate whether or not a range improvement should be made, it is crucial that these rates of return be consistently defined in studies whose results will be compared by decision-makers. All researchers doing work on the economics of range improvements should recognize the importance of standardizing methods, thus, doing away with many of the problems of interpreting the results of different studies.

Non-use costs are treated as negative returns in Gardner's paper. This enables one to take into account the fact that non-use costs may be incurred over a two year period (t_1 and t_2). This comes into effect when future annual returns are discounted back to the present and set equal to the present value of the costs. In this study non-use costs were added to the initial investment in range improvements; therefore, they are handled as if they were all made in time period t_o. The way non-use is handled in this study would cause decisions to be made on the conservative side, if it has a significant effect.

The internal rates of return were computed using the following method. At each investment level the MVP of public capital represents an undiscounted rate of return per dollar invested. These MVPs must be discounted by that rate of interest which will make their present value over the life of the investment equal to the investment. Care must be taken to be sure to include each level of capital where a change in the MVP occurs. Every level of investment is not considered in Table IV; therefore, it is not complete enough for computing the internal rates of return. Table VI includes each level of investment where there is a different MVP of public capital. The internal rate of return for each level of investment is computed in Table VI. Acres of sprayed and seeded range are also listed.

Consider the case, from Table VI, where the MVP of public

TABLE VI. INTERNAL RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT FOR MODEL I.

Levels of Investment	$10	$238	$337	$365	$1, 814	$1, 985	$2, 097	$5, 370	$6, 257	$6, 737	$6, 760
MVP of Public Capital	2. 27	1. 94	1. 87	1. 77	1. 72	1. 36	1. 28	1. 24	1. 21	1. 21	. 85
Internal Rate of Return		15. 5%	12%	11%	10%	9. 5%	3. 25%	2. 5%	2. 25%	2%	2%
Acres Sprayed	23	542	767	832	4, 130	4, 517	4, 517	4, 517	4, 517	4, 517	4, 517
Acres Seeded	0	0	0	0	0	0	131	3, 942	4, 975	5, 534	5, 562
Total Adjusted Ranch Income for the Allotment	50, 236	50, 754	50, 938	50, 991	53, 556	53, 850	54, 003	58, 199	59, 298	59, 879	59, 908
Allocation of Public Grazing (Animal Units)											
Rancher I	78	79	80	80	87	87	87	99	103	106	106
Rancher II	757	769	772	773	816[a]	836	847	921	958	958	958
Rancher III	302	307	308	309	338	338	338	382	401	410	411
Rancher IV	102	103	104	104	114	114	114	129	135	138	139

[a]At investment levels above $3, 213 Rancher II comes in for use on the low price cow - calf - yearling activity which cause the proportionality assumption not to hold on an animal unit basis. However, this assumption still holds if figured on an AUM basis. At the extremely high investment levels it pays Rancher II to take non-use so that the other ranchers can get additional use.

capital is equal to $1. 36. Public investment at this rate of return is being made in range reseeding with a 20 year life. At this level of investment the cost is $20 in the first year to get an income stream of $1. 36 per year over the next 20 years. The following equation is used to find the factor needed to make the income stream over the 20 years equal to the $20 investment.

$$MVP(X) = n \text{ dollars}$$

or

$$\$1.36X = \$20$$

$$X = 14.70588$$

Comparing 14. 70588 with the values in the "Present Value of Annuity" table, it is found that this corresponds to an interest rate between 3. 0 and 3. 5 percent. The value found in the table at 3. 0 percent is 14. 8774749 and 14. 2124033 at 3. 5 percent. Therefore, the internal rate of return is about 3. 25 percent for an annual investment of $2, 097 in range improvements.

In some instances a decision-maker may want a more exact estimate of the internal rate of return than can be obtained by interpolation from the tables. A mathematical procedure known as "Newton's Method" can be used to get as close an approximation of the internal rate of return as one desires (35, p. 124-125).

Newton's formula is

$$a_2 = a_1 - \frac{f(a_1)}{f'(a_1)}$$

where a_1 is some estimate of the desired value and a_2 is the first approximation of the value. A third approximation could be obtained by the following formula:

$$a_3 = a_2 - \frac{f(a_2)}{f'(a_2)}$$

In this study the internal rate of return, r, is the variable to be approximated. Thus,

$$r_2 = r_1 - \frac{f(r_1)}{f'(r_1)}$$

where r_1 is some estimate of the real internal rate of return. The present value of an annuity formula discussed above is the function of particular interest. Let k equal present value of annuity:

$$k = \left[\frac{1-(1+i)^{-n}}{i}\right] \text{ or } ki - \left[1-(1+i)\right]^{-n} = 0.$$

Thus: $f(r_1) = ki - \left[(1+i)^{-n}\right]$ and $f'(r_1) = k - n(1+i)^{-(n+1)}$.

Putting all of the above into one formula for approximating the internal rate of return one obtains

$$r_2 = r_1 - \frac{ki - \left[1-(1+i)^{-n}\right]}{k - n(1+i)^{-(n+1)}}$$

Using the \$2,097 public investment level from Table VI as an example of this method, the following equation would result. Let

r_1 = 3 percent, n = 20, and k = 14.705882.

Then:

$$r_2 = .03 - \frac{(14.705882)(.03) - \left[1-(1+.03)^{-20}\right]}{14.705882 - 20\,(1+.03)^{-21}}$$

$$r_2 = .03 - \frac{-.00514779}{3.954897}$$

$$r_2 = .03 + .001302$$

$$r_2 = .031302$$

$$r_3 = .031320 - \frac{(14.705882)(.031302) - \left[1-(1+.031302)^{-20}\right]}{14.705882 - 20\,(1+.031302)^{-21}}$$

$$r_3 = .031302 - \frac{.00018557}{4.236358}$$

$$r_3 = .031302 - .0000438$$

$$r_3 = .0312582$$

The above procedure could be carried one more interation which would put it even nearer the real value, but for the purpose at hand two iterations are enough. However, if one had no idea of what the internal rate of return was and had guessed six or eight percent, then additional iterations would be required.

It can be seen from the above calculations that the real internal rate of return was nearer three and one-eight percent than three and one-quarter percent. If one wanted this much accuracy, a program could be written for the computer that would handle the calculations. This was not done in this study.

In cases where the "Present Value of Annuity" tables did not consider interest rates high enough to equate the discounted annual returns to the cost, the following general formula was used:

$$\text{Present Value of Annuity} = \frac{\left[1-(1+i)^{-n}\right]}{i}.$$

For example, to find the present value of an annuity over 12 years at an interest rate of 15. 5 percent, one could use the following procedure.

$$\text{Present Value} = \frac{1 - \frac{1}{(1+.155)^{12}}}{.155} = 5.306928$$

This figure is very close to the factor (5. 28634) needed to equate an annual return of $2. 27 over the cost.

How could a public land manager use the information in Table VI to help him decide on the level of investment to make in range improvements? First, he must have some idea of the opportunity rate of interest for public funds. For maximum efficiency in the use of public funds, all possible uses of public funds would have to be known and a rate of return computed for each use. Then public funds could be invested as long as they were available, starting with the highest return projects and working down. Under such a situation the decision-maker would always know the opportunity rate of interest. Since no one ever knows all of the uses that could be made of public capital, let alone the rate of return on them, it is impossible to use this method.

Many factors enter into decisions regarding the use of public funds. Economic factors are important but not necessarily the overriding factors; however, the consequences of making decisions based on other factors should be pointed out. Putting these considerations aside and assuming a particular decision-maker has public funds to invest in range improvements, he has alternative ways of estimating the opportunity rate of interest. If he had estimates of the rates of return of several projects that were not mutually exclusive,[4] the opportunity rate of interest for any one project would be the highest rate of return on the other projects (assuming funds were to be invested in one or more of these projects).

Another way of identifying an opportunity rate of interest would be to use the method described in Senate Document 97 (41, p. 12). The procedure is described in the section on time considerations.

> Discount Rate . . . The interest rate to be used in plan formulation and evaluation for discounting future benefits and computing costs, or otherwise converting benefits and costs to a common time basis shall be based upon the average rate of interest payable by the Treasury on interest-bearing marketable securities of the United States outstanding at the end of the fiscal year preceeding such computation which, upon original issue had terms to maturity

---

[4] Mutually exclusive projects are projects where the decision to invest in one automatically eliminates the others as possibilities, i. e., the projects are alternative ways of doing the same thing. An example of mutually exclusive projects in range improvements would be a case where land was classified as sprayable or reseedable, thus a decision to reseed would automatically rule out spraying.

> of 15 years or more. Where the average rate so calculated is not a multiple of one-eighth of 1 percent, the rate of interest shall be the multiple of one-eighth of 1 percent next lower than such average rate.
>
> This procedure shall be subject to adjustment when and if this is found desirable as a result of continuing analysis of all factors pertinent to selection of a discount rate for these purposes (41, p. 12).

For illustrative purposes the interest rate described in Senate Document 97 will be used as the opportunity interest rate. The interest rate used for discounting future returns by those doing benefit-cost analysis is three percent as of July 1964. This interest rate was computed using the procedure outlined above.

With this information the public land management decision-maker would conclude that an annual investment of $2,097 in range improvements would be the optimum. Under this paln 4,517 acres of federal rangeland would be sprayed and an additional 131 acres would be seeded to crested wheatgrass. If no reinvestments were made at the end of the assumed life of these improvements, the total public investment would be $23,819.40 for spraying and $2,253.00 for reseeding, giving a combined total of $26,072.40. There may be many cases where the public agency does not have enough funds to invest out to the point where the internal rate of return is equal to the interest rate described in Senate Document 97. Nevertheless this rate of interest can be used to eliminate investment alternatives with lower rates of return.

Before the optimum annual investment of $26,072 in range improvements, the 82 percent use of the total AUMs on the allotment by the four ranchers considered was broken down as follows.[5]

RI	310 AUMs
RII	3010 AUMs
RIII	1200 AUMs
RIV	405 AUMs

The AUMs available to these four ranchers after the optimum investment of $26,072 would be:

RI	454 AUMs
RII	4471 AUMs
RIII	1758 AUMs
RIV	593 AUMs

This represents about a 46 percent increase in the number of AUMs of federal grazing available to these four ranchers.

If one is willing to accept the assumption that the ranchers using the other 18 percent of the allotment are on the average about the same as these four ranchers, then the total figures could be adjusted up by 18 percent to account for all of the use on the allotment. For example, this would increase the total investment of public capital in range improvements to $30,665 for the allotment.

Methods of Checking the Linear Programming Solution

There are several ways to check the solution for accuracy and

[5] Based on use during the 1961 grazing season.

completeness. They will be illustrated for the initial (public capital $10) solution of Model I.

One of the simplest tests is to see if the number of breeding units in the solution times their respective prices minus the cost of private capital equals the total adjusted income to the allotment. Total adjusted income for the initial solution is $50, 236 which should equal the following:

Rancher I	40. 98970 breeding units x $78. 00	= $ 3, 197. 19
Rancher II	458. 64212 breeding units x $72. 50	= 33, 251. 55
Rancher III	251. 44475 breeding units x $58. 00	= 14, 583. 80
Rancher IV	78. 29079 breeding units x $41. 00	= 3, 209. 93
Rancher II	Capital investment $3, 519. 44298 x -$1. 10	= -3, 871. 37
Rancher IV	Capital investment $122. 63094 x -$1. 10	= - 134. 89
TOTAL		$50, 236. 21

The MVPs of the limiting input factors times the amounts used minus the private capital costs should again equal the total adjusted income figure:

				MVPs	
Rancher I	Apr. 1 - May 1	AUMs	77.88 x	$41.05257 =	$ 3, 196
Rancher II	Apr. 1 - May 1	AUMs	756.76 x	4.9198 =	3, 715
Rancher II	July 1 - Aug. 1	AUMs	756.76 x	.10604 =	75
Rancher II	Aug. 1 - Oct. 1	AUMs	908.11 x	9.32087 =	8, 463
Rancher II	Aftermath	AUMs	605.41 x	5.07273 =	3, 069
Rancher II	Oct. 1 - Nov. 20	AUMs	1, 261.27 x	5.07088 =	6, 394
Rancher II	Hay	Tons	917.29 x	12.61335 =	11, 567
Rancher III	May 1 - June 1	AUMs	301.73 x	36.89571 =	11, 130
Rancher III	July 1 - Aug. 1	AUMs	301.73 x	11.52028 =	3, 475
Rancher IV	July 1 - Aug. 1	AUMs	101.78 x	26.19304 =	2, 665
Rancher IV	Aftermath	AUMs	81.42 x	2.1648 =	175
Rancher IV	Oct. 1 - Nov. 20	AUMs	169.89 x	2.1648 =	366
Rancher I	Capital investment		$3519.44640 x	$-1.10 =	-3, 871
Rancher IV	Capital investment		122.62880 x	$-1.10 =	- 135
TOTAL					$50, 284[6]

[6] Error of $48.00 is due to rounding in the program.

One can go further in checking the model by multiplying the MVPs of the limiting land and public capital inputs times the amounts used as follows:

			MVPs	
Reseeded range	3,874 acres	x	$2.18506 =	$ 8,464.92
Reseedable range	9,499 acres	x	.58384 =	5,545.90
Sprayable range	4,517 acres	x	1.03296 =	4,665.88
Other good range	1,034 acres	x	1.03106 =	1,066.12
Other poor range	22,117 acres	x	.58308 =	12,895.98
Public capital	$10	x	2.26737 =	22.67
Rancher II Meadow	923 acres	x	12.61335 =	11,642.12
Rancher II Private range	474 AUMs	x	5.07088 =	2,403.60
Rancher II Aftermath	615 AUMs	x	5.07273 =	3,119.73
Rancher IV Private range	72 AUMs	x	2.16480 =	155.86
Rancher IV Aftermath	117 AUMs	x	2.16480 =	253.28
TOTAL				$50,236.06

It is possible to go one step further to see if the total AUMs of grazing and tons of hay required by the total number of breeding units of the four ranchers is supplied by the federal and private resources used. This check is made below:

	Federal AUMs required
Rancher I	404.98
Rancher II	3,935.15
Rancher III	1,596.00
Rancher IV	529.25
TOTAL	6,438.38

	Federal AUMs produced
Reseeded range	1,622.67
Reseedable range	1,233.64
Sprayable Range	817.13
Other good range	187.66
Other poor range	2,569.22
Sprayed range	8.13
	6,438.45

All of the federal range resources are used to produce the 6,438 AUMs required to graze the total number of breeding units determined by the solution of Model I.

The private resources must produce the forage required to feed the animals while not on the federal range. Use patterns for the private resources are presented below:

Rancher I's private resources were used as follows:

	Amount Required	Amount Produced	Source of Production	Amount Unused
Aug. 1-Oct. 1 Aftermath	62.30	180.00	Row 44 Col. P_o	117.70 AUMs
Oct. 1-Nov. 20	129.53	270.50	Row 14 Col. P_o	140.97 AUMs
Hay (tons)	79.52	79.52	Activity P_{33}	190.48 Acres

Rancher II's private resources were used as follows:

	Amount Required	Amount Produced	Source of Production	Amount Unused
Aug. 1-Oct. 1 Aftermath	605.40	615.00	Row 45 Col. P_o	0.0
Oct. 1-Nov. 20		474.00	Row 23 Col. P_o	0.0
		778.00	Activity P_{54}	0.0
		9.28	Activity P_{33}	0.0
Total	1261.26	1261.28		
Hay (tons)		512.20	Activity P_{35}	0.0
		405.08	Activity P_{36}	0.0
Total	917.28	917.28		

Rancher III's private resources were used as follows:

	Amount Required	Amount Produced	Source of Production	Amount Unused
Aug. 1-Oct. 1 Aftermath	241.39	1082.00	Row 46 Col. P_o	546.88 AUMs
Oct. 1-Nov. 20		209.00	Row 32 Col. P_o	0.0
		293.73	Activity P_{44}	
Total	502.89	502.73		
Hay (tons)	452.60	452.60	Activity P_{39}	116.70 Acres
			(Meadow)	80.00 Acres

Rancher IV's private resources were used as follows:

	Amount Required	Amount Produced	Source of Production	Amount Unused
Aug. 1-Oct. 1 Aftermath	81.42	117.00	Row 47 Col. P_o	0.0
Oct. 1- Nov. 20		62.31	Activity P_{55}	0.0
		72.00	Row 42 Col. P_o	0.0
		35.58	Activity P_{42}	0.0
Total	169.89	169.89		
Hay (tons)	137.01	137.01	Activity P_{40}	0.0

Rancher II uses all of the possible ways set up in the model to get forage from his private resources.. For example, 605.40 AUMs of August 1 to October 1 grazing are required; 615 AUMs are available leaving 9.28 AUMs to be transferred for use October 1 - November 20. A total of 1,261.26 AUMs are required for October 1 - November 20; 474.00 of them are available from his rangeland, 778 AUMs are produced by grazing or hay production on uncut, improved meadow, and the 9.28 mentioned above furnish enough forage to meet the requirement. About 917 tons of hay are needed to winter the livestock; 512 tons are produced on unimproved meadow and 405 tons are produced on improved meadow. Rancher II uses all of his resources while Rancher I and III have private resources that are going unused.

Model I has been described in considerable detail. It will be used as a source of reference for discussing the other models developed in this study.

Model II

It is quite simple to change some of the assumptions made in the original model and see how this affects the decision-making process. Model II is very much like Model I; in fact only two items are different. At the time the study was made there were 3,874 acres of crested wheatgrass in the allotment. This crested wheatgrass is considered a part of the initial federal resources available in Model I. In Model II the assumption is made that there is no crested wheatgrass in the allotment. With this model a range improvement program can be worked out as if the public land management decision-maker were considering the allotment before any improvements were made. A tabular description of Model II is exactly like Table III with two exceptions. The acreages in rows 1and 2 of column P_o are changed. Only one acre of reseeded range is left in row 1, column P_o. The acres of reseedable range in row 2, column P_o now becomes 9,499 plus 3,873 or 13,372. One acre was left in row 1 to prevent problems in the parametric program.

Results Obtained from the Model II

Model II was solved using the same procedures as discussed for Model I. Results obtained from the solution of the model at several levels of public investment are presented in Table VII. The MVPs

TABLE VII. RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENTS, ASSUMING THAT THE RANCHERS UTILIZE THE INCREASED FORAGE IN THE SAME RATIO AS PRESENT USE. [a]

Levels of Investment	$10	$654	$1,989	$3,210	$4,688	$5,122	$8,719	$9,602	$10,105
MVP Public Capital	3.77	3.45	1.85	1.83	1.39	1.35	1.24	1.21	.85
MVP April Grazing	8.16	8.43	5.56	5.48	4.81	4.72	4.21	4.23	4.46
MVP May Grazing	11.78	11.77	9.02	8.88	7.80	7.64	6.83	6.86	7.23
MVP June Grazing	.49	1.89	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MVP July Grazing	8.35	7.64	5.04	4.96	4.07	3.90	3.48	3.43	2.78
MVP August-Sept. Grazing	9.45	8.64	5.62	5.54	4.43	4.30	4.11	3.98	3.21
Av. MVP Public Grazing	7.72	7.71	5.07	5.00	4.23	4.12	3.75	3.71	3.52
MVP Aug. 1 - Oct. 1 Pvt. Grazing	1.50	1.50	3.28	3.80	8.90	8.90	8.34	8.14	7.43
MVP Oct. 1 - Nov. 20 Pvt. Grazing	1.50	1.50	3.28	3.28	3.24	3.31	3.68	3.65	3.93
MVP Hay - Pvt.	0	0	7.30	7.30	7.53	7.53	8.75	8.68	9.32
RI Private Investment	0	0	0	0		0	0	0	0
RII Private Investment	817	996	2,498	3,822	4,625	4,847	7,918	7,918	7,918
RIII Private Investment	0	0	0	0	0	0	0	0	0
RIV Private Investment	27	51	96	130	171	182	582	748	841
Acres Sprayed	23	1,488	4,517	4,517	4,517	4,517	4,517	4,517	4,517
Acres Seeded	0	0	0	1,481	3,138	3,643	7,831	8,858	9,445

[a] It was assumed that there was no reseeded crested wheatgrass initially.

are generally higher than they were in Model I until about 3,874 acres of crested wheatgrass come into a solution. Both models produce essentially the same results at investment levels above the point where 3,874 acres are seeded. For example, at an annual investment of $8,719 in Model II and at an annual investment of $5,370 in Model I, both models indicate an MVP of public capital at $1.24. In both models all 4,517 acres of sprayable range are sprayed and the total number of acres of crested wheatgrass are about the same. At the $5,370 investment level in Model I, 3,942 acres come in for seeding plus the 3,874 acres already seeded give a total of 7,816 acres which compares closely to the 7,831 acres reseeded at the $8,719 investment level in Model II. One would expect both models to yield similar results since they are so much alike. However, it does give one more confidence in the logic which went into the development of the models.

The high MVPs shown in Table VII at the first few levels of public investment results from the fact that fewer AUMs of public grazing are available, thus, the private resources have a greater potential for increased use. Also, spraying is allowed to come in before any reseeding is done, whereas in Model I spraying did not have a chance to compete with seeding in the production of the first AUMs of grazing from improvements. The first few hundred dollars invested in spraying yields high returns as indicated by MVPs of $3.77, $3.45, $2.93 and $2.24. This is further evidence that spraying is a more profitable use of public funds than reseeding crested wheatgrass for this allotment.

Determination of Land Use Patterns

Table VIII shows the seasonal use patterns for the various range types as more public capital is invested in range improvements. Of course, the use patterns are different than in Model I at the lower levels of investment because there is not any crested wheatgrass. As crested wheatgrass comes in, the use patterns move more and more toward those established in Model I. At the highest level of investment they are essentially the same in both models. Sprayed range furnishes feed in the late summer grazing periods until seedings come in; then it shifts to April use. The crested wheatgrass seedings furnish late season use, and the sprayed range furnishes carry-over feed for the next April. This may at first glance appear to be a poor way to use these resources, but it is the best way to use them given the economic and biological factors incorporated into the model.

Federal Range Improvement Decisions

Parametric programming was again used to determine the MVPs of public capital at each level of investment which caused a new activity to come into the basic solution of the problem. Most of these activity changes brought about a decrease in the MVP of public capital.

TABLE VIII. SEASONAL USE PATTERNS FOR EACH TYPE OF FEDERAL RANGELAND FOR MODEL II.

Investment Levels	$10	$654	$1,989	$3, 210	$4, 688	$5, 122	$8, 719	$9, 602	$10, 106
<u>Season of Use for Each Range Type</u>									
Reseedable Range									
May 1- Aug. 1	13, 372	13, 372	13, 372	7, 608	0	0	0	0	0
May 1- July 1	0	0	0	4, 346	10, 234	9, 729	5, 542	4, 515	3, 928
Sprayable Range									
Aug. 1 - Oct. 1	4, 494	3, 029	0	0	0	0	0	0	0
Other Good									
Aug. 1 - Oct. 1	1, 034	1, 034	1, 034	1, 034	1, 034	1, 034	1, 034	1, 034	0
April - May 1	0	0	0	0	0	0	0	0	1, 034
Other Poor									
April 1 -May	9, 491	10, 066	11, 146	11, 961	11, 412	10, 476	3, 496	1, 308	73
May 1 - Aug. 1	10, 597	12, 051	4, 152	0	0	0	0	0	0
Aug. 1 - Oct. 1	2, 029	0	0	0	0	0	0	0	0
May 1 - July 1	0	0	6, 819	10, 156	10, 705	11, 641	18, 621	20, 809	22, 044
Crested Wheatgrass									
July 1 - Aug. 1	0	0	0	1, 418	3, 138	3, 202	3, 620	3, 793	3, 891
Aug. 1 - Oct. 1	0	0	0	0	0	441	4, 210	5, 064	5, 554
Spraying									
Aug. 1 - Oct. 1	23	1, 488	3, 413	3, 701	4, 040	3, 661	916	0	0
July 1 - Aug. 1	0	0	1, 104	816	0	0	0	0	0
April - May	0	0	0	0	477	856	3, 601	4, 517	4, 517

Eighteen changes took place in the basic solution before the MVP of public capital fell below one dollar. Sixteen of the investment levels are summarized in Table IX. Two levels of investment ($1,989 and $3,043) have the same MVP. Both were included because reseeding comes in first at the $3,043 level of investment and all of the sprayable range is sprayed at the $1,989 level of investment. Since reseeding is the only improvement left for consideration above the $1,989 level of investment, the MVP is dependent entirely on the use that can be made of AUMs produced on reseeded rangeland and the private resources. The internal rate of return is calculated using a 12 year time period at the $1,989 level and a 20 year time period at the $3,043 level, thus the different internal rates of return for the same MVP.

The internal rate of return for spraying goes from 31 percent down to 15.5 percent and for reseeding it goes from 6.75 percent down to 2.0 percent in Model II. In Model I the internal rate of return goes from 15.5 percent down to 9.5 percent and from 3.25 percent down to 2.0 percent for spraying and reseeding respectively. One can see that the rate of return for these improvements depends, among other things, on what resources are available prior to the decision to improve one more acre. It would be very risky to take these rates of return for the various improvement practices and use them to make specific decisions under different circumstances. One could say that in areas with the same physical responses from spraying and

TABLE IX. INTERNAL RATE OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENTS FOR MODEL II

Levels of Investment	$10	$654	$89.82	$890.93	$1,989	$3,043	$3,209	$3,213	$4,146	$4,688	$5,122	$5,448	$8,719	$9,602	$10,106
MVP Public Capital	3.77	3.45	2.93	2.24	1.85	1.85	1.83	1.52	1.41	1.39	1.35	1.28	1.24	1.21	.85
Internal Rate of Return		31%	27%	22%	15.5%	6.75%	6.75%	5%	4.5%	3.75%	3.25%	3%	2.5%	2.25%	2%
Acres Sprayed	23	1,488	2,025	2,025	4,517	4,517	4,517	4,517	4,517	4,517	4,517	4,517	4,517	4,517	4,517
Acres Seeded	0	0	0	0	0	0	1,481	1,484	2,506	3,138	3,643	4,023	7,831	8,858	9,445
Total Adjusted Ranch Income	42,792	45,220	46,028	46,028	48,493	50,448	50,755	50,760	52,182	52,946	53,551	53,992	54,170	59,262	59,871
Animal Units of Federal Grazing															
Rancher I	63	67	68	68	74	78	79	79	83	85	87	87	100	103	106
Rancher II	610	647	659	659	716	762	769	769[a]	793	806	816	847	956	958	958
Rancher III	243	258	263	263	286	304	307	307	323	331	338	338	382	400	411
Rancher IV	82	87	89	89	96	102	103	103	109	111	114	114	130	135	139

[a]At investment levels above $3,213 Rancher II comes in for use on the low price cow - calf - yearling activity which cause the proportionality assumption not to hold on an animal unit basis. However, this assumption still holds if figured on an AUM level. At the extremely high investment levels it pays Rancher II to take non-use so that the other ranchers can get additional use.

reseeding as the East Cow Creek allotment that a dollar invested in spraying will return more than a dollar invested in reseeding. Of course, these returns are measured through the production of livestock.

Suppose the public land management decision-maker uses the same interest rate (3.0 percent) that he used in Model I to determine the optimum level of investment, will he reach the same conclusion? Equating the 3.0 percent interest rate with the internal rates of return in Table IX, the optimum level of investment is $5,448. At this level of investment 4,517 acres would be sprayed and 4,023 acres would be seeded to crested wheatgrass. In Model I the optimum level of investment would spray 4,517 acres and seed 131 acres to crested wheatgrass. If the 131 acres are added to the 3,874 acres already available, the total is 4,005. Both models indicate almost the same level of spraying and seeding at the optimum level of investment.

The assumption is made in Model I and Model II that the AUMs of grazing from the federal lands should be allocated to each rancher in a fixed ratio. Is this a valid assumption and why was it made? To begin with, no rules have been established by the BLM to indicate how increased forage would be allocated to ranchers. Some ranchers have permits to graze livestock in more than one BLM allotment. The private land owned by such a rancher is used to feed all of his cattle while off the federal range. If in a study like this he is given increased grazing on a particular allotment which uses all of his commensurate property, then this commensurate property should not be counted for another allotment. If such double counting were allowed, then decisions made on such information would be erroneous. Keeping the number of AUMs allotted to each rancher in a fixed ratio helps prevent the occurrence of the above problem, but brings about other problems that will be discussed later.

With no hard and fast rules or regulations established by the BLM to cover the allocation of increased grazing, the fixed ratio assumption is believed to be a fair way to allocate the increased grazing on the East Cow Creek Allotment. It could be argued that this is not a fair way to allocate the grazing. For instance, a rancher who does not have any grazing permits on the federal range could argue that he should have the opportunity to graze these lands before those already grazing them are given more grazing privileges. In many areas a very good case could be made for this argument, but in the study area every ranch has permits to graze the federal range.

A strong point against the fixed ratio assumption is that it may act as an obstacle to maximum economic efficiency in the use of available resources. For example, Rancher II gets such a large share of the increased grazing that he is forced to use his private land resources to the absolute maximum. At the highest levels of public investment it even pays him to take non-use of federal grazing so that the other ranchers can increase further. On the other hand, Rancher III has resources going unused at most levels of investment because of the fixed ratio restriction. Rancher III does not have permits in other allotments so all of his private resources can be used in connection with the study allotment. Rancher I has grazing permits in an allotment in Idaho so the non-use of his resources is not serious. Model III was developed under the assumption that the forage from the federal range would be allocated to these four ranchers according to their individual profitability.

Model III

Changing the proportionality assumption necessitates many alterations in the basic model. The available resources (column P_o) are the same as they were in Model II, i. e. , the assumption is made that there is no crested wheatgrass seedings initially. It was shown in Models I and II that after 3,874 acres of seeding came in both models gave almost the same results anyway.

Model III is set up in Table X. The seasons of use considered for each classification of federal rangeland are the same as before. The acres per AUM for each classification of rangeland and for each season of use are also the same as before. The method of reflecting the forage production from the various types of rangeland and seasons of use has been changed. This change can best be explained by again

TABLE X. LINEAR PROGRAMMING MODEL III WHERE EACH RANCHER'S

		Resources	Unit	B_i's P_o	Apr. 1 May 1 P_1
	1	Reseeded range	Acres	1.0	-
	2	Reseedable range	Acres	13,372.0	9.5
	3	Sprayable range	Acres	4,517.0	-
	4	Other (good) range	Acres	1,034.0	-
	5	Other (poor) range	Acres	22,117.0	-
	6	Public capital	$	10.0	-
	7	Apr. 1 - May 1 grazing (public)	AUMs	.01	-1.0
	8	May 1 - June 1 grazing (public)	AUMs	.02	-
	9	June 1 - July 1 grazing (public)	AUMs	.03	-
	10	July 1 - Aug. 1 grazing (public)	AUMs	.04	-
	11	Aug. 1 - Oct. 1 grazing (public)	AUMs	.041	-
R I	12	Aug. 1 - Oct. 1 aftermath (pvt.)	AUMs	180.0	-
R I	13	Oct. 1 - Nov. 20 grazing (pvt.)	AUMs	270.5	-
R I	14	Meadow	Acres	270.0	-
R I	15	Hay	Tons	.011	-
R I	16	Capital	$	.012	-
R II	17	Aug. 1 - Oct. 1 aftermath (pvt.)	AUMs	615.0	-
R II	18	Oct. 1 - Nov. 20 grazing (pvt.)	AUMs	474.0	-
R II	19	Meadow	Acres	923.0	-
R II	20	Hay	Tons	.013	-
R II	21	Capital	$	.014	-
R III	22	Aug. 1 - Oct. 1 aftermath (pvt.)	AUMs	1,082.0	-
R III	23	Oct. 1 - Nov. 20 grazing (pvt.)	AUMs	209.0	-
R III	24	Meadow	Acres	80.0	-
R III	25	Alfalfa	Acres	343.0	-
R III	26	Hay	Tons	.015	-
R III	27	Capital	$	.016	-
R IV	28	Aug. 1 - Oct. 1 aftermath (pvt.)	AUMs	117.0	-
R IV	29	Oct. 1 - Nov. 20 grazing (pvt.)	AUMs	72.0	-
R IV	30	Meadow	Acres	175.0	-
R IV	31	Hay	Tons	.017	-
R IV	32	Capital	$	.018	-

USE OF THE FEDERAL RANGE IS DETERMINED ACCORDING TO PROFITA

May 1 July 1 P_2	May 1 Aug. 1 P_3	June 1 July 1 P_4	July 1 Aug. 1 P_5	Aug. 1 Oct. 1 P_6	Apr. 1 May 1 P_7	June 1 July 1 P_8	July 1 Aug. 1 P_9
-	-	-	-	-	-	-	-
7.7	8.0	7.0	10.0	11.0	-	-	-
-	-	-	-	-	6.0	10.6	5.0
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-1.0	-	-
-.5	-.3333	-	-	-	-	-	-
-.5	-.3333	-1.0	-	-	-	-1.0	-
-	-.3333	-	-1.0	-	-	-	-1.0
-	-	-	-	-1.0	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

BILITY

Aug. 1 Oct. 1 P_{10}	Apr. 1 May 1 P_{11}	June 1 July 1 P_{12}	July 1 Aug. 1 P_{13}	Aug. 1 Oct. 1 P_{14}	Apr. 1 May 1 P_{15}	May 1 July 1 P_{16}
-	-	-	-	-	-	-
-	-	-	-	-	-	-
5.5	-	-	-	-	-	-
-	6.02	10.61	5.01	5.51	-	-
-	-	-	-	-	9.51	7.71
-	-	-	-	-	-	-
-	-1.0	-	-	-	-1.0	-
-	-	-	-	-	-	- .5
-	-	-1.0	-	-	-	- .5
-	-	-	-1.0	-	-	-
-1.0	-	-	-	-1.0	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

May 1 Aug. 1 P_{17}	June 1 July 1 P_{18}	July 1 Aug. 1 P_{19}	Aug. 1 Oct. 1 P_{20}	May 1 July 1 P_{21}	June 1 July 1 P_{22}	July 1 Aug. 1 P_{23}
-	-	-	-	7.0	2.0	2.3
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
8.01	7.01	10.01	11.01	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-.3333	-	-	-	-.5	-	-
-.3333	-1.0	-	-	-.5	-	-
-.3333	-	-1.0	-	-	-	-1.0
-	-	-	-1.0	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

Aug. 1 Oct. 1 P_{24}	May 1 June 1 P_{25}	June 1 July 1 P_{26}	July 1 Aug. 1 P_{27}	Aug. 1 Oct. 1 P_{28}	Apr. 1 May 1 P_{29}	June 1 July 1 P_{30}
2.6	-	-	-	-	-	-
-	6.01	2.01	2.31	2.61	-	-
-	-	-	-	-	3.0	5.3
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	5.17	1.73	1.99	2.24	1.32	2.33
-	-	-	-	-	-1.0	-
-	-1.0	-	-	-	-	-
-	-	-1.0	-	-	-	-1.0
-	-	-	-1.0	-	-	-
-1.0	-	-	-	-1.0	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

July 1 Aug. 1 P_{31}	Aug. 1 Oct. 1 P_{32}	R I Hay P_{33}	R I 60# N P_{34}	R II Hay P_{35}	R II 60# N P_{36}	R III Meadow Hay P_{37}	R III 60# N P_{38}
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
2.5	2.8	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
1.11	1.23	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-1.0	-	-	-	-	-	-	-
-	-1.0	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	1.0	1.0	-	-	-	-
-	-	-1.0	-1.75	-	-	-	-
-	-	-	8.60	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	1.0	1.0	-	-
-	-	-	-	-1.0	-1.75	-	-
-	-	-	-	-	8.60	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	1.0	1.0
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-1.0	-1.75
-	-	-	-	-	-	-	8.60
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

							R I
							78.00
R III Alfalfa P_{39}	R IV Hay P_{40}	R IV 60# N P_{41}	Oct. 1 Nov. 20 P_{42}	Oct. 1 Nov. 20 P_{43}	Oct. 1 Nov. 20 P_{44}	Oct. 1 Nov. 20 P_{45}	Cow-calf yearling P_{46}
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	1.9
-	-	-	-	-	-	-	1.9
-	-	-	-	-	-	-	1.9
-	-	-	-	-	-	-	1.9
-	-	-	-	-	-	-	2.28
-	-	-	3.16	-	-	-	1.52
-	-	-	-3.16	-	-	-	3.16
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	1.94
-	-	-	-	-	-	-	-
-	-	-	-	2.75	-	-	-
-	-	-	-	-2.75	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	2.00	-	-
-	-	-	-	-	-2.00	-	-
-	-	-	-	-	-	-	-
1.0	-	-	-	-	-	-	-
-2.0	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	2.17	-
-	-	-	-	-	-	-2.17	-
-	1.0	1.0	-	-	-	-	-
-	-1.0	-1.75	-	-	-	-	-
-	-	8.60	-	-	-	-	-

R I 68.00	R II 72.50	R II 62.50	R III 58.00	R III 48.00	R IV 41.00	R IV 31.00	R I -1.10
Cow-calf yearling P_{47}	Cow-calf yearling P_{48}	Cow-calf yearling P_{49}	Cow - calf P_{50}	Cow - calf P_{51}	Cow - calf P_{52}	Cow - calf P_{53}	Capital P_{54}
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
1.91	1.65	1.651	1.2	1.21	1.3	1.31	-
1.91	1.65	1.651	1.2	1.21	1.3	1.31	-
1.91	1.65	1.651	1.2	1.21	1.3	1.31	-
1.91	1.65	1.651	1.2	1.21	1.3	1.31	-
3.8	1.98	3.30	1.44	2.4	1.56	2.6	-
-	-	-	-	-	-	-	-
3.161	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
1.941	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-1.0
-	1.32	-	-	-	-	-	-
-	2.75	2.751	-	-	-	-	-
-	-	-	-	-	-	-	-
-	2.0	2.01	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	.96	-	-	-	-
-	-	-	2.0	2.01	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	1.8	1.81	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	1.04	-	-
-	-	-	-	-	2.17	2.171	-
-	-	-	-	-	-	-	-
-	-	-	-	-	1.75	1.751	-
-	-	-	-	-	-	-	-

R II -1.10	R III -1.10	R IV -1.10	R I	R II	R III	R IV
Capital	Capital	Capital	Grazing meadow			
P_{55}	P_{56}	P_{57}	P_{58}	P_{59}	P_{60}	P_{61}
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-4.38	-	-	-
-	-	-	1.0	-	-	-
-	-	-	-	-	-	-
-	-	-	8.60	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-4.38	-	-
-	-	-	-	1.0	-	-
-	-	-	-	-	-	-
-1.0	-	-	-	8.60	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-4.38	-
-	-	-	-	-	1.0	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-1.0	-	-	-	8.60	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-4.38
-	-	-	-	-	-	1.0
-	-	-	-	-	-	-
-	-	-1.0	-	-	-	8.60

using column P_2 as an example. Activity P_2 depicts the fact that 7.7 acres of reseedable rangeland are required to produce one AUM of grazing if used during the two month period May 1 - July 1. Therefore, this activity supplies one-half an AUM for May 1 - June 1 grazing (-.5 in row 8) and one-half an AUM for June 1 - July 1 grazing (-.5 in row 9). A set of grazing seasons are not necessary for each rancher in this model.

All of the AUMs of grazing produced on the federal rangeland are supplied to a common set of grazing seasons as represented by rows 7-11. The ranchers are supplied AUMs of forage from this common set of grazing seasons based on profitability. Activities P_{46} - P_{53} allow livestock production to enter the model. Two alternative livestock activities are presented for each rancher for the same reasons given in Model I. All of the livestock activities, regardless of which rancher they represent, are supplied AUMs of forage for the period April through August from the federal rangeland (rows 7-11). For example, each breeding unit of Rancher I requires 1.9 AUMs of April, May, June, and July forage and 2.28 or 3.8 AUMs of August and September forage from the federal grazing (rows 7-11). Each breeding unit of Rancher II requires 1.65 AUMs of federal grazing from rows 7-10 and 1.98 or 3.3 AUMs of federal grazing from row 11. However, the forage to feed livestock the rest of the year is supplied from each rancher's private resources. August 1 - October 1 grazing is made available through row 12, October 1 - November 20 grazing through row 13, and hay through row 15 for Rancher I. Rows 17, 18, and 20 perform the same respective functions for Rancher II. The same sort of pattern holds for Ranchers III and IV.

No changes were made in the hay producing activities. Forage not used August 1 - October 1 can be transferred and used October 1 - November 20 through columns P_{41} - P_{45}. Activities were built into Model I which allowed Ranchers II and IV to use improved meadow to produce forage for use during October 1 - November 20. In Model III these activities are set up for each of the four ranchers in columns P_{58} - P_{61}. Model III is not quite so complicated and solves in less time than the other two models.

Results Obtained from Model III

Several levels of public investment determined by the parametric program are summarized in Table XI. The MVP of public capital and the average MVP of federal grazing are quite different than in Model I. At most levels of investment these MVPs are substantially higher in Table XI. However, at the highest levels of public investment these MVPs drop off much faster in Model III. The reason for this will be discussed later.

All of the sprayable federal rangeland is improved before any reseeding takes place. One would expect this since no changes were

TABLE XI. RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENTS, ASSUMING THAT THE FORAGE IS UTILIZED BY THE MOST PROFITABLE RANCHES[a]

Levels of Investment	$10	$653	$1,553	$1,989	$2,869	$4,606	$5,259	$5,930	$6,647	$7,448	$9,331
MVP Public Capital	3.85	3.53	3.49	2.71	2.71	2.33	2.03	2.03	1.77	1.09	1.02
MVP Apr. Grazing AUM	8.35	8.63	8.66	8.15	8.15	7.81	6.90	6.90	6.04	3.72	3.58
MVP May Grazing AUM	13.54	14.00	14.05	13.21	13.21	12.66	11.19	11.19	9.79	6.03	5.80
MVP June Grazing AUM	0	0	0	0	0	0	0	0	0	0	0
MVP July Grazing AUM	7.56	7.82	7.85	7.38	7.38	6.53	5.71	5.71	5.00	3.08	2.91
MVP Aug. - Sept. Grazing AUM	9.67	8.84	8.74	8.23	8.23	7.28	6.44	6.44	5.63	3.47	3.28
Av. MVP Public Grazing	8.13	8.02	8.00	7.53	7.53	6.93	6.11	6.11	5.35	3.30	3.14
RII Private Investment	0	0	0	179	479	1,058	1,058	1,058	1,058	1,058	3,693
RI Private Investment	0	0	0	0	0	0	204	204	204	242	242
RIII Private Investment	0	0	0	0	0	0	0	0	218	218	688
RIV Private Investment	0	0	0	0	0	0	0	0	0	183	183
Total Private Investment	0	0	0	179	479	1,058	1,262	1,262	1,480	1,663	4,806
Acres Sprayed	23	1,483	3,529	4,517	4,517	4,517	4,517	4,517	4,517	4,517	4,517
Acres Seeded	0	0	0	0	1,023	3,043	3,804	4,584	5,419	6,352	8,543

[a]It was assumed that there was no reseeded crested wheatgrass initially.

made in the respective costs or expected yield increases of these improvements. It should be kept in mind that these improvements had a higher net return per dollar invested for most investment levels than was the case in Model I.

The amount of private investment at each level of public investment is much lower in this model as one can see by comparing Table XI with Table IV. Rancher II is required to invest far more than the other ranchers; nevertheless, his investment is much less in Model III. Private investment comes in first at the $1,989 level of public investment with Rancher II having to invest $179. It is profitable for Rancher I to start investing in meadow improvements at the $4,688 level of public investment. Rancher I did not improve any meadow in the other models. Meadow improvement on Ranch III does not come in until public investment gets up to $6,648. However, Rancher III would improve all of his meadow at the highest level of investment considered in Table XII. Under the assumptions of Model I Rancher IV was forced to invest at the lower levels of public investment. In Model III he is the last rancher to invest private capital.

The private investment pattern shown in Table XI can be explained by the way the ranchers are allocated increased federal grazing in Model III. The number of animal units permitted to graze the federal range for each rancher at each level of public investment are shown in Table XIII. Initially all of the grazing is allocated to three of the ranchers. Rancher IV is the high cost operation and does not come into the solution until the other ranchers have used their private resources almost to the limit. As more federal grazing is made available at each level of investment in range improvements, the linear program determines which rancher can make the most profitable use of this forage and allocates it to him. Rancher I can make the most profitable use of the first forage brought about by range improvements on the federal rangeland. The forage allocated to him increases over the first four levels of investment, while the forage allocated to the other ranchers remains unchanged. As bottle-necks come about in Rancher I's feed program with this increased federal grazing, it becomes more profitable for Rancher II to get the increased forage. At about the $5,259 level of investment the allocation is again made to Rancher I. Rancher IV is allocated forage for 77 head on the federal range at the $6,450 level of investment. This shifting allocation pattern continues on through the remaining levels of investment.

The method of allocating federal grazing described above explains the private investment pattern in Table XI. As long as the amount of federal grazing allocated to a particular rancher is unchanged there is no need to change his private investment. Therefore, the changes in private investment are directly tied to the way federal grazing is allocated. This does not show up clearly because all levels of public investment are not presented in Table XI.

Determination of Land Use Patterns

The seasonal use patterns for the federal range resources are presented in Table XII. Essentially, the use pattern is the same as it was in Model II. At any particular investment level there may be a few acres difference for a grazing season between the two models. However, there are not significant changes in the seasons of use for the various types of federal rangeland.

After the above results were obtained, Model III was revised slightly to allow more flexibility in the use pattern for other "poor" and reseedable range. In the original Model III other "poor" and reseedable range were allowed to furnish grazing for May 1 - July 1 but not for May 1 - June 1 and June 1 - July 1 separately. Consequently, it was not profitable for crested wheatgrass to provide June 1-July 1 grazing since May 1 - June 1 grazing could not be supplied from any other rangeland.

The revision of Model III merely added two new activities. These two activities allow other "poor" and reseedable range to furnish grazing during the May 1 - June 1 season. In this revised model reseedable (unimproved) rangeland tended toward an earlier season of use, being used April 1 - May 1 and June 1 - July 1 at the higher levels of capital. Crested wheatgrass was used earlier in the season also.

TABLE XII. SEASONAL USE PATTERNS FOR EACH TYPE OF FEDERAL RANGELAND FOR MODEL III.

Levels of Investment	$10	$653	$1,554	$1,989	$2,870	$4,606	$5,260	$5,930	$6,648	$7,449	$9,332
Season of Use For Each Range Type											
Reseedable Acres:											
June 1 - Aug. 1	13,371	13,371	8,784	6,563	0	0	0	0	0	0	0
May 1 - July 1	0	0	4,589	6,810	12,348	10,329	9,569	8,788	7,954	7,021	4,830
Crested Wheatgrass Acres:											
July 1 - Aug. 1	0	0	0	0	1,023	3,042	3,223	3,323	3,429	3,544	3,823
Aug. 1 - Oct. 1	0	0	0	0	0	0	581	1,262	1,990	2,808	4,720
Sprayable Acres:											
Aug. 1 - Oct. 1	4,494	3,029	988	0	0	0	0	0	0	0	0
Sprayed Acres:											
Aug. 1 - Oct. 1	23	1,488	744	3,413	3,620	4,022	3,541	2,955	2,329	1,644	0
July 1 - Aug. 1	0	0	2,785	1,104	897	90	0	0	0	0	0
April 1 - May 1	0	0	0	0	0	405	976	1,562	2,188	2,873	4,517
Other Good Acres:											
Aug. 1 - Oct. 1	1,034	1,034	1,034	1,034	1,034	1,034	1,034	1,034	1,034	1,034	1,034
Other Poor Acres:											
April - May	9,491	10,067	10,794	11,147	11,734	11,588	10,178	8,731	7,184	5,485	1,425
Aug. - Oct.	2,030	0	0	0	0	0	0	0	0	0	0
May - Aug.	10,596	12,050	11,323	10,970	10,383	0	0	0	0	0	0
May - July	0	0	0	0	0	10,529	11,939	13,386	14,933	16,632	20,692

Some 3,600 acres were grazed in July and about 2,000 acres were grazed in June at an investment level of $7,000. At investment levels greater than $7,000 crested wheatgrass grazing shifts toward August 1 - October 1 use. Sprayed rangeland is grazed for the most part August 1 - October 1 as is other "good" rangeland. Other "poor" rangeland furnishes most of the April grazing and all of the May grazing. These land-use patterns are more realistic in some cases than the original results from Model III. Adding the more flexible land-use activities to Model III had very little effect on the MVP's; the new land-use pattern may be just as appropriate. However, one should be careful to avoid getting too much flexibility which could require more control over the livestock than is feasible on the open range. These revised land-use patterns are presented for several levels of investment in Appendix D.

Federal Range Improvement Decisions

Internal rates of return were calculated for each level of public investment and summarized in Table XIII. When reading Table XIII one should remember that the MVP at any particular level of investment holds up to the next investment level. Therefore, the internal rate of return corresponding to a particular MVP is shifted to the right by one column. The internal rate of return of 31 percent at the $654 investment level is based on the $3.85 MVP at the $10 investment

TABLE XIII. INTERNAL RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENT FOR MODEL III

Level of Investment	$10	$654	$1,553.78	$1,553.81	$1,989	$2,870	$4,146	$4,606	$4,688
MVP Public Capital	3.86	3.53	3.49	3.28	2.71	2.71	2.51	2.33	2.30
Internal Rate of Return		31%	27.5%	27%	26%	12.5%	12.5%	11%	10%
Acres Sprayed	23	1,488	3,529	3,529	4,517	4,517	4,517	4,517	4,517
Acres Seeded	0	0	0	0	0	1,023	2,506	3,043	3,138
Total Adjusted Ranch Income	45,965	48,450	51,590	51,590	53,020	55,408	58,870	60,026	60,216
Allocation of Public Grazing (head)									
Rancher I	46	106	183	183	183	183	183	183	188
Rancher II	441	441	441	441	479	540	630	660	660
Rancher III	510	510	510	510	510	510	510	510	510
Rancher IV	0	0	0	0	0	0	0	0	0

Level of Investment	$5,259	$6,450	$6,648	$6,863	$7,449	$7,705	$9,332	$9,398
MVP Public Capital	2.03	1.89	1.77	1.68	1.09	1.04	1.02	0.79
Internal Rate of Return	9.75%	8%	7%	6.25%	5.5%	1%	0.5%	0.25%
Acres Sprayed	4,517	4,517	4,517	4,517	4,517	4,517	4,517	4,517
Acres Seeded	3,804	5,189	5,419	5,670	6,352	6,650	8,543	8,620
Total Adjusted Ranch Income	61,531	63,945	64,318	64,670	65,687	65,967	67,663	67,731
Allocation of Public Grazing (head)								
Rancher I	225	225	225	225	225	237	237	237
Rancher II	660	660	660	660	660	660	765	769
Rancher III	510	510	523	523	523	540	540	540
Rancher IV	0	77	77	77	114	114	114	114

level.

Assuming again the 3.0 percent opportunity rate of interest based on Senate Document 97, the optimum level of investment is $7,449. At this level of investment the internal rate of return is approximately 5.5 percent. Again the 4,517 acres of sprayable range would be sprayed and 6,352 acres of crested wheatgrass would be seeded. Some 1,329 more acres of crested wheatgrass would be seeded at the optimum level of investment in Model III than for Model II.

At the optimum level of investment, federal forage would be allocated in the following manner: Rancher I could graze 225 animal units, Rancher II could graze 660 animal units, Rancher III could graze 523 animal units, and Rancher IV could graze 114 animal units. As expected, the assumptions of Model III cause a reapportionment of the federal grazing to the four ranchers. Each rancher's relative share of the federal grazing was held constant in Models I and II. These percentages were 6.29, 61.12, 24.37, and 8.22 respectively for the four ranchers in Model I. At the indicated optimum level of investment in Model III they are 15.0 percent, 43.0 percent, 34.0 percent, and 8.0 percent. Ranchers I and III get a larger share, Rancher II gets a smaller share, and Rancher IV remains in about the same relative position. Some question might arise as to the feasibility of allowing Rancher I to increase his relative share as much as indicated above. However, before one could say more about this, information would have to be gathered on the rancher's private resources located in Idaho.

The internal rate of return takes a sudden drop at the $7,705 level of investment where the MVP of public capital up to that level is $1.09. This fact was mentioned earlier but not explained. One of the most significant changes in the solution at this level is the fact that the next most profitable alternative is to have Rancher I bring breeding units in at the lower $68 price. Up to this level of investment the high priced option was selected by the program for each rancher.

In summary, Model III has some advantages over Model I. The full potential of Rancher III's resources can come into the program. This is important since he has no permits in any other allotment. Another advantage is that the pressure which was put on Rancher II to expand because of the fixed proportionality is eliminated. Rancher I may be over extending his private resources in the study allotment, which is a disadvantage or limitation. This limitation could be remedied with more prior planning in getting private resource inventories. Model III causes a break with the institutional framework developed around federal rangeland use. That is, grazing is allocated on profitability and Rancher IV does not come in for any federal grazing until at least $6,450 dollars are invested annually in range improvements. At the optimum level of public investment determined for illustrative purpose by using a 3.0 percent interest rate, Rancher IV comes in for about the number of livestock that his private ranch resources can reasonably support. Model III does not use so much computer space and solves much faster than Model I. Therefore, a model similar to III is used to illustrate a somewhat hypothetical case which is set up in Model IV.

Model IV

Crested wheatgrass seedings tend to come into the solutions for summer grazing, July 1 - October 1, where it usually makes its maximum contribution to the year-long forage program. However, grazing crested wheatgrass during these summer months conflicts with the opinions of many range managers.

The BLM held a range management seminar during the summer of 1963 where, among other things, the proper management of crested wheatgrass was discussed. They concluded: "Under the most proper use, crested wheatgrass should be used in May and earlier grazing use should be made on native ranges. Usable old feed should be available on native range, as little growth takes place prior to May (23, p. 31-35)." Hyder and Senva, 1963, found: "crested wheatgrass exhibited maximum productivity in the second growing season, a stable productivity in the fifth and sixth seasons, low palatability in July and August, early and fast accumulation of total water-soluable carbohydrates, and morphological characteristics favorable to spring grazing (23, p. 3)." Reynolds and Springfield in 1953 reported the following: "Crested wheatgrass furnishes the best forage during the spring and early fall. . . . Cattle do well on it, however, during a May to October grazing season (38, p. 18)."

All of these things were taken into consideration by the range management personnel when they made their estimates of the acres required per AUM for the various seasons of use. Another factor that was taken into account is the fact that the crested wheatgrass has to be grazed quite intensively during the summer to get proper utilization.

A grass that will furnish better quality summer forage would do much to round out the seasonal grazing on this allotment. Whitmar wheatgrass, (Agropyron inerme), is such a grass. No experimental work has been done in the study area with whitmar wheatgrass, but it appears to be a feasible alternative that should be considered for the allotment. Whitmar wheatgrass is more difficult to get established and can be damaged more by improper grazing than crested wheatgrass. Because of the above difficulties it was assumed that only the best 5,000 acres of the 13,372 acres of reseedable rangeland would be adaptable to whitmar wheatgrass seedings. It was further assumed that, even on these best sites, whitmar wheatgrass would cost $2.50 more per acre for seed and require one more year of non-use than crested wheatgrass. The reseeding cost for whitmar wheatgrass was $1.00 per acre per year as shown below in Table XIV.

(Reseeding cost for crested wheatgrass was only $ .86 per acre per year.)

TABLE XIV. RESEEDING COST ESTIMATES FOR WHITMAR WHEATGRASS

Initial Costs:	
Plowing and Drilling	$12.21
Fencing	.99
Water Development	2.20
Non-Use	1.00
	$16.40
Annual Costs:	
Fence Maintenance	$ .08
Water Maintenance and Use	.10
	$ .18

20 Year Life of the Seeding:

$$\frac{\$16.40}{20} = \$\ .82 + \$\ .18 = \$1.00 \text{ per acre per year}$$

Whitmar wheatgrass would extend the high quality grazing season on the federal land; thus, it would not be necessary to bring the salable livestock off the federal range in August to get the weight gain needed for the higher priced livestock activities. Some pressure would be taken off the private grazing as whitmar wheatgrass replaces the aftermath grazing furnished by the private meadows. The aftermath grazing could then be used to provide forage for October 1 - November 20 grazing.

Table XV shows the additions to Model III that are required to

TABLE XV. ADDITIONAL ROWS AND ACTIVITIES ADDED TO MODEL III TO OBTAIN MODEL IV, WHICH REFLECTS THE WHITMAR WHEATGRASS ALTERNATIVE.

Column				Transfer Activities				April 1 May 1	June 1 July 1	July 1 Aug. 1	Aug. 1 Oct. 1	RI Aug. 1 Oct. 1	RII Aug. 1 Oct. 1	RIII Aug. 1 Oct. 1	RIV Aug. 1 Oct. 1
	Row	Resources	P_0	P_{42}	P_{43}	P_{44}	P_{45} ...	P_{62}	P_{63}	P_{64}	P_{65}	P_{66}	P_{67}	P_{68}	P_{69}
	1	Reseeded Range	1.0												
	2	Reseedable Range	13,372.0					2.8	5.0	1.8	2.5	2.5	2.5	2.5	2.5
	3	Sprayable Range	4,517.0												
	4	Other Good Range	1,034.0												
	5	Other Poor Range	22,117.0												
	6	Public Capital	10.0					2.8	5.0	1.8	2.5	2.5	2.5	2.5	2.5
	7	Apr. 1-May 1 Grazing	0.0					-1.0							
	8	May 1 - June 1 Grazing	0.0												
	9	June 1 - July 1 Grazing	0.0						-1.0						
	10	July 1 - Aug. 1 Grazing	0.0							-1.0					
	11	Aug. 1 - Oct. 1 Grazing	0.0								-1.0				
	12	Aug. 1 - Oct. 1 Aftermath (Pvt)	180.0	3.16								-1.0			
	13	Oct. 1 - Nov. 20 Grazing (Pvt)	270.5	-3.16											
RI	14	Meadow	270.0												
	15	Hay	0.0												
	16	Capital	0.0												
	17	Aug. 1-Oct. 1 Aftermath (Pvt)	615.0		2.75								-1.0		
	18	Oct. 1-Nov. 20 Grazing (Pvt)	474.0		-2.75										
RII	19	Meadow	923.0												
	20	Hay	0.0												
	21	Capital	0.0												
	22	Aug. 1-Oct. 1 Aftermath (Pvt)	1,082.0			2.00								-1.0	
	23	Oct. 1-Nov. 20 Grazing (Pvt)	209.0			-2.00									
RIII	24	Meadow	80.0												
	25	Alfalfa	343.0												
	26	Hay	0.0												
	27	Capital	0.0												
	28	Aug. 1-Oct. 1 Aftermath (Pvt)	117.0				2.17								-1.0
RIV	29	Oct. 1-Nov. 20 Grazing	72.0				-2.17								
	30	Meadow	175.0												
	31	Hay	0.0												
	32	Capital	0.0												
	33	Whitmar Reseeding	5,000.0						2.8	5.0	1.8	2.5	2.5	2.5	2.5
	34	Limits Oct. 1-Nov. 20 to Pvt. Land	180.0	3.16											
	35	Limits Oct. 1-Nov. 20 to Pvt. Land	615.0		2.75										
	36	Limits Oct. 1-Nov. 20 to Pvt. Land	1,082.0			2.00									
	37	Limits Oct. 1-Nov. 20 to Pvt. Land	117.0				2.17								

reflect the whitmar wheatgrass reseeding alternative. The easiest way to explain how the whitmar reseeding fits into the model is to start with the new columns.

New entries were made in columns P_{42} - P_{45}, rows 34, 35, 36, and 37. These activities allowed aftermath grazing not used during August 1 - October 1 to be transferred and used October 1 - November 20 in Model III. With the inclusion of the whitmar wheatgrass alternative the possibility arises of having August 1 - October 1 AUMs produced on federal land transferred to October 1 - November 20 grazing. To avoid this possibility the transfer activities are limited to the amounts available in column P_o, rows 34, 35, 36, and 37. For example, Activity P_{44} indicates that 2.00 AUMs of aftermath grazing, row 22, are required to produce 2.00 AUMs of October 1 - November 20 grazing. There are 1,082 AUMs available (column P_o, row 22) and additional AUMs can be produced by Activity P_{68}. Two AUMs are also required by row 36 where only the 1,082 AUMs are available; thus when the 1,082 AUMs are exhausted in row 36 the transfer stops.

Activities P_{62} - P_{65} consider the seasonal grazing alternatives for whitmar wheatgrass. For example, 2.5 acres of reseedable rangeland (row 2), $2.50 of public capital (row 6), and 2.5 acres of the 5,000 acres of reseedable rangeland suited for whitmar (row 33) are required to produce one AUM of August 1 - October 1 grazing (row 11) Activity P_{65}. The 5,000 acres that can be seeded to whitmar wheatgrass were not subtracted from the 13,372 total acres of reseedable rangeland initially. They are subtracted as they are used by rows 2 and 33. If all 5,000 acres are not used for whitmar seeding they are still available for use as reseedable range or for seeding to crested wheatgrass. Activity P_{65} supplies AUMs of grazing for the 60 percent of the livestock remaining on the federal rangeland during August and September. The last four activities listed in Table XV supply AUMs of grazing from the whitmar wheatgrass reseedings on the federal rangeland for the 40 percent of the livestock which usually go onto the meadow aftermath. Thus, it is possible to graze livestock on the federal range from April 1 - October 1 and still take advantage of the high price livestock option. However, this will happen only if reseeding whitmar wheatgrass is a more economical way of getting this late summer grazing than the other alternatives considered.

Results Obtained from Model IV

Some of the general trends in resource use are presented in Table XVI which is much like the seasonal use pattern tables discussed for the earlier models. Since some of the results have been discussed before, only the real differences will be mentioned. The MVPs for public capital remain fairly high at large annual investments, such as $1.23 at $11,100 annual investment. Private investment is the variable that shows the greatest change in this model. For Ranchers

TABLE XVI. RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENTS, ASSUMING THAT THE FORAGE IS UTILIZED BY THE MOST PROFITABLE RANCHES AND WITH THE RESEEDING OF WHITMAR WHEATGRASS CONSIDERED.[a]

Levels of Investment	$10	$1,989	$4,020	$4,951	$6,113	$6,878	$11,100	$11,340	$11,348
MVP Public Capital	3.86	3.24	3.03	2.07	1.94	1.33	1.23	1.15	.93
MVP April Grazing	8.35	8.15	8.43	7.07	6.60	4.54	4.30	4.02	3.72
MVP May Grazing	13.54	13.21	13.67	11.47	10.70	7.35	6.97	6.52	7.95
MVP June Grazing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MVP July Grazing	7.56	7.38	7.06	5.08	4.74	3.25	3.03	3.26	3.06
MVP Aug.-Sept. Grazing	9.67	8.22	7.86	6.60	6.15	4.23	3.94	3.68	3.45
Av. MVP Public Grazing	7.89	7.42	7.42	6.06	5.65	3.89	3.66	3.50	3.64
RI Private Investment	0	0	0	242	242	242	0	0	0
RII Private Investment	0	180	1,005	1,058	1,058	1,058	270	270	270
RIII Private Investment	0	0	0	0	0	0	218	390	396
RIV Private Investment	0	0	0	0	0	183	183	183	183
Acres Sprayed	23	4,517	4,517	4,517	4,517	4,517	4,517	4,517	4,517
Acres Seeded (Crested)	0	0	0	477	1,670	2,455	4,884	5,071	5,078
Acres Seeded (Whitmar)	0	0	2,033	2,557	2,695	2,786	4,921	5,000	5,000

[a]It was assumed that there was no reseeded crested wheatgrass initially.

I and II it seems quite erratic, going up then going back down as public investment increases. At the lower levels of public investment whitmar wheatgrass comes in to furnish July grazing. The ranchers have to furnish 40 percent of the August 1 - October 1 grazing and all of the October 1 - November 20 grazing from their private resources. Grazing for October 1 - November 20 can be produced most economically for Ranchers I and II by investing in meadow improvements for this forage at the lower investment levels. Activities P_{66} and P_{67} come into the solution at annual investment levels over $10,000 which produce August 1 - October 1 AUMs for these two ranchers. This, in turn, allows them to use aftermath grazing for October 1 - November 20 and reduce their private investments. Another interesting fact to note is that Rancher III is the only one that has to invest in meadow improvement for hay production.

Spraying, as in the other models, is the best alternative use of public capital. As soon as all of the sprayable rangeland is sprayed, whitmar wheatgrass seedings come in. After about 2,500 acres of whitmar wheatgrass are seeded, crested wheatgrass comes in and they complement each other at the higher levels of investment.

Determination of Land Use Patterns

The seasonal use patterns for the different types of federal rangeland are presented in Table XVII. Reseedable rangeland is

TABLE XVII. SEASONAL USE PATTERNS FOR EACH TYPE OF FEDERAL RANGE FOR MODEL IV.

Levels of Investment	$10	$1,989	$4,020	$4,951	$6,113	$6,878	$11,100	$11,340	$11,348
Season of Use for Each Range Type									
Reseedable Range									
May 1- Aug. 1	13,372	6,563	0	0	0	0	0	0	0
May 1- July 1	0	6,809	11,339	10,338	9,007	8,132	3,566	3,301	3,291
Sprayable Range									
Aug. 1 - Oct. 1	4,494	0	0	0	0	0	0	0	0
Other Good Range									
Apr. 1 - May 1	0	0	0	0	0	0	519	845	857
Aug. 1 - Oct. 1	1,034	1,034	1,034	1,034	1,034	1,034	519	189	177
Other Poor Range									
Apr. 1 - May 1	9,491	11,147	12,768	10,765	8,253	6,599	435	15	0
May 1 - July 1	0	0	9,349	11,352	13,864	15,518	21,682	22,102	22,117
May 1 - Aug. 1	10,596	10,970	0	0	0	0	0	0	0
Aug. 1 - Oct. 1	2,030	0	0	0	0	0	0	0	0
Sprayed									
Apr. 1 - May 1	0	0	0	827	1,849	2,522	4,517	4,517	4,517
July 1 - Aug. 1	0	1,104	531	0	0	0	0	0	0
Aug. 1 - Oct. 1	23	3,413	3,986	3,690	2,668	1,995	0	0	0
Seeded (Crested)									
Aug. 1 - Oct. 1	0	0	0	477	1,670	2,455	4,884	5,071	5,078
Seeded (Whitmar)									
July 1- Aug. 1	0	0	2,033	2,533	2,671	2,762	2,948	2,965	2,963
Aug. 1 - Oct. 1	0	0	0	24	24	24	1,973	2,035	2,037

grazed May, June, and July until whitmar wheatgrass is reseeded on part of it. The whitmar wheatgrass first comes in for use during July which shifts unimproved reseedable range to May and June grazing. Sprayable and sprayed range furnish late season grazing, but as reseeding comes in, sprayed range use is changed to April grazing. Other "good" range is grazed from August 1 - October 1 at most levels of investment. However, at the higher levels of investment some of it is used in April. Other "poor" range furnishes much of the early season grazing. At many levels of public investment it provides April grazing and tends toward more and more use during May and June. Crested wheatgrass is only used August and September in this model. Reseeding rangeland provides additional forage for summer use on the allotment. The results obtained from Model IV indicate that whitmar wheatgrass would replace some but not all of the crested wheatgrass. This is shown by the fact that all 5,000 acres of whitmar wheatgrass did not come into the solution before any crested wheatgrass came in. If the assumptions made in Model IV regarding the costs and yields of whitmar wheatgrass are realistic, then some amount of whitmar should have a place in the management plans for this allotment.

Federal Range Improvement Decisions

Over 20 parametric changes were required to get the MVP of public capital below one dollar. Nineteen of these levels of public investment are presented in Table XVIII. The internal rates of return at the lower levels of investment follow a pattern very much like they did in Model III. One of the most significant points brought out in Table XVIII is the fact that whitmar wheatgrass comes in at an internal rate of return of 16 percent. Crested wheatgrass does not come in until the internal rate of return gets down to about 13 percent. Crested wheatgrass comes into the solution at about 12. 5 percent in Model III which is about the same as in Model IV. Whitmar wheatgrass comes into the solution at a higher internal rate of return than crested wheatgrass in any of the previous models.

If the Senate Document 97 alternative rate of interest of 3. 0 percent is again used, the optimum level of annual public investment is $6, 878. The number of livestock grazed by the permittees on the federal rangeland is almost the same under this optimum as they were at the optimum level of investment in Model III. At the optimum level of investment in Model IV, 2, 786 acres of whitmar wheatgrass and 2, 455 acres of crested wheatgrass would be seeded. This would indicate that the public land managers have already seeded too much crested wheatgrass on the allotment. It was assumed in Model IV that there was no crested wheatgrass already on the allotment, but 3, 874 acres were seeded prior to this study.

Model IV brings up an interesting problem concerning the proper

TABLE XVIII. INTERNAL RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENTS FOR MODEL IV

Levels of Investment	$10	$653	$1, 553	$1, 989	$2, 828	$4, 019	$4, 159	$4, 463	$4, 739	$4, 951
MVP Public Capital	3. 86	3. 55	3. 28	3. 24	3. 24	3. 03	2. 81	2. 35	2. 09	2. 08
Internal Rate of Return		31. 0%	28. 0%	26. 0%	16. 0%	16. 0%	14. 0%	13. 0%	10. 0%	8. 5%
Acres Sprayed	23	1, 488	3, 529	4, 517	4, 517	4, 517	4, 517	4, 517	4, 517	4, 517
Acres Crested Wheatgrass	0	0	0	0	0	0	0	282	477	477
Acres Whitmar Seeded	0	0	0	0	839	2, 033	2, 173	2, 479	2, 536	2, 557
Total Adjusted Ranch Income	15, 965	48, 449	51, 590	53, 020	55, 737	59, 603	60, 026	60, 881	61, 530	63, 334
Animal Units of Federal Grazing										
Rancher I	46	106	183	183	183	183	183	207	225	237
Rancher II	441	441	441	479	549	649	660	660	660	660
Rancher III	510	510	510	510	510	510	510	510	510	510
Rancher IV	0	0	0	0	0	0	0	0	0	0

Levels of Investment	$6, 113	$6, 306	$6, 878	$10, 026	$10. 624	$11, 100. 47	$11, 100. 58	$11, 337	$11, 384
MVP Public Capital	1. 94	1. 73	1. 33	1. 31	1. 29	1. 26	1. 23	1. 15	.93
Internal Rate of Return	8. 25%	7. 75%	7. 0%	2. 8%	2. 75%	2. 5%	2. 25%	2. 0%	1. 5%
Acres Sprayed	4, 517	4, 517	4, 517	4, 517	4, 517	4, 517	4, 517	4, 517	4, 517
Acres Crested Wheatgrass	1, 670	1, 868	2, 455	4, 248	4, 600	4, 884	4, 884	5, 068	5, 078
Acres Whitmar Seeded	2, 695	2, 718	2, 786	4, 393	4, 689	4, 921	4, 921	4, 982	5, 000
Total Adjusted Ranch Income	64, 388	64, 762	65, 749	69, 943	70, 726	71, 342	71, 342	71, 633	71, 646
Animal Units of Federal Grazing									
Rancher I	237	237	237	237	252	264	264	264	264
Rancher II	660	660	660	736	736	736	736	736	736
Rancher III	510	523	523	523	523	523	523	533	534
Rancher IV	77	77	114	114	114	114	114	114	114

interest rate that the decision-maker should use. It was assumed that 3.0 percent should be the cut-off point. However, the next higher level of investment has an internal rate of return of 2.8 percent, which does not quite meet the assumed interest rate. At the next higher level of investment ($10,026) the acres of crested and whitmar wheatgrass seeded would almost double. Should the public land management decision-maker assume 2.8 percent is close enough to the three percent interest rate decided upon? The answer to this question raises still other points of discussion. Because of the crudeness of some of the data used in the determination of the internal rates of return, it may seem rather superfluous to hold absolutely firm on a given rate of interest as the cut-off point. The danger is that a decision-maker can rationalize his position until an economic optimum level of investment is meaningless. The fact that decisions might have to be made on the basis of a fraction of one percent in the internal rate of return should cause the researcher to be very careful in collecting the data and setting up the models. Linear programming is a powerful analytical tool that can be used to compute these decision indicators such as internal rates of return, but the final decision has to be made by the decision-maker himself. His decisions should be based upon experience, knowledge, judgement, and the empirical evidence available.

Model V

Up to this point the linear programming models have not considered the possibility of improving the individual rancher's private rangeland. Models V and VI are set up in such a way that improvement of private rangeland is taken into account. Improvement of private rangeland was not considered in the earlier models because the limited memory capacity on the IBM 1620 computer prevented the solving of such large models. Near the end of the study an IBM 1410 computer became available, thus making possible the use of larger models.

Model V is essentially the same as Model II with the crested wheatgrass seeding (established prior to the study) acreage set at one acre and the fixed proportionality assumption built into the model. However, additional rows and columns were added to permit the possibility of range improvements on the private rangeland of the cooperating ranchers.

A tabular arrangement of Model V similar to the tables used for the previous models is too cumbersome to put in the thesis. Therefore, Model V is arranged in the form of a set of mathematical equations and inequalities. Each equation or inequality represents a row of coefficients from the linear programming model. The equations and inequalities for Model V are set-up in Table XIX. The various columns or activities are identified by the subscripts on the variables designated by "X". For example the objective function in the first row of Table XIX is the equation that is being maximized by the linear programming solution, subject to the constraints represented by the inequalities listed in the remaining rows of the table. The coefficients of this first equation are the prices of the breeding unit activities and the cost of private capital to each rancher. Total adjusted income to the allotment is computed by the maximization of the equation. Reseeded range is represented by the first inequality of Table XIX. The numbers to the right of the inequality sign indicate the number of acres required per AUM of reseeded rangeland at the different seasons of use. Numerical values in the other inequalities can be interpreted in the same manner as similar numbers in Model II.

One could construct a table of the same type used for the earlier models from these equations and inequalities. The only difficulty arises in knowing what the column headings are. The first 32 columns or activities have the same headings as Model I. Columns 33-37 are activities which allow Rancher I's private rangelands to be used October 1 - November 20. These activities consider the use of unimproved as well as improved rangeland. The improvements considered for each of the ranchers' private rangeland are seeding and spraying. Meadow aftermath grazing for Rancher I is entered in

TABLE XIX. EQUATIONS AND INEQUALITIES REPRESENTING MODEL V.

Objective function	$= 78X_{44} + 68.0X_{45} - 1.10X_{46} + 72.5X_{58} + 62.5X_{59} - 1.10X_{60} + 58.0X_{75} + 48.0X_{76} - 1.10X_{77} + 41.0X_{87} + 31.0X_{88} - 1.10X_{89}$
Reseeded range	$1.0 \geq 7.0X_{21} + 2.0X_{22} + 2.3X_{23} + 2.6X_{24}$
Reseedable range	$13,372.0 \geq 9.5X_1 + 7.7X_2 + 8.0X_3 + 7.0X_4 + 10.0X_5 + 11.0X_6 + 6.0X_{25} + 2.0X_{26} + 2.3X_{27} + 2.6X_{28}$
Sprayable range	$4,517.0 \geq 6.0X_7 + 10.6X_8 + 5.0X_9 + 5.5X_{10} + 3.0X_{29} + 5.3X_{30} + 2.5X_{31} + 2.8X_{32}$
Other good range	$1,034.0 \geq 6.0X_{11} + 10.6X_{12} + 5.0X_{13} + 5.5X_{14}$
Other poor range	$22,117.0 \geq 9.5X_{15} + 7.7X_{16} + 8.0X_{17} + 7.0X_{18} + 10.0X_{19} + 11.0X_{20}$
Public capital	$10.0 \geq 5.17X_{25} + 1.73X_{26} + 1.99X_{27} + 2.24X_{28} + 1.32X_{29} + 2.33X_{30} + 1.11X_{31} + 1.23X_{32}$
Reseedable range	$824.0 \geq 10.0X_{33} + 2.6X_{34}$
Sprayable range	$166.0 \geq 5.5X_{35} + 2.8X_{36}$
Other poor range	$1,800.0 \geq 11.0X_{37}$
Meadow	$270.0 \geq .2283X_{40} + .2283X_{41} + 1.0X_{42} + 1.0X_{43}$
Meadow aftermath	$270.0 \geq 1.5X_{38} + 1.5X_{39}$
Hay	$0.0 \geq -1.0X_{42} - 1.75X_{43} + 1.94X_{44} + 1.94X_{45}$
April - May 1 grazing	$0.0 \geq -.0629X_1 - .0629X_7 - .0629X_{11} - .0629X_{15} - .0629X_{29} + 1.9X_{44} + 1.9X_{45}$
May - June 1 grazing	$0.0 \geq -.03145X_2 - .0210X_3 - .03145X_{16} - .0210X_{17} - .03145X_{21} - .0629X_{25} + 1.9X_{44} + 1.9X_{45}$
June - July 1 grazing	$0.0 \geq -.03145X_2 - .0210X_3 - .0629X_4 - .0629X_8 - .0629X_{12} - .03145X_{16} - .0210X_{17} - .0629X_{18} - .03145X_{21} - .0629X_{22} - .0629X_{26} - .0629X_{30} + 1.9X_{44} + 1.9X_{45}$
July - Aug. 1 grazing	$0.0 \geq -.0210X_3 - .0629X_5 - .0629X_9 - .0629X_{13} - .0210X_{17} - .0629X_{19} - .0629X_{23} - .0629X_{27} - .0629X_{31} + 1.9X_{44} + 1.9X_{45}$
Aug. - Oct. (Public)	$0.0 \geq -.0629X_6 - .0629X_{10} - .0629X_{14} - .0629X_{20} - .0629X_{24} - .0629X_{28} - .0629X_{32} + 2.28X_{44} + 3.8X_{45}$
Aug. - Oct. (Private)	$0.0 \geq -1.0X_{38} - 1.0X_{40} + 1.52X_{44}$
Oct. - Nov. 20 (Private)	$0.0 \geq -1.0X_{33} - 1.0X_{34} - 1.0X_{35} - 1.0X_{36} - 1.0X_{37} - 1.0X_{39} - 1.0X_{41} + 3.16X_{44} + 3.16X_{45}$
Rancher I capital	$0.0 \geq 2.24X_{34} + 1.23X_{36} + 8.6X_{40} + 8.6X_{41} + 8.6X_{43} - 1.0X_{46}$
Reseedable range	$310.0 \geq 10.0X_{47} + 2.6X_{48}$
Sprayable range	$366.0 \geq 5.5X_{49} + 2.8X_{50}$

TABLE XIX. con't.

Other poor range	$1,065.0 \geq 10.0X_{51}$
Meadow	$923.0 \geq .2283X_{54} + .2283X_{55} + 1.0X_{56} + 1.0X_{57}$
Meadow aftermath	$923.0 \geq 1.5X_{52} + 1.5X_{53}$
Hay	$0.0 \geq -1.0X_{56} - 1.75X_{57} + 2.0X_{58} + 2.0X_{59}$
April 1 - May 1	$0.0 \geq -.6112X_{1} - .6112X_{7} - .6112X_{11} - .6112X_{15} - .6112X_{29} + 1.65X_{58} + 1.65X_{59}$
May - June 1	$0.0 \geq -.3056X_{2} - .2037X_{4} - .3056X_{16} - .2037X_{17} - .3056X_{21} - .6112X_{25} + 1.65X_{58} + 1.65X_{59}$
June - July 1	$0.0 \geq -.3056X_{2} - .2037X_{3} - .6112X_{4} - .6112X_{8} - .6112X_{12} - .3056X_{16} - .2037X_{17} - .6112X_{18} - .3056X_{21} - .6112X_{22} - .6112X_{26} - .6112X_{30} + 1.65X_{58} + 1.65X_{59}$
July - Aug. 1	$0.0 \geq -.2037X_{3} - .6112X_{5} - .6112X_{9} - .6112X_{13} - .2037X_{17} - .6112X_{19} - .6112X_{23} - .6112X_{27} - .6112X_{31} + 1.65X_{58} + 1.65X_{59}$
Aug. - Oct. 1 (Public)	$0.0 \geq -.6112X_{6} - .6112X_{10} - .6112X_{14} - .6112X_{20} - .6112X_{24} - .6112X_{28} - .6112X_{32} + 1.98X_{58} + 3.30X_{59}$
Aug. - Oct. 1 (Private)	$0.0 \geq -1.0X_{52} - 1.0X_{54} + 1.32X_{58}$
Oct. - Nov. 20	$0.0 \geq -1.0X_{47} - 1.0X_{48} - 1.0X_{49} - 1.0X_{50} - 1.0X_{51} - 1.0X_{53} - 1.0X_{55} + 2.75X_{58} + 2.74X_{59} - 1.0X_{90}$
Rancher II capital	$0.0 \geq 2.24X_{48} + 1.23X_{50} + 8.60X_{54} + 8.60X_{55} + 8.60X_{57} - 1.0X_{60} + 4.50X_{90}$
Reseedable	$210.0 \geq 10.0X_{61} + 2.6X_{62}$
Sprayable	$932.0 \geq 5.5X_{63} + 2.8X_{64}$
Other poor range	$361.0 \geq 11.0X_{65}$
Meadow	$80.0 \geq .2283X_{68} + .2283X_{69} + 1.0X_{72} + 1.0X_{73}$
Meadow aftermath	$80.0 \geq 1.5X_{66} + 1.5X_{67}$
Alfalfa	$343.0 \geq 1.0X_{74}$
Alfalfa aftermath	$343.0 \geq .3333X_{70} + .3333X_{71}$
Hay	$0.0 \geq -1.0X_{72} - 1.75X_{73} - 2.0X_{74} + 1.8X_{75} + 1.8X_{76}$
April - May 1	$0.0 \geq -.2437X_{1} - .2437X_{7} - .2437X_{11} - .2437X_{15} - .2437X_{29} + 1.2X_{75} + 1.2X_{76}$

TABLE XIX. con't.

May - June 1	$0.0 \geq -.12185X_2 - .0812X_3 - .12185X_{16} - .0812X_{17} - .12185X_{21} - .2437X_{25} + 1.2X_{75} + 1.2X_{76}$
June - July 1	$0.0 \geq -.12185X_2 - .0812X_3 - .2437X_4 - .2437X_8 - .2437X_{12} - .12185X_{16} - .0812X_{17} - .2437X_{18} - .12185X_{21} - .2437X_{22} - .2437X_{26} - .2437X_{30} + 1.2X_{75} + 1.2X_{76}$
July - Aug. 1	$0.0 \geq -.0812X_3 - .2437X_5 - .2437X_9 - .2437X_{13} - .0812X_{17} - .2437X_{19} - .2437X_{23} - .2437X_{27} - .2437X_{31} + 1.2X_{75} + 1.2X_{76}$
Aug. - Oct. 1 (Public)	$0.0 \geq -.2437X_6 - .2437X_{10} - .2437X_{14} - .2437X_{20} - .2437X_{24} - .2437X_{28} - .2437X_{32} + 1.44X_{75} + 2.4X_{76}$
Aug. - Oct. 1 (Private)	$0.0 \geq -1.0X_{66} - 1.0X_{68} - 1.0X_{70} + .96X_{75}$
Oct. - Nov. 20	$0.0 \geq -1.0X_{61} - 1.0X_{62} - 1.0X_{63} - 1.0X_{64} - 1.0X_{65} - 1.0X_{67} - 1.0X_{69} - 1.0X_{71} + 2.00X_{75} + 2.00X_{76}$
Rancher III Capital	$0.0 \geq 2.24X_{62} + 1.23X_{64} + 8.60X_{68} + 8.60X_{69} + 8.60X_{73} - 1.0X_{77}$
Reseedable	$174.0 \geq 10.0X_{78} + 2.6X_{79}$
Other poor range	$546.0 \geq 10.0X_{80}$
Meadow	$175.0 \geq .2283X_{83} + .2283X_{84} + 1.0X_{85} + 1.0X_{86}$
Meadow aftermath	$175.0 \geq 1.5X_{81} + 1.5X_{82}$
Hay	$0.0 \geq -1.0X_{85} - 1.75X_{86} + 1.75X_{87} + 1.75X_{88}$
April - May 1	$0.0 \geq -.0822X_1 - .0822X_7 - .0822X_{11} - .0822X_{15} - .0822X_{29} + 1.3X_{87} + 1.3X_{88}$
May - June 1	$0.0 \geq -.0411X_2 - .0274X_3 - .0411X_{16} - .0274X_{17} - .0411X_{21} - .0822X_{25} + 1.3X_{87} + 1.3X_{88}$
June - July 1	$0.0 \geq -.0411X_2 - .0274X_3 - .0822X_4 - .0822X_8 - .0822X_{12} - .0411X_{16} - .0274X_{17} - .0822X_{18} - .0411X_{21} - .0822X_{22} - .0822X_{26} - .0822X_{30} + 1.3X_{87} + 1.3X_{88}$
July - Aug. 1	$0.0 \geq -.0274X_3 - .0822X_5 - .0822X_9 - .0822X_{13} - .0274X_{17} - .0822X_{19} - .0822X_{23} - .0822X_{27} - .0822X_{31} + 1.3X_{87} + 1.3X_{88}$
Aug. - Oct. 1 (Public)	$0.0 \geq -.0822X_6 - .0822X_{10} - .0822X_{14} - .0822X_{20} - .0822X_{24} - .0822X_{28} - .0822X_{32} + 1.56X_{87} + 2.6X_{88}$
Aug. - Oct. 1 (Private)	$0.0 \geq -1.0X_{81} - 1.0X_{83} + 1.04X_{87}$
Oct. - Nov. 20	$0.0 \geq -1.0X_{78} - 1.0X_{79} - 1.0X_{80} - 1.0X_{82} - 1.0X_{84} + 2.17X_{87} + 2.17X_{88}$

TABLE XIX. con't.

Rancher IV capital	$0.0 \geq 2.24X_{79} + 8.60X_{83} + 8.60X_{84} + 8.60X_{86} - 1.0X_{89}$
Rancher II leased AUM's	$267.0 \geq 1.0X_{90}$

columns 38 and 39, being used August 1 - October 1 and October 1 - November 20, respectively. Improved meadow not used for hay production can be used to supply August 1 - October 1 and October 1 - November 20 AUMs of forage in columns 40 and 41. These activities require 0.2283 acres of improved meadow per AUM. (About 4.38 AUMs are produced on one acre, therefore it required 0.2283 acres per AUM.) Hay production for Rancher I is considered in columns 42 and 43. The same cow - calf - yearling and capital buying activities used in the earlier models for Rancher I are found in columns 44, 45, and 46.

Rancher II's private range resources are entered in columns 47 - 60. Columns 47 - 51 allow use of his private rangeland to produce October 1 - November 20 AUMs both from unimproved and improved rangeland. Use of the improved rangeland comes in only when it is profitable to make the necessary investment of private capital. August 1 - October 1 and October 1 - November 20 grazing of the meadow aftermath is set up in columns 52 and 53. Grazing improved meadow during August 1 - October 1 and October 1 - November 20 enters through columns 54 and 55. Hay production from unimproved and improved meadow enters through columns 56 and 57. Columns 57 - 60 consider the two cow - calf - yearling activities and the capital buying activities. The possibility of leasing grazing land is set up in column 90 for Rancher II.

Rancher III's private range resources are set up in columns 61 - 77. Columns 61 - 69 have the same headings as columns 47 - 55 for Rancher II. Rancher III has 343 acres of alfalfa aftermath that can be grazed. Use of this alfalfa aftermath to produce August 1 - October 1 and October 1 - November 20 AUMs of grazing is considered in columns 70 and 71. One-third of an acre of this alfalfa aftermath will produce an AUM of feed. Rancher III has three sources of hay: (1) unimproved meadow (column 72), (2) improved meadow (column 73), and (3) alfalfa (column 74). This rancher's cow - calf activities and capital buying activity are in columns 75, 76, and 77.

Rancher IV does not have any sprayable range. Therefore, all of his private rangeland is considered in columns 78, 79, and 80 to produce October 1 - November 20 AUMs of forage. Columns 81 - 89 for Rancher IV have essentially the same headings as columns 52 - 60 for Rancher II.

The same reseeding and spraying costs used for improvements on the federal rangeland are used for the private rangeland. Also the same expected increases in production, given some improvement practice, were used both for the federal and private rangeland.

The linear programming routine available for use on the IBM 1410 computer does not have the parametric programming feature. Therefore, it was not possible to get every change in the MVP of public capital. It is very important to have every MVP of public capital over the range of investment possibilities being considered. With these MVPs the internal rates of return can be computed which can be used as decision indicators. However, it is possible to determine the upper and lower limits over which a particular MVP will hold from the output of the IBM 1410 computer. To do this takes time and increases the computer costs. Available research funds would not allow the necessary number of solutions to get every possible MVP of public capital above one dollar. For the above reason, Models V and VI are not as useful as the earlier models for decision purposes but they do provide information on the possibilities of private rangeland improvement. The levels of public capital used in these models were selected in an attempt to get the MVPs of public capital at the most important levels which would aid the decision-maker. However, the levels selected did not prove as useful as hoped.

Only four levels of public investment are considered for Model V. The MVPs at these four levels of public investment, the private investment, and private range resource improvements are summarized in Table XX. The MVPs for Model V are about the same as the MVPs of Model II at the lower investment levels. At the higher investment levels the MVPs of Model V tend to be higher than for Model II.

In Model V only Ranchers II and IV invest in range improvements. The reason for this is that Rancher II gets such a large share of the grazing on the allotment and Rancher IV has so few private ranch

TABLE XX. RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENTS ASSUMING THAT THE RANCHERS USE THE INCREASED FORAGE IN THE SAME RATIO AS PRESENT USE, WITH PRIVATE RANGELAND IMPROVEMENT CONSIDERED

Levels of Investment	$10	$1,989	$2,500	$7,500
MVP of Public Capital	3.76	1.86	1.86	1.57
Internal Rate of Return		30%	6.75%	6.75%
MVP April Grazing AUM	8.15	5.56	5.56	5.34
MVP May Grazing AUM	14.63	9.00	9.00	8.65
MVP June Grazing AUM	0.0	0.0	0.0	0.0
MVP July Grazing AUM	7.38	5.04	5.04	4.42
MVP Aug. - Sept. Grazing AUM	11.31	5.61	5.61	4.14
Weighted Average MVP Public Grazing	8.41	5.06	5.06	4.50
RI Private Investment	0	0	0	0
RII Private Investment	1,372	3,451	4,007	9,144
RIII Private Investment	0	0	0	0
RIV Private Investment	28	99	113	443
Total Private Investment	1,400	3,550	4,120	9,587
Public Acres Sprayed	23	4,517	4,517	4,517
Public Acres Seeded	0	0	591	6,384
Private Acres Seeded				
Rancher I	0	0	0	0
Rancher II	0	310	310	310
Rancher III	0	0	0	0
Rancher IV	0	0	0	174
Private Acres Sprayed				
Rancher I	0	0	0	0
Rancher II	0	366	366	366
Rancher III	0	0	0	0
Rancher IV	0	0	0	0
Acres Meadow Improved				
Rancher I	0	0	0	0
Rancher II	156	210	274	869
Rancher III	0	0	0	0
Rancher IV	3	11	13	34
No. of Animal Units				
Rancher I	63	74	76	97
Rancher II	610	716	739	942
Rancher III	244	286	294	376
Rancher IV	82	96	99	126
Total Animal Units	999	1,172	1,208	1,541

resources. The other two ranchers can furnish all of the forage required for their allotted use without private range improvements. Rancher II would reseed all of his reseedable rangeland and spray all of his sprayable rangeland at levels of public investment of $1,989 and above. Rancher IV would reseed all of his reseedable rangeland at an investment level of $7,500. Application of 60 pounds of nitrogen on the meadows is profitable only for Ranchers II and IV under the assumptions of this model.

The internal rate of return at a public investment level of $7,500 is about five percent; however, the limits over which it is applicable are quite narrow. Information gained from the solution at the $7,500 level of public investment indicate that the internal rate of return would be less than three percent at an investment level below $8,000. If the interest rate defined in Senate Document 97 is again used the optimum level of public investment would fall between $7,500 and $8,000.

Model V adds more supporting evidence to the hypothesis that spraying returns more per dollar invested than does reseeding to crested wheatgrass. All of the sprayable rangeland is sprayed at the $1,989 level of public investment where the internal rate of return is about 30 percent. The internal rate of return drops to around 6.75 percent when reseeding to crested wheatgrass is the only alternative open for public investment funds.

The last four rows of Table XX give the number of animal units or number of head that each rancher can graze on the federal range. These figures are kept in a fixed ratio to one another. For example, a total of 1,541 head graze the federal range at the $7,500 level of investment. The use ratio breaks down as follows:

$$\text{Rancher I} \quad \frac{97}{1,541} = .0629$$

$$\text{Rancher II} \quad \frac{942}{1,541} = .6112$$

$$\text{Rancher III} \quad \frac{376}{1,541} = .2439$$

$$\text{Rancher IV} \quad \frac{126}{1,541} = .0821$$

It can be seen that the proportionality assumption is met, with the exception of some rounding error on the last two ranchers.

Seasonal use patterns for the federal rangeland are summarized in Table XXI. These use patterns do not differ significantly from those use patterns found in earlier models. The seasonal use patterns determined by the more flexible model discussed in the sections analyzing Model III would probably hold for this model also.

TABLE XXI. SEASONAL USE PATTERNS FOR EACH PUBLIC RANGE-LAND CLASSIFICATION FOR MODEL V

Levels of Public Investment	$10	$1,989	$2,500	$7,500
Type of Range				
Reseedable range				
April 1 - May 1	9,487	11,140	11,482	5,374
May 1 - Aug. 1	1,853	2,232	1,299	0
Aug. 1 - Oct. 1	2,032	0	0	0
May 1 - July 1	0	0	1,301	1,614
Seeded range				
July 1 - Aug. 1	0	0	591	3,543
Aug. 1 - Oct. 1	0	0	0	2,841
Sprayable range				
Aug. 1 - Oct. 1	4,494	0	0	0
Sprayed range				
Aug. 1 - Oct. 1	23	3,414	3,534	1,591
July 1 - Aug. 1	0	1,103	983	0
Apr. 1 - May 1	0	0	0	2,926
Other good range				
Aug. 1 - Oct. 1	1,034	1,034	1,034	1,034
Other poor range				
May 1 - Aug. 1	22,117	15,316	12,103	0
May 1 - July 1	0	6,802	10,014	22,117

Model VI

Improvement of the private rangeland is included in Model VI and the proportionality assumption is dropped. Ranchers are allocated grazing according to their relative profitability in the unrestricted use models such as Model VI. The advantages and disadvantages of the two different assumptions about the way public grazing should be allocated have been discussed earlier and will not be discussed further here.

Model VI has exactly the same column headings as Model V. Less rows are required for Model VI since a set of inequalities representing the grazing seasons on the federal range are not required for each rancher. They were required in Model V in order that the proportionality assumption could be worked in. The equations and inequalities for Model VI are presented in Table XXII. Since the logic and activities of this model are so much like the other models discussed previously there is no need for further explanations.

Model VI was solved on the IBM 1410 computer also. Two more levels of capital were considered in Model VI than in Model V. Some of the results obtained from these solutions are summarized in Table XXIII. The weighted average MVPs of public grazing are somewhat higher than for Model V and somewhat lower than the MVPs computed for Model III. Model III is essentially the same model except for the

TABLE XXII. EQUATION AND INEQUALITIES REPRESENTING MODEL VI.

Objective Function	$= 78.0X_{44} + 68.0X_{45} - 1.1X_{46} + 72.5X_{58} + 62.5X_{59} - 1.1X_{60} + 58.0X_{75} + 48.0X_{76} - 1.1X_{77} + 41.0X_{87} + 31.0X_{88} - 1.1X_{89}$
Reseeded range	$1.0 \geq 7.0X_{21} + 2.0X_{22} + 2.3X_{23} + 2.6X_{24}$
Reseedable range	$13,372.0 \geq 9.5X_1 + 7.7X_2 + 8.0X_3 + 7.0X_4 + 10.0X_5 + 11.0X_6 + 6.0X_{25} + 2.0X_{26} + 2.3X_{27} + 2.6X_{28}$
Sprayable range	$4,517.0 \geq 6.0X_7 + 10.6X_8 + 5.0X_9 - 5.5X_{10} - 3.0X_{29} + 5.3X_{30} + 2.5X_{31} + 2.8X_{32}$
Other good range	$1,034.0 \geq 6.0X_{11} + 10.6X_{12} + 5.0X_{13} + 5.5X_{14}$
Other poor range	$22,117.0 \geq 9.5X_{15} + 7.7X_{16} + 8.0X_{17} + 7.0X_{18} + 10.0X_{19} + 11.0X_{20}$
Public capital	$10.0 \geq 5.17X_{25} + 1.73X_{26} + 1.99X_{27} + 2.24X_{28} + 1.32X_{29} + 2.33X_{30} + 1.11X_{31} + 1.23X_{32}$
Apr. - May 1 Graz. (Pub.)	$0.0 \geq -1.0X_1 - 1.0X_7 - 1.0X_{11} - 1.0X_{15} - 1.0X_{29} + 1.9X_{44} + 1.9X_{45} + 1.65X_{58} + 1.65X_{59} + 1.2X_{75} + 1.2X_{76} + 1.3X_{87} + 1.3X_{88}$
May - June 1 Graz. (Pub.)	$0.0 \geq -.5X_2 - .3333X_3 - .5X_{16} - .3333X_{17} - .5X_{21} - 1.0X_{25} + 1.9X_{44} + 1.9X_{45} + 1.65X_{58} + 1.65X_{59} + 1.2X_{75} + 1.2X_{76} + 1.3X_{87} + 1.3X_{88}$
June - July 1 Graz. (Pub.)	$0.0 \geq -.5X_2 - .3333X_3 - 1.0X_4 - 1.0X_8 - 1.0X_{12} - .5X_{16} - .3333X_{17} - 1.0X_{18} - .5X_{21} - 1.0X_{22} - 1.0X_{26} - 1.0X_{30} + 1.9X_{44} + 1.9X_{45} + 1.65X_{58} + 1.65X_{59} + 1.2X_{75} + 1.2X_{76} + 1.3X_{87} + 1.3X_{88}$
July - Aug. Graz. (Pub.)	$0.0 \geq -.3333X_3 - 1.0X_5 - 1.0X_9 - 1.0X_{13} - .3333X_{17} - 1.0X_{19} - 1.0X_{23} - 1.0X_{27} - 1.0X_{31} + 1.9X_{44} + 1.9X_{45} + 1.65X_{58} + 1.2X_{75} + 1.2X_{76} + 1.3X_{87} + 1.3X_{88}$
Aug. - Oct. 1 Graz. (Pub.)	$0.0 \geq -1.0X_6 - 1.0X_{10} - 1.0X_{14} - 1.0X_{20} - 1.0X_{24} - 1.0X_{28} - 1.0X_{32} + 2.28X_{44} + 3.8X_{45} + 1.98X_{58} + 3.3X_{59} + 1.44X_{75} + 2.4X_{76} + 1.56X_{87} + 2.6X_{88}$
Reseedable range	$824.0 \geq 10.0X_{33} + 2.6X_{34}$
Sprayable range	$166.0 \geq 5.5X_{35} + 2.8X_{36}$
Other poor range	$1800.0 \geq 11.0X_{37}$
Meadow aftermath	$270.0 \geq 1.5X_{38} + 1.5X_{39}$
Aug. - Oct. 1 grazing	$0.0 \geq -1.0X_{38} - 1.0X_{40} + 1.52X_{44}$
Oct. 1 - Nov. 20 grazing	$0.0 \geq -1.0X_{33} - 1.0X_{34} - 1.0X_{35} - 1.0X_{36} - 1.0X_{37} - 1.0X_{39} - 1.0X_{41} + 3.16X_{44} + 3.16X_{45}$

TABLE XXII. con't.

Meadow	$270.0 \geq .2283X_{40} + .2283X_{41} + 1.0X_{42} + 1.0X_{43}$
Hay	$0.0 \geq -1.0X_{42} - 1.75X_{43} + 1.94X_{44} + 1.94X_{45}$
R. I. Capital	$0.0 \geq 2.24X_{34} + 1.23X_{36} + 2.0X_{40} + 2.0X_{41} + 8.6X_{43} - 1.0X_{46}$
Reseedable range	$310.0 \geq 10.0X_{47} + 2.6X_{48}$
Sprayable range	$366.0 \geq 5.5X_{49} + 2.8X_{50}$
Other poor range	$1,065.0 \geq 10.0X_{51}$
Meadow aftermath	$923.0 \geq 1.5X_{52} + 1.5X_{53}$
Aug. - Oct. 1 grazing	$0.0 \geq -1.0X_{52} - 1.0X_{54} + 1.32X_{58}$
Oct. - Nov. 20 grazing	$0.0 \geq -1.0X_{47} - 1.0X_{48} - 1.0X_{49} - 1.0X_{50} - 1.0X_{51} - 1.0X_{53} - 1.0X_{55} + 2.75X_{58} + 2.75X_{59} - 1.0X_{90}$
Meadow	$923.0 \geq .2283X_{54} + .2283X_{55} + 1.0X_{56} + 1.0X_{57}$
Hay	$0.0 \geq -1.0X_{56} - 1.75X_{57} + 2.0X_{58} + 2.0X_{59}$
R. II Capital	$0.0 \geq 2.24X_{48} + 1.23X_{50} + 2.0X_{54} + 2.0X_{55} + 8.6X_{57} - 1.0X_{60} + 4.5X_{90}$
Reseedable range	$210.0 \geq 10.0X_{61} + 2.6X_{62}$
Sprayable range	$932.0 \geq 5.5X_{63} + 2.8X_{64}$
Other poor range	$361.0 \geq 11.0X_{65}$
Meadow aftermath	$80.0 \geq 1.5X_{66} + 1.5X_{67}$
Alfalfa aftermath	$343.0 \geq .3333X_{70} + .3333X_{71}$
Aug. - Oct. 1 grazing	$0.0 \geq -1.0X_{66} - 1.0X_{68} - 1.0X_{70} + .96X_{75}$
Oct. 1 - Nov. 20 grazing	$0.0 \geq -1.0X_{61} - 1.0X_{62} - 1.0X_{63} - 1.0X_{64} - 1.0X_{65} - 1.0X_{67} - 1.0X_{69} - 1.0X_{71} + 2.0X_{75} + 2.0X_{76}$
Meadow	$80.0 \geq .2283X_{68} + .2283X_{69} + 1.0X_{72} + 1.0X_{73}$
Alfalfa	$343.0 \geq 1.0X_{74}$
Hay	$0.0 \geq -1.0X_{72} - 1.75X_{73} - 2.0X_{74} + 1.8X_{75} + 1.8X_{76}$
R. III Capital	$0.0 \geq 2.24X_{62} + 1.23X_{64} + 2.0X_{68} + 2.0X_{69} + 8.6X_{73} - 1.0X_{77}$
Reseedable range	$174.0 \geq 10.0X_{78} + 2.6X_{79}$

TABLE XXII. Con't.

Other poor range	$546.0 \geq 10.0X_{80}$
Meadow aftermath	$175.0 \geq 1.5X_{81} + 1.5X_{82}$
Aug. 1 - Oct. 1 grazing	$0.0 \geq - 1.0X_{81} - 1.0X_{83} + 1.04X_{87}$
Oct. - Nov. 20 grazing	$0.0 \geq - 1.0X_{78} - 1.0X_{79} - 1.0X_{80} - 1.0X_{82} - 1.0X_{84} + 2.17X_{87} + 2.17X_{88}$
Meadow	$175.0 \geq .2283X_{83} + .2283X_{84} + 1.0X_{85} + 1.0X_{86}$
Hay	$0.0 \geq - 1.0X_{85} - 1.75X_{86} + 1.75X_{87} + 1.75X_{88}$
R. III capital	$0.0 \geq 2.24X_{79} + 2.0X_{83} + 2.0X_{84} + 8.6X_{86} - 1.0X_{89}$
R. II leased AUMs	$267.0 \geq 1.0X_{90}$

TABLE XXIII. RATES OF RETURN FOR VARIOUS LEVELS OF PUBLIC INVESTMENT IN RANGE IMPROVEMENTS, ASSUMING UNRESTRICTED USE OF THE INCREASED FORAGE, WITH PRIVATE RANGELAND IMPROVEMENT CONSIDERED

Levels of Investment	$10	$1,989	$2,500	$7,500	$8,000	$10,000
MVP of Public Capital	3.86	2.71	2.71	1.68	1.20	.49
Internal Rate of Return		31%	12.5%	12.5%	5.5%	2%
MVP Apr. Grazing	8.35	8.13	8.13	5.72	4.06	4.33
MVP May Grazing	12.50	13.17	13.17	9.26	6.59	5.27
MVP June Grazing	0.0	0.0	0.0	0.0	0.0	1.76
MVP July Grazing	8.70	7.35	7.35	4.73	3.36	2.02
MVP Aug. - Sept. Grazing	9.67	8.21	8.21	5.33	3.79	2.28
Weighted Av. MVP	7.91	7.40	7.40	5.02	3.57	3.10
Rancher I Private Investment	0	0	0	503	605	1,855
Rancher II Private Investment	0	714	891	1,666	1,666	3,111
Rancher III Private Investment	0	0	0	321	820	820
Rancher IV Private Investment	0	0	0	157	187	267
Total Private Investment	0	714	891	2,647	3,278	6,053
Public Acres Seeded	0	0	591	6,384	6,964	9,284
Public Acres Sprayed	23	4,517	4,517	4,517	4,517	4,517
Private Acres Seeded						
Rancher I	0	0	0	438	466	824
Rancher II	0	0	0	310	310	310
Rancher III	0	0	0	0	0	0
Rancher IV	0	0	0	0	0	174
Private Acres Sprayed						
Rancher I	0	0	0	166	166	166
Rancher II	0	0	0	366	366	366
Rancher III	0	0	0	0	300	300
Rancher IV	0	0	0	0	0	0
Acres Meadow Improved						
Rancher I	0	0	0	6	15	124
Rancher II	0	83	102	141	141	270
Rancher III	0	0	0	37	80	80
Rancher IV	0	0	0	18	21	13
Animal Units						
Rancher I	156	184	184	258	264	323
Rancher II	332	477	513	645	645	703
Rancher III	510	510	510	529	551	551
Rancher IV	0	0	0	108	114	120
Total Animal Units	998	1,171	1,207	1,540	1,574	1,697

improvements of the private rangeland.

Private investment is not nearly as high in Model VI as it is in Model V. Also, private investment in some resource improvement is undertaken by all four of the ranchers. This points out another weakness of the fixed proportionality models, i. e., they would require one of the ranchers to invest more money annually than the public investment. Institutional factors could make it difficult for one rancher to borrow the required amount of capital. At the same time there may be no difficulty in four ranchers getting the required amounts of capital. The amount required by any individual rancher was substantially less than the amount required for the one rancher in the restricted use models.

The internal rate of return for spraying federal rangeland is 31 percent in this model. Reseeding has an internal rate of return of about 12.5 percent which is substantially higher than the 6.75 percent for reseeding federal rangeland in Model V. A different allocation of the federal rangeland use to the four ranchers probably accounts for much of this difference between the rates of return for the two models. The higher profit ranchers get the first and the most use of the federal grazing. Since the total number of animal units in the allotment are the same in both models the difference in returns has to be due to the way they are allocated.

Reseeding of the private rangeland does not come in at the lower levels of public investment, as it does in Model V. However, more acres come in for reseeding and more ranchers reseed in Model VI. Spraying on the private rangeland comes in at the same level of public investment as reseeding of private rangeland. Because of the way private capital is handled in the models one cannot say much about the relative profitability of the two improvement alternatives. Never-the less, since spraying is consistantly more profitable than reseeding on the federal range, there is little reason not to assume the same relationship would hold for the private improvement alternatives. The fact that Rancher III sprays 300 acres of his private rangeland at the two higher levels of public investment and does not reseed any of his reseedable rangeland adds further evidence to the idea that spraying is a better alternative than reseeding to crested wheatgrass.

Meadow improvement does not come in for as much total private investment at the $7, 500 level of public investment in this model as it did in Model V. Also the investment is spread out over the ranchers more in this model. In Model V Rancher II was forced to improve almost all 923 acres of his meadow.

For the most part the seasonal use patterns for the federal range are the same as in the other models. These use patterns are summarized in Table XXIV. Funds did not permit the rerunning of all of the models to see how the addition of more flexible grazing seasons for reseedable and other "poor" rangeland would affect the seasonal use

TABLE XXIV. SEASONAL USE PATTERNS FOR EACH TYPE OF FEDERAL RANGE FOR MODEL VI

Levels of Investment	$10	$1,989	$2,500	$7,500	$8,000	$10,000
Reseedable						
April 1 - May 1	9,487	11,141	11,482	5,374	4,298	0
May 1 - Aug. 1	1,853	2,231	0	0	0	0
May 1 - July 1	0	0	1,299	1,614	2,110	4,088
Aug. 1 - Oct. 1	2,032	0	0	0	0	0
Sprayable Range						
Aug. 1 - Oct. 1	4,494	0	0	0	0	0
Sprayed Range						
Apr. 1 - May 1	0	0	0	2,926	3,362	4,517
July 1 - Aug. 1	0	1,103	982	0	0	0
Aug. 1 - Oct. 1	23	3,414	3,535	1,591	1,155	0
Other Good						
April 1 - May 1	0	0	0	0	0	1,034
Aug. 1 - Oct. 1	1,034	1,034	1,034	1,034	1,034	0
Other Poor						
April 1 - May 1	0	0	0	0	0	196
May 1 - July 1	0	6,802	8,714	22,117	22,117	21,921
May 1 - Aug. 1	22,117	15,315	13,403	0	0	0
Seeded Range						
July 1 - Aug. 1	0	0	591	3,543	3,617	3,906
Aug. 1 - Oct. 1	0	0	0	2,841	3,347	5,300
May 1 - June 1	0	0	0	0	0	58
June 1 - July 1	0	0	0	0	0	20

patterns. The fact that the seasonal use patterns were not significantly different among the models originally, would cause one to believe that the use patterns obtained from the solutions of a revised model (Model III) would be generally applicable to the other models. The seasonal use patterns for the revised model are summarized in Appendix D and explained earlier in this chapter.

In summary Models V and VI reflect the alternatives for improvement of the private rangeland quite well. However, due to a less versatile linear programming routine for the IBM 1410 computer it was impractical to get a solution for each of the two models at every MVP of public capital. This reduces the usefulness of the results as a decision-making device. The models appear to be logically sound; thus, the above limitation does not impair their value as tools that can be used as aids in the decision making process.

CHAPTER VI

IMPLICATION AND ADDITIONAL USES OF THE RESULTS OF THE STUDY

At various places throughout this thesis the usefulness of the information gained from the different models has been mentioned. Some of the uses were discussed in considerable detail. For example, the use of the MVPs of public capital as the crucial factor in determining the internal rates of return was discussed. Internal rates of return were used as decision indicators to be compared with the appropriate rate of interest of the particular decision-maker.

The weighted average MVP of federal grazing is an important variable to know when the problem of setting grazing fees comes up. Even if the goal of the government land agency is something other than maximization of returns from these lands, these MVPs provide estimates of what the federal range resource is returning to society. These weighted average MVPs for federal grazing make it possible to place the forage evaluation problem in a framework such as the one described in Chapter two. The fact that the MVPs were the appropriate values to use as long as they fell between the acquisition price and the salvage value was mentioned before. In the past the salvage value for much of the grazing on the federal range was probably quite low. That is, there were few competitive uses bidding (so to speak) for the use of this resource. Also for many years the costs to the government for providing this forage were very low. Looking at this situation in light of the forage evaluation framework, the acquisition price or cost was very low (at least until the available forage was allocated). Also the salvage value was considered to be quite low. It seems at least plausible that some of the early grazing fees could have been set under such reasoning. Mention was made that the first fees were set up to cover costs of administration and to provide some range improvements. These early fees seem to be almost synonymous with acquisition cost.

As competition for use of the federal rangeland increases over the years the salvage value is forced up, i. e., now the federal range has an increasing value for other uses. (Some of these other uses are water shed, wildlife habitat, and many forms of recreation.) This increased competition forces the salvage value up. In an attempt to meet the demands of all of these uses the BLM has initiated programs where intensive range improvement practices have been undertaken, thus, forcing the acquisition price or cost up. One would expect that fees would increase under this situation. However, many factors prevent fees from being set where one would expect, based only on economic considerations.

The point here is not to argue that grazing fees should be higher but to show that knowing the MVPs of grazing is important. These

MVPs at least give an indication of the value of federal range as measured through livestock use. If and when tools of analysis are applied that will yield comparable estimates of the value of the federal range for the competing uses, these values could then be used to help determine the allocation of the federal range between uses.

The hypothesis that the difference between the value of federal range to the rancher (MVP) and the grazing fee has been capitalized into the value of the commesurate property and/or the value of the grazing permits can be tested. The MVPs estimated by a study like this could be used to test this hypothesis.

What would be the best way to measure the capitalized value of the difference between the value of the federal range (MVP) and the grazing fee? This capitalized value could be estimated from two sources of information: (1) from commensurate property values, and (2) from the sales value of grazing permits. Of these two sources of information, sales value of grazing permits would seem to be the most direct and accurate. Some difficulty would be encountered in trying to separate out the value of the commensurate property in and of itself and the added value capitalized from the grazing rights on the federal range.

For example, assume the weighted average MVP for federal grazing over a period of years is $5.00, the grazing fee is $ .30, other associated costs of grazing are $1.00, and the interest rate to use is 5.5 percent. The value of the grazing permit on an AUM basis would be as follows:

$5.00 - $ .30 - $1.00 = $3.70/AUM;
$3.70 capitalized at 5.5 percent = $67.27/AUM.

For a five month grazing season a permit would be worth about $336. It is very doubtful that any grazing permits have sold for this price. Of course, the above situation is strictly hypothetical and would require much more thought and investigation than it was afforded here.

Many times the public land administrators would like to have estimates of the productive value of the lands under their direction. The MVPs computed in the models of this study can be used to estimate the productive value of these lands for grazing. For example, with a MVP of grazing of $5.00 and 5.0 acres required per AUM an estimate of the value of this range would be as follows:

$5.00 capitalized at 5.5 percent = $90.90/AUM;
$90.90 ÷ 5.0 = $18.18 per acre.

Using the MVPs to estimate productive values of federal rangeland can provide valuable information for use in land trades and/or land sales.

It would be interesting to use one or more of the models developed in this thesis in a seminar or class in range management economics. Time could be spent on discussions of what goes into the determination of the physical-biological and economic coefficients. After the coefficients were agreed upon the problem would be solved and the resulting land use patterns could be compared with land use patterns determined considering only the physical-biological factors. It is possible but unlikely, that both methods might give almost identical land use patterns.

Changes in one or more of the coefficients could be traced through to see how they would effect the results obtained from the model. Information could be gained concerning the degree to which changes in the coefficients change the solution. This procedure would give insight to areas where more physical-biological research was needed. The ideal situation would be one where the results obtained from the solutions could be taken out and tested under actual range conditions. The land use patterns could be tried to see if they were feasible under the general open range conditions found in the West. It might be that the models where the seasonal use patterns are broken down into single months would indicate land use patterns that would require excessive amounts of fencing for handling the livestock. If the plans developed from the models could be tried under actual range conditions, the acreages per AUM for the various seasonal use of the different types of rangeland could be tested. All of these things would help in checking the validity of the assumptions of the models.

The feasibility of new range improvement practices could be checked by using models similar to Model IV, where the feasibility of whitmar wheatgrass reseedings was investigated. Before public capital is invested in a new improvement practice, the proposed improvement practice could be worked out in one of the models. Knowledge could be gained concerning the relative profitability and the way the proposed improvement would fit into the overall grazing plan. By using this type of analysis the decision-maker would have some idea of the effect of a proposed improvement practice without having to make a large investment in the practice.

The relative profitability of different improvement practices is brought out quite well in the models developed. Spraying consistently turned out to be the most profitable use of public funds, given the alternative improvement practices considered in the study. Also a method of determining the optimum level of public investment was described in Chapter five.

It is possible that a dynamic linear programming model or a dynamic programming model might be developed where the optimum time to spray a reseeding for brush invasion could be determined. However, this was not attempted in this study. The problem becomes very complicated and would take much time and effort to work out, i. e. , if it could be developed.

A few uses of linear programming models such as the ones developed in this thesis are presented in this chapter. Many of the uses would call for new research projects to get data needed to test the validity of the proposed uses. Nevertheless, it is believed that linear programming, properly used, is a tool that offers a great deal as a decision making aid to the government land management agencies.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The BLM has the responsibility of managing millions of acres of federal land. Measured on an acreage basis, the most important use of this land is for livestock grazing. Each year large investments of public capital are made to improve these federal rangelands. Reseeding the native ranges to crested wheatgrass and spraying sagebrush and rabbitbrush are the most common improvement practices undertaken by the BLM. Generally, there are costs of fencing and water development associated with these improvement practices.

Administrators of these BLM rangelands are interested in application of analytical tools that would be useful to their federal rangeland management decision-makers in making decisions relative to the use and improvement of the federal rangeland. This study was initiated and funded by the BLM to apply linear programming for the above purpose. A study was also set up with Range Management to furnish the physical-biological coefficients needed for the economic study.

The three main objectives of this study were:

(1) Show the rates of return from public investment in various range improvement practices on a given management unit of federal rangeland as measured by the effect upon costs

and returns to the individual ranchers.

(2) Compute the marginal value product of an animal unit month of grazing for various seasons and given range conditions of the management unit under study.

(3) Evaluate the potential usefulness of programming models as an aid to decision making by public land administrators.

Linear programming models were developed to reflect the physical-biological and economic situation of the East Cow Creek allotment. This allotment is located in the Vale grazing district of the BLM. MVPs of public capital at several levels of public investment were obtained from the solutions of these linear programming models. These MVPs were discounted over the life of the investment. The discount rate used was that rate which would equate the present value of the income stream over the life of the investment to the initial investment. Discount rates which perform the above function are known as "internal rates of return".

Internal rates of return for public investment in range improvements were computed for all relevant levels of public investment. These internal rates of return ranged from 31.0 percent to 3.25 percent for spraying and from 13.0 percent to 1.0 percent for reseeding to crested wheatgrass. Whitmar wheatgrass seeding was considered in Model IV where its return was about 16.0 percent to 2.0 percent. Objective number one was fulfilled by the computation of these internal rates of return.

As many as 23 different levels of public investment were considered for some of the models. At each level of public investment considered, a complete solution of the linear programming problem was obtained. MVPs for the various grazing seasons on the federal range were part of each solution. Weighted average MVPs for federal grazing were computed for the most relevant levels of public investment. At essentially zero public investment the weighted average MVPs were from $7.91 to $5.09, depending on the assumptions of the model. These weighted average MVPs were from $3.00 to $3.76 at the optimum level of investment determined for each model. The optimum level of investment was considered to be where the internal rate of return was 3.0 percent (which was approximately the average rate of interest payable by the U.S. Treasury as recommended by Senate Document 97).

Several uses of these MVPs were presented and discussed. One of the big advantages of using linear programming models to estimate these MVPs is that all measurable factors effecting them are considered simultaneously. Weighting each grazing season by the number of AUMs used by the individual ranchers further generalized these quantities. Thus, objective number two of the study was accomplished.

With additional research and thought these linear programming models could be used to get information relative to other public land management problems. The productive value of rangeland as measured through livestock can be estimated from present research results. With additional research, changes in management plans could be checked for feasibility in a model before funds had to be expended. If benefit-cost analysis is applied to range improvement projects, the rates of return and MVPs would provide valuable data for evaluating an additional AUM of range forage. Only a few of the potential uses of the models are mentioned here.

Several assumptions were built into these linear programming models, thus causing each one to be different from the others. Despite these differences in the models, there were certain consistencies in the results from which some general conclusions can be drawn:

(1) Returns on public investment in range improvement practices as measured through livestock production are high enough to justify investment in such practices. However, at levels of public investment where the commensurate properties of the ranchers are being used near their capacity, these returns are soon pushed down to zero.

(2) Spraying the federal rangeland for brush control returns more per dollar invested in range improvements than a dollar invested in reseeding to crested wheatgrass.

(3) A high degree of interdependence exists between private and public decision-making. Returns on public investments in

range improvements are dependent on the investment of private funds to improve the commensurate properties. The amount of private investment required is indicated in the solutions of the linear programming models.

It is concluded from the results of this study that the linear programming models have great potential usefulness as an aid to decision making by public land administrators.

BIBLIOGRAPHY

1. Barr, Alfred L. Dynamic and static analysis of cattle systems and range improvement practices, Northeastern Oklahoma. Ph. D. thesis. Stillwater, Oklahoma State University, 1960. 178 numb. leaves.

2. Boles, James N. LP20 Linear Programming System. 1620 General Program Library, 10. 1. 009. Berkeley, Calif., University of California, n. d. 183 p.

3. Brown, William G. Estimation of rates of return from investments in range improvement practices by linear programming. Corvallis, Oregon State University, 1961. (Oregon. Agricultural Experiment Station. Technical Paper No. 1383)

4. Castle, Emery N., Professor of Agricultural Economics, Oregon State University. Personal correspondence, April 29, 1964.

5. Caton, D. D. and Christoph Beringer. Costs and benefits of reseeding range lands in Southern Idaho. Moscow, University of Idaho, 1960. 31 p. (Idaho. Agricultural Experiment Station. Bulletin 326)

6. Cooper, Clee S. More mountain meadow hay with fertilizer. Corvallis, Oregon State College, 1955. (Oregon. Agricultural Experiment Station and U. S. Department of Interior. Station Bulletin 550)

7. Culver, Roger N. An ecological reconnaissance of the Artemisia steppe on the east central Owyhee uplands of Oregon. Masters thesis. Corvallis, Oregon State University, June, 1964. 99 numb. leaves.

8. Dean, Joel. Measuring the productivity of capital. Harvard Business Review 32:120-130. 1954.

9. Eckstein, Otto. Water resource development. Cambridge, Harvard University Press, 1961. 300 p.

10. Fellows, Irving F. Budgeting. Storrs, 1960. 47 p. (Connecticut. Agricultural Experiment Station. Bulletin 357)

11. French, Charles E. Activity analysis. Journal of Farm Economics 37:1236-1248. December 1955.

12. Fulcher, Glen D. Economics of meadow improvement in Northern Nevada. Reno, University of Nevada, 1960. (Nevada. Agricultural Experiment Station. Bulletin 215)

13. Gardner, B. D. Costs and returns from sagebrush range improvements in Colorado. Fort Collins, Colorado State University, 1961. 18 p. (Colorado. Agricultural Experiment Station. Bulletin 511-S)

14. Gardner, B. Delworth. The internal rate of return and decisions to improve the range. In: Proceedings of the Committee on Economics of Range Use and Development Western Agricultural Economics Research Council, Laramie, 1963. p. 87-109.

15. Griliches, Zvi. Specification bias in estimates of production functions. Journal of Farm Economics 39:8-20. February 1957.

16. Heady, Earl O. Economics of agricultural production and resource use. New York, Prentice-Hall, 1952. 850 p.

17. Heady, E. O. Efficiency in public conservation programs. Journal of Political Economy 59:47-60. February 1951.

18. Heady, Earl O. and Wilfred Candler. Linear programming methods. Ames, Iowa State University Press, 1960. 597 p.

19. Henderson, James M. and Richard E. Quant. Microeconomic theory. New York, McGraw-Hill, 1958. 291 p.

20. Hyder, D. N. and Forrest A. Sneva. Studies of six grasses seeded on sagebrush - bunchgrass range. Corvallis, Oregon State University, 1963. 20 p. (Oregon. Agricultural Experiment Station. Technical Bulletin 71)

21. Johnson, Glen L. and Lowell S. Hardin. Economics of forage evaluation. Lafayette, Purdue University, 1955. 20 p. (Indiana. Agricultural Experiment Station. Station Bulletin 623)

22. Krenz, Ronald D. Costs and returns from spraying sagebrush with 2, 4, -D. Laramie, University of Wyoming, 1962. 31 p. (Wyoming. Agricultural Experiment Station. Bulletin 390)

23. Lea, George. How should crested wheatgrass seedings be managed? In: Proceedings of the Oregon Range Management Seminar, Burns, 1963. 48 p.

24. LeBaron, Allen. A discussion - The internal rate of return and decisions to improve the range. In: Proceedings of the Committee on Economics of Range Use and Development Western Agricultural Economics Research Council, Laramie, 1963. p. 117-127.

25. Leftwich, Richard H. The price system and resource allocation. Rev. ed. New York, Holt, Rinehart and Winston, 1961. 381 p.

26. Lorie, James H. and Leonard S. Savage. Three problems in rationing capital. Journal of Business 28:229-239. 1955.

27. Lloyd, Russell D. and C. Wayne Cook. Seeding Utah's ranges. Logan, Utah State University, 1960. 19 p. (Utah. State Agricultural Experiment Station. Bulletin 423)

28. Lutz, Friedrich and Vera Lutz. The theory of investment of the firm. Princeton, Princeton University Press, 1951. 253 p.

29. McAlexander, R. H. and R. F. Hutton. Linear programming techniques applied to agricultural problems. University Park, Pennsylvania State University, 1959. 96 p. (Pennsylvania. Agricultural Experiment Station. A. E. and R. S. #18)

30. McCorkle, C. O. and D. D. Caton. Economic analysis of range improvement. Davis, University of California, 1962. 79 p. (California. Agricultural Experiment Station. Giannini Foundation of Agricultural Economics. Bulletin No. 255)

31. McKean, Roland N. Efficiency in government through systems analysis. New York, Wiley, 1958. 336 p.

32. Nelson, Michael and Emery N. Castle. Profitable use of fertilizer on native meadows. Journal of Range Management 2:80-83. March 1958.

33. Nielsen, Darwin B. Valuation of public range land for grazing purposes. Masters thesis. Logan, Utah State University, 1962. 50 numb. leaves.

34. Peffer, Louise E. The closing of the public domain. Stanford, University Press, 1951. 372 p.

35. Peterson, Thurman S. Elements of calculus. New York, Harper, 1960. 369 p.

36. Pingrey, H. B. and E. J. Dortignac. Cost of seeding Northern New Mexico rangelands. Las Cruces, New Mexico College, 1957. 43 p. (New Mexico. Agricultural Experiment Station in cooperation with Rocky Mountain Forest and Range Experiment Station U. S. Forest Service. Bulletin 413)

37. Plaxico, James S. Problems of factor-product aggregation in Cobb-Douglas value productivity analysis. Journal of Farm Economics 37:664-675. November 1955.

38. Reynolds, H. G. and H. W. Springfield. Reseeding southwestern rangelands with crested wheatgrass. 1953. 20 p. (U. S. Department of Agriculture. Farmers' Bulletin No. 2056)

39. Sneva, Forrest A. and Donald N. Hyder. Forcasting range herbage production in Eastern Oregon. Corvallis, Oregon State University, 1962. 11 p. (Oregon. Agricultural Experiment Station. Station Bulletin No. 588)

40. Solomon, Ezra. The arithmetic of capital budgeting decisions. Journal of Business 29:124-129. 1956.

41. U. S. Congress. Senate. The President's Water Resources Council. Policies, standards, and procedures in the formulation, evaluation, and review of plans for use and development of water and related land resources. Washington, May 29, 1962. 13 p. (87th Congress, 2nd session. Document No. 97)

42. U. S. Dept. of the Interior. Bureau of Land Management. Public land statistics, 1963. Washington, D. C. 1964. 198 p.

43. U. S. Dept. of the Interior. Bureau of Land Management. The BLM at work in Oregon and Washington, 1961. Portland, 1961. 31 p.

44. Willhite, Forrest M. How to improve mountain meadows in the west. Plant Food Review, Summer 1963, 5-8 p.

APPENDICES

APPENDIX A

INDIVIDUAL RANCH COSTS AND RETURNS

Rancher I

Livestock Sales:

Cows 23 head at 975 pounds per head x $.1625	= $ 3,644.70
Steers 71 head at 688 pounds per head x $.26	= 12,700.00
Heifers 59 head at 580 pounds per head x $.2450	= 8,384.00
	$24,728.70

Operating Expenses:

Leased land	$ 122
Labor	6,140
Feed	600
Seed	30
Supplies	235
Repairs	800
Vet. Bills	300
Fuel	800
Taxes	1,284
Insurance	180
Utilities	300
Marketing Costs	134
Accounting	50
Salt	240
	$11,215

Investment:

Machinery	$ 7,000
Buildings	6,000
	$13,000
	.06
	$780.00

Cost of bulls	$650

Total Income	$24,729
Operating Expenses	-11,215
Depreciation	- 780
Cost of bulls	- 650
Adjusted Income =	$12,084

$$\text{Adjusted income per breeding unit} = \frac{\$12,084}{155} = \$78.00$$

Rancher II

Livestock Sales:

Cows 49 head at 1,050 pounds per head x $.16 per pound	= $ 8,232
Cows 20 head at 1,000 pounds per head x $.1250 per pound	= 2,500
Heifers 13 head at 500 pounds per head x $.23 per pound	= 1,495
Steers 124 head at 595 pounds per head x $.26 per pound	= 19,183
	$31,410
Value of home consumption	= 672
Increase in inventory: 39 cows at $225 per head	= 8,775
85 heifers at 575 pounds x $.23	= 11,241
Total	$52,098

Operating Expenses:

Labor	$11,672.00
Feed purchased	464.00
Seed	231.00
Supplies	1,221.34
Repairs	1,030.73
Vet. bills	251.70
Fuel	1,867.36
Taxes	3,050.00
Insurance	1,413.00
Utilities	748.00
Trucking	253.00
Marketing costs	98.00
	$22,300.13

Investment:

Machinery	$12,400
Buildings	10,000
	$22,400
	.06
	$1,344.00

7 bulls purchased	= $2,575
Salvage value of 7 bulls	= 1,820
Cost of bulls	= $ 755

Total Income	$52,098
Operating expenses	-22,300
Depreciation	- 1,344
Cost of bulls	- 755
Adjusted Income	$27,699

Adjusted income per breeding unit $= \frac{\$27,699}{382} = \$72.50$

Rancher III

Livestock Sales:

Cows 16 head at 940 pounds per head x $.14	= $ 2,105.60
Steer calves 97 head at 430 pounds per head x $.26	= 10,844.60
Heifer calves 63 head at 425 pounds per head x $.24	= 6,426.00
Wool and lambs	= 1,000.00
	$20,376.20
Increase in inventory: 9 cows at $225 per head	= 2,025.00
10 heifers at $110 per head	= 1,100.00
100 ton of hay at $20.00 per ton	= 2,000.00
Total	$25,501.20

Operating Expenses:

Labor	$4,700
Supplies and repairs	1,400
Fuel	1,500
Taxes and Insurance	2,050
Utilities	204
Seed	100
	$9,990

Investment:

Machinery	11,000
Buildings	8,000
	19,000
	.06
	$1,140.00

3 bulls purchased	$1,225
Salvage value 3 bulls	696
Cost of bulls	$ 529

Total Income	$25,501
Operating expenses	- 9,990
Depreciation	- 1,140
Cost of bulls	- 529
Adjusted Income	$13,842

$$\text{Adjusted income per breeding unit} = \frac{\$13,842}{240} = \$58.00$$

Rancher IV

Livestock Sales:

Cows 5 head at $80.00 per head	= $ 400
Calves 85 head at $105 per head after marketing expenses	= 9,010
Yearlings 40 head at 500 pounds per head x $.27	= 5,400
Total	$14,810

Operating Expenses:

Labor	$2,400
Feed	1,800
Seed	400
Supplies	250
Repairs	850
Fuel	675
Taxes	750
Insurance	300
Utilities	270
Accounting	75
Marketing	150
	$7,920

Investment:

Machinery	5,000
Buildings	2,500
	7,500
	.06
	$450.00

2 bulls purchased	$800
Salvage value 2 bulls	500
Cost of bulls	$300

Total Income	$14,810
Operating expenses	- 7,920
Depreciation	- 450
Cost of bulls	- 300
Adjusted Income	$ 6,140

Adjusted income per breeding unit $= \frac{\$6,140}{150} = \$41.00$

APPENDIX B

PROJECTED RESEEDING AND ASSOCIATED COSTS FOR THE EAST COW CREEK UNIT

	Acres	Cost
Big Ridge Seeding	3,200	$33,400
Little Sandy Seeding	2,880	35,570
Cowgill Seeding	4,000	39,000
Barlow Seeding	4,000	39,000
Arock Seeding	13,000	116,000
Crater Seeding	2,000	19,500
Total	29,080	$282,470

$$\frac{\$282,470}{29,080} = \$9.71 \text{ per acre for reseeding.}$$

Fencing Cost:

	Miles	Total cost	Acres
Little Sandy Protective Fence	6.0	$4,275	2,880
Big Ridge Protective Fence	6.0	4,500	3,200
Barlow Protective Fence	2.5	1,880	4,000
Cowgill Protective Fence	3.0	2,225	4,000
Arock Protective Fence	8.0	5,698	13,000
Arock Division Fence	9.0	6,350	
Crater Protective Fence	5.0	3,975	2,000
Total		$28,911	29,080

$$\frac{\$28,911}{29,080} = \$.99 \text{ per acre for fencing the seedings.}$$

Water Developments:

	Miles	Total cost	Acres
Barlow Pipeline	6	$15,000	4,000
Cowgill Pipeline	7	16,000	4,000
Arock Pipeline and Well		15,500	13,000
Total		$46,500	21,000

$$\frac{\$46,500}{21,000} = \$2.20 \text{ per acre for water developments.}$$

APPENDIX C

PROJECTED SPRAYING AND ASSOCIATED COSTS FOR THE EAST COW CREEK UNIT

	Acres	Total Cost
Cow Lake Brush Spray	4,100	$15,300
Hooker Creek Brush Spray	1,200	4,100
Wind Creek Brush Spray	10,000	32,000
Mud Creek Brush Spray	18,000	56,000
Crater Brush Spray	3,000	10,000
Lodge Brush Spray	6,595	29,380
Total	42,895	$146,780

$$\frac{\$146,780}{42,895} = \$3.42 \text{ per acre for spraying}$$

Fencing Costs:

	Miles	Total Cost	Acres
Hooker Creek Protective Fence	3.5	$2,288	1,200
Wind Creek Protective Fence	4.5	3,663	10,000
Mud Creek Protective Fence	5.0	3,675	18,000
Mud Creek Division Fence	3.0	2,525	
Lodge Protective Fence	5.5	4,192	29,380
Total		$16,343	58,580

$$\frac{\$16,343}{58,580} = \$.28 \text{ per acre for fencing the sprayings.}$$

Water Developments:

	Miles	Total Cost	Acres
Mud Creek Well and Pipeline	9	$18,500	18,000
Lodge Well and Pipeline	3	13,200	29,380
Total		$31,700	47,380

$$\frac{31,700}{47,380} = \$.67 \text{ per acre for water developments.}$$

APPENDIX D

SEASONAL USE PATTERNS FOR EACH TYPE OF FEDERAL RANGE FOR REVISED GRAZING SEASONS OF MODEL III

Level of Capital	$10	$1,989	$4,368	$6,051	$6,815
Range Type					
Reseedable acres:					
May 1 - Aug. 1	13,372	10,371	0	0	0
June 1 - July 1	0	3,001	9,594	5,720	3,996
Apr. 1 - May 1	0	0	1,013	2,930	3,766
Crested wheatgrass acres:					
July 1 - Aug. 1	0	0	2,765	3,381	3,545
June 1 - July 1	0	0	0	1,341	1,935
Aug. 1 - Oct. 1	0	0	0	0	130
Sprayable acres:					
Aug. 1 - Oct. 1	4,494	0	0	0	0
Sprayed acres:					
Aug. 1 - Oct. 1	23	3,446	4,081	4,464	4,517
July 1 - Aug. 1	0	1,071	436	53	0
Other good acres:					
Aug. 1 - Oct. 1	1,034	1,034	1,034	1,034	1,034
Other poor acres					
April 1 - May 1	9,491	11,241	12,025	11,188	10,823
May 1 - June 1	0	3,156	10,092	10,929	11,294
May 1 - Aug. 1	10,596	7,720	0	0	0
Aug. 1 - Oct. 1	2,029	0	0	0	0