SELECTING AND PLANNING HIGH COUNTRY RESERVOIRS FOR RECREATION WITHIN A MULTIPURPOSE MANAGEMENT FRAMEWORK

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ABSTRACT

This report is presented to help decision makers, managers, planners, and owners of water and its adjacent lands make more informed decisions on the selection and development of high country reservoirs for recreation. Following are the major research topics addressed in this report:

- Decision Process and Essential Factors to be Considered for Selection, Planning and Management of Reservoirs
- River Basin Simulation Model for Determining Feasibility for Managing Reservoir Storage Levels for Recreation
- Fishery Capabilities and Requirements of Cold Water Reservoirs
- Legal Aspects Associated with Maintaining Water in High Country Reservoirs for Recreation

The following questions are answered in varying degrees by the scientific findings of the study.

- How can we determine which reservoirs are best suited for various recreation user groups?
- What important factors must be considered in selecting suitable reservoirs and developing these reservoirs for recreation? Why is it important to consider those factors?
- What is the recreation fishery capability of cold water reservoirs?
- What is the effect of drawdown on the reservoir fishery?
- Is there enough available water in the river basin to meet recreation needs and, at the same time, meet the water rights of agricultural, municipal, and domestic users?
- How can the practitioner determine water availability for recreation?
- What managerial options are available for enhancing use as much as possible without harming other water users?
- What are the legal options, liabilities, and limitations on obtaining water and utilizing reservoirs for recreation?

Recreation resources, fishery biology, water resources engineering and law combine in a truly interdisciplinary study to provide findings which are incorporated into a practical decision process. The process orders data and provides a framework for selecting, planning, and managing reservoirs for recreation.

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TABLE OF CONTENTS

INTRODUCTION 1

OBJECTIVES AND PROBLEMS 11
Objectives 11
Problems 11

STUDY AREA 15

FINDINGS 17
Step I: 17
Reservoir User Groups 20
Existing Situation 25
Summary 25
Step II: 25
Institutional Considerations 27
Management Policies 27
Legal Liability 30
Physical Considerations 36
Access Type 36
Travel Time 38
Facilities/Space, Slope and Soils 40
Biological Considerations 42
Fishery Capability 42
Artificial Substrates 49
Description of Substrates 51
Discussion of Substrate Characteristics 54
Natural Substrates 57
Conclusion 59
Shading and Screening 61
Cost Considerations 61
Summary 63
Step III: 64
Step IV: 71
Physical Feasibility 73
River Basin Simulation Model 74
Data Requirements 77
Model Calibration 79
Management Studies 80
Legal Aspects Associated with Maintaining Water in High Mountain Reservoirs 83
Diversion 84
Beneficial Use 85
Water Storage Rights 85
Over-Appropriation 87
Minimum Stream Flows and Lake Levels 87
Existing Transfer Mechanisms 89
Exchanges 90
Status of the Poudre River 92

Alternative Methods of Providing Water for for Recreational Use in High Mountain Reservoirs . . 92
Step V: 94

EXAMPLE OF THE USE OF THE DECISION-MAKING FRAMEWORK 101
Step I 101
Reservoir User Group 101
Existing Situation 102
Step II 104
Step III 108
Weighted Decision Process 114
Step IV 130
Step V 131
Summary 133

SUMMARY AND CONCLUSIONS 135

LITERATURE CITED 141

APPENDIX I -- RIVER BASIN SIMULATION MODEL FOR DETERMINING WATER AVAILABILITY FOR RECREATION 147

APPENDIX II -- EFFECTS OF WATER DRAWDOWN ON THE FAUNA IN SMALL COLD-WATER RESERVOIRS 207

APPENDIX III -- LEGAL ASPECTS ASSOCIATED WITH MAINTAINING WATER IN HIGH MOUNTAIN RESERVOIRS 273

LIST OF FIGURES

1. Study Area 14

2. Flow Diagram of the Decision Making Process 18

3. Essential Factors in The Decision Process 19

4. User Group Profile
   Group 1 - Facilities and Access Oriented 21
   Group 2 - Solitude Oriented 22
   Group 3 - Hiking and Scenic Oriented 23

5. Sensitivity of Model Output to Adjustments in Priority Factors 82

6. Legal Considerations in Planning for the Construction and Use of High Mountain Reservoirs in Colorado 95

7. Legal Considerations in Planning for the Recreational Use and Maintenance of High Mountain Reservoirs in Colorado 97

8. Case Study Reservoirs Used in Decision Making Framework . . . 100

LIST OF TABLES

1. Distance of Reservoirs from Four Colorado Population Centers 39

2. Desired Facilities and Required Minimum Space - By User Group 99

3. Existing Situations at Alternative Colorado Springs Reservoirs 103

4. Group II Evaluation Matrix 105

5. Group III Evaluation Matrix 111

6. Considerations With or Without Scientific Foundation 119

7. Assigned Weightings by Recreation Group 120

8. Weighted Selection Process - Group II Reservoirs 122

9. Group II Considerations Receiving No Weighting 123

10. Weighted Selection Process - Group III Reservoirs 126

11. Group III Considerations Receiving No Weighting 128

INTRODUCTION

The information in this report is presented to help managers, planners, and owners of water and its adjacent lands make more informed decisions on the selection and development of reservoirs for recreation. Following are the basic topics addressed by our research:

- How can we determine which reservoirs are best suited for different recreation user groups?
- What important factors must be considered in selecting suitable reservoirs and developing these reservoirs for recreation? Why is it important to consider these factors?
- What is the recreation fishery capability of cold water reservoirs?
- What is the effect of drawdown on the reservoir fishery?
- Is there enough available water in the river basin to meet recreation needs and, at the same time, meet the water rights of agricultural, municipal, and domestic users?
- How can the practitioner determine water available for recreation?
- What managerial options are available for enhancing recreation use as much as possible without harming other water users?
- What are the legal options, liabilities, and limitations on obtaining water and utilizing reservoirs for recreation?

All of these major questions are answered in varying degrees by the scientific findings of this study. The real challenge of this report is to present the findings so that water owners, planners and managers understand and utilize them. In attempting to meet this challenge, two models have been developed and combined to incorporate all of our findings into one practical decision model.

Four major disciplines contributed information to the model: recreation resources, fishery biology, water resources engineering and law. Information was gathered through basic research, literature review, and collaboration with field managers and planners. The decision model is not the end product of the research, but a tool which has helped make the research study a truly interdisciplinary team effort. With four separate disciplines involved, four separate studies could have ensued. However, the decision model will not work without major input from the legal, engineering, fishery, and recreation investigators. Furthermore, the model requires that each discipline understand and rely upon the other disciplines for information to pursue their research. For example, the water resource or engineering team needed to know the recreation demand for reservoir water to operate the river basin simulation. Reciprocally, the recreation team needed to know how much water was available in the water delivery system to determine how close they can come to meeting recreation demand. These tradeoffs continually presented themselves in the study and are reflected in a decision model which includes a broad and comprehensive set of variables which need to be considered together to make rational decisions.

Therefore, the model is not only important as a tool for making our study truly interdisciplinary but also represents a framework for structuring and ordering information which should be considered in making informed and intelligent decisions for providing water and developing reservoirs for recreation.

NEED

"Would you rather eat or recreate?" "Water is too scarce to use for recreation." "We have always drawn down reservoirs and distributed water this way. It works. Why change it?" "It is probably too costly to manage reservoirs for recreation." "What is in it for me? Why should I allow my water to be used by others?" "This city cannot take the chances of polluting our water supply." "We are legally liable and they will sue us if anything goes wrong." "Recreationists vandalize and destroy our dams by driving on them." "We would need too many expensive facilities and constant police patrol."

Questions and statements such as these were encountered frequently by our researchers, not just from private water owners but from government leaders and "professional" managers. To the uninformed or misdirected, these seem to be logical statements. However, our research and that of many other scientists prove that in many cases these statements are wrong. The real danger in these thoughts and statements is that they are often strongly believed, or used as excuses by those who direct or dictate water used in Colorado and the West. Unfortunately, for the public, this often means single-purpose use.

In these days of growing water demands and dwindling supplies, there is little, if any, place for single-purpose use of water. To utilize this valuable resource for only one purpose is both inefficient and wasteful. There is a definite moral obligation for every farmer, industrialist, municipality, recreationist, contractor and other water owners* to consider every other potential use of the water, and to determine if there are other compatible uses for the water. If it is found that other uses do not affect the delivery time, amount, or the quality of water required by the water owner, then every effort should be made by the water owner to accommodate these other water uses. The other water users must themselves make every effort to use the water efficiently and to avoid creating problems for the water owners. Every effort should also be made to provide economic incentives for the water owners. As is the case with recreation, water-related activities can often be financially rewarding. If moral or economic incentives are not enough to entice the water owner to accommodate other uses, then most certainly the day will come when political and legal measures will force multiple use. The resource is too scarce and too much in demand to allow single uses to continue much longer.

Force does not have to be the answer. We can work together as intelligent, concerned water owners to make multiple use a reality. This is probably idealistic, yet some of us can and will work together toward this goal; and we will, according to our scientific data, profit physically, emotionally and economically from our endeavor. We will be the ultimate winners.

In order to determine whether or not recreation should be one of the uses of a reservoir, and how that reservour should

*Water owner is defined in this report as a water user who owns the right to use water.

be developed, one must first understand the consequences of opening and developing the reservoir for recreation. This is what our scientific study attempts to do. Yet the report goes one important step further---it presents a comprehensive decision model for making the most efficient use of reservoirs and reservoir water for recreation within a multipurpose use system.

The need to provide information which will make recreation an accepted use of most reservoirs stems from the growing demands of a public seeking a better and more fulfilling life. Mountains of the Western United States provide some of the most beautiful spots in the United States. High in this country are many glacial and man-made lakes surrounded by dense forests and majestic snow-capped peaks. On any given day, the changing aura of the surroundings is reflected in the lakes and reservoirs, providing a focal point, unsurpassed in nature, for meeting the leisure time desires of man.

Recreationists in Colorado and throughout this country and the world are aware of this recreation opportunity. The result is bumper-to-bumper caravans of people heading for existing public areas on the high country lakes. Even the most fragile and inaccessible lakes hidden in the cirques of the highest peaks are constantly being assaulted by increasing numbers of back-packers, jeepers, and horsepackers.

The result has been the inevitable overcrowding and overuse of the existing water sites open to the public. With this overuse has come destruction of the very physical environment which the recreating public seeks. The mere numbers of people packed together in a near-wilderness setting cause degradation of the recreation experience. Furthermore, the management problems created by overuse call for unpopular solutions in order to save the environment.

Current management practices and projected plans call for restricting the number of recreation users. Even without restrictions, current demands exceed available public facilities. People, are regularly being turned away, not just from one water area, but from all areas. On weekends, the news media along the Front Range of the Rockies in Colorado frequently announce that people should stay out of the mountains because all open public areas in the high country are full. Most of these areas are near water. With projected further cutbacks and restrictions places by public agencies on use of facilities and areas surrounding water sites, the situation can only become worse. Compounding the problem is the rapid population growth along the Front Range which, according to recent census figures, is one of the fastest in the country.

According to the 1970 Outdoor Recreation Plan for Colorado, a deficit in sites for fishing, boating, swimming, tent camping, trailer camping, and hiking already exists in the Front Range region. Predicted urban population growth along the Front Range from 1.6 million in 1970 to 2.5 million by 1980 and to 3.8 million by the year 2000 (State Planning Office, 1969) will undoubtedly be accompanied by a rapid increase in demand for water-oriented recreation.

In the Western United States, the supply of water is limited. In most cases water comes from snow melt and is stored in a complex series of reservoirs. The water is owned as a property right and used mainly for agricultural, industrial, and domestic purposes. Recreation, in most cases, is only an incidental use of water. The majority of reservoirs are single purpose. Some reservoirs are open for public recreation, but most are not. Few reservoirs are managed for recreation.

In a time when recreation demand for water already exceeds existing available resources, and in a time of projected increases in demand for water recreation, it seems inconceivable that reservoirs will continue to be managed for single purpose, excluding recreation as a use of the water resources. However, since water is a property right, the owner must be convinced that there is a legitimate demand, that there are practical reasons for him to make his reservoir available for recreation, and that the management of water for recreation is not in direct conflict with his major use.

The situation is, therefore, critical. A rapidly increasing demand for water recreation in the high country is, and will continue to be, met by a cutback in the supply of existing public water areas and facilities. Managing existing usable public water areas for even heavier recreation use is not the answer. Just the opposite is being done.

The problem is twofold:

1. Additional extensive water resources which are not being used for recreation but have the potential for recreation use must be found, developed, and managed for recreation. Such water would necessarily provide additional user days for handling the existing and potential surplus user demand. Recreation use of these waters would, hopefully, help alleviate the overuse of existing areas by distributing the recreation user load.
2. Areas which are already being used for recreation often need proper development and management. This means that accurate information must be available for the most efficient recreation use of the reservoirs.

We now know that such a water resource does exist in the high country of the Colorado Rockies. This resource takes the form of water in storage reservoirs. At present, many of these reservoirs are receiving no use or, at best, minimal use by recreationists. This is due to the fact that private and public water owners and managers either restrict use of the reservoirs or improperly manage the reservoirs for recreation.

"Restricting use" means either closing, signing and/or fencing reservoirs for no use or limited use. It also means legal limitations. The structure of western water rights and water laws often fosters single use and restricts recreation use of reservoirs.

"Improper management" means ignoring or not knowing the needs and management techniques necessary for the recreating public. This leads to such problems as inadequate access, inappropriate facilities, overcrowding, and, in general, providing for the wrong public. It may also lead to increased legal liability, vandalism, and environmental impact. Furthermore, "improper management" means restricting recreation use by drawing water out of reservoirs (drawdown) during the critical recreation use time--June, July, and August. This management practice means both reduction in the usable resource and aesthetic degradation. Drawdown also leads to the destruction or reduction of the physical and biological capability of the water to meet recreation needs. A good example is the reduction or destruction of the fishery capability of the reservoirs due to drawdown. This means stunting of growth or loss of fish due to the loss of spawning habitat, reduction of food organisms, loss of cover, loss of young through the spillway, winterkill and oxygen depletion.

The need to find answers to all of these problems is critical. Our study is in part an attempt to find answers and provide information on each of these problems. Yet, these problems are but a part of the larger water problems associated with Colorado and arid regions of the United States in general. Lack of adequate knowledge of physical, legal, political, and social potentials and/or constraints with regard to water reservoirs has prohibited the fullest and best utilization of the water that is available. In addition, the concern over limited amounts of water allocated to first interests has so overshadowed other considerations, which might be incorporated into the agri-industrial municipal ones, that other benefits remain largely ignored. Hence, a resource such as water, which is in short supply and high demand, is not managed in the most advantageous manner for all concerned. If enlightened management practices (e.g., providing access, desired facilities, fisheries, and timed water delivery) were developed which caused little or no conflict with primary user rights, then the various publics involved in the use of water might take major strides toward realizing the multiple use of this critical resource.

Management practices necessary to meet recreation demand on high country reservoirs were identified in both Phase I and II of this research study (O.W.R.T. Phase I Aukerman 1975). To meet these recreation demands, we have scientifically shown to what degree these recreation management plans can be met within the framework of physical, biological, sociological, legal, and environmental restraints.

The limitations identified in both phases of the research form the parameters in which a practical decision model has been designed. Hopefully this will lead to more informed and systematic reservoir selection, planning, and management for incorporating recreation as one of the multiple uses of the high country reservoirs.

OBJECTIVES AND PROBLEMS

Objectives

Objective A — Design a decision model and identify the factors essential for selection, planning and management of reservoirs for recreation.

Objective B — Demonstrate physical, biological and legal feasibility and potential for enhancing water recreation opportunities on high country reservoirs.

Problems

In Phase I of our research, management practices desired by recreationists were identified. In this second phase of our research, we isolated those management practices which should be considered in selecting, developing and managing reservoirs which are best suited for recreation. The isolation process meant: identifying those factors which had the greatest effect on the attitudes and behaviors of recreationists; identifying the management practices managers felt were important; identifying the fishery potential and water needs; and determining ways of meeting these needs by timed water delivery, water management, and legal manipulation. These data were then combined into a decision framework for enhancing recreation use of reservoirs in an optimum fashion. To do this the following specific problems had to be solved:

Objective A — Problem 1: Can a decision framework be designed which logically orders the data and leads to accurate and informed selection, planning and management of reservoirs?

Problem 2: What factors must be considered in selecting, planning, and managing reservoirs? Why is each factor important?

Objective B — Problem 1: Is it physically possible, from a management and allocation standpoint, to maintain water in reservoirs to meet recreation needs? How can this be determined? What are the alternatives? What are the implications for both recreation users and other water users?

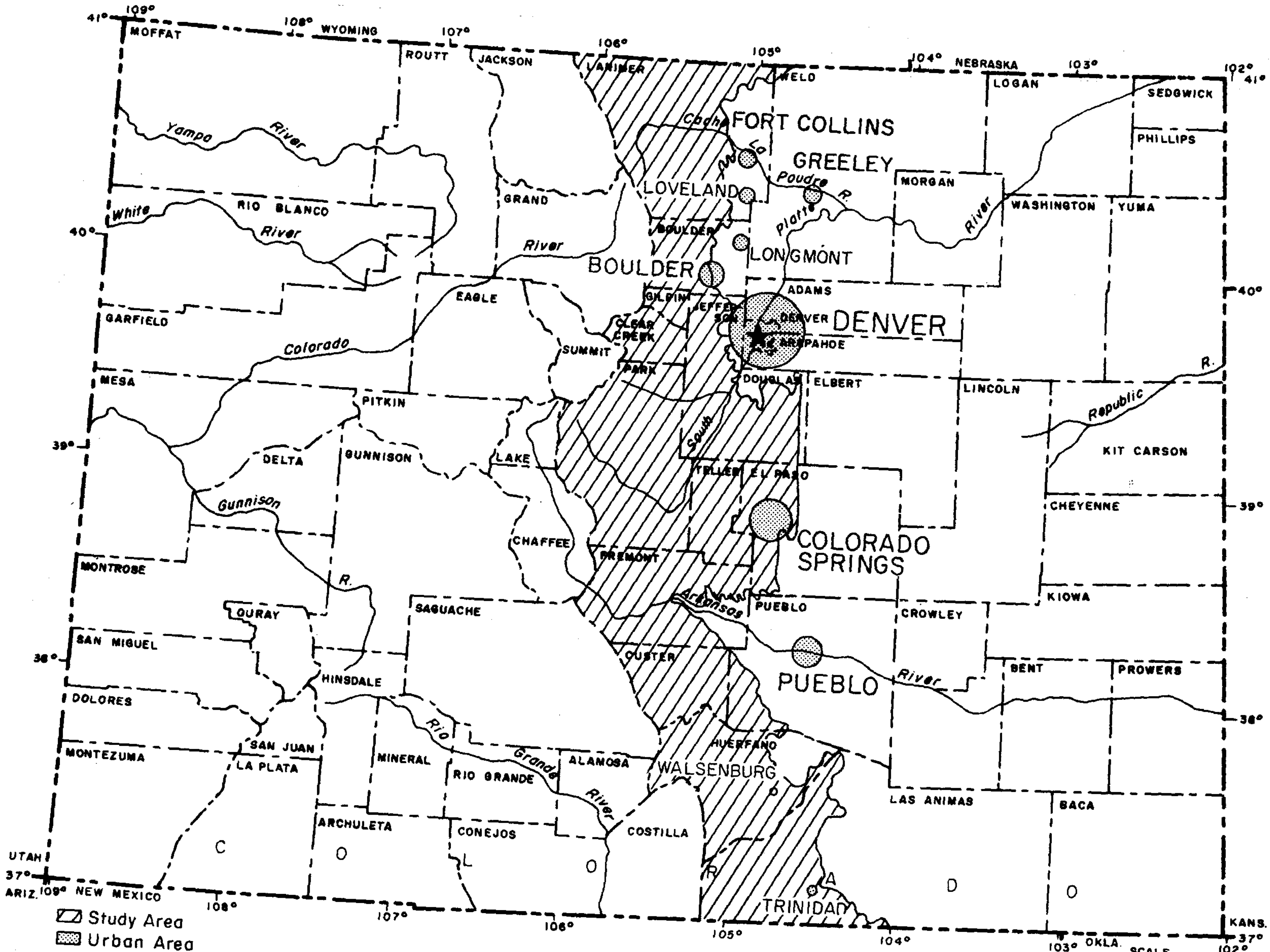
Problem 2: Is it physically and biologically possible to provide a recreation fishery in mountain reservoirs which meets the recreation fishing demand? How can this be accomplished?

Problem 3: What are the legal limitations and alternatives of present water laws for meeting recreation needs on high country reservoirs?

The findings section of this report gives a synopsis of our research on these problems and identifies the rationale behind studying each problem and the implications of the findings.

The data came from four years of research by these investigators plus collaboration with other researchers, managers, planners, and water owners. Detailed information on the findings and research methods is given in the appendices, in the Phase I report, and in C.S.U. Environmental Resources Center Special Report #23 (Aukerman, Springer and Judge 1977).

The detailed information is presented in these media in an attempt to condense our findings into a report which is not overly burdensome to the general reader. Those seeking detailed findings and information should, after reading the text of this report, consult the Phase I report or one of the appendices.



Study Area

FIGURE I

STUDY AREA

The Study Area is shown by the cross-hatched pattern on the map (Figure 1). It covers the length of Colorado and is bordered on the north and south by the Wyoming and New Mexico state lines respectively. The eastern boundary is the 6,000-foot elevation contour. The western boundary is the Continental Divide from the Wyoming border to approximately the center of the state where the boundary becomes the Park and Fremont county lines. In the southern portion of the state, the western boundary is the Sangre de Cristo mountain range. The large park areas (North, Middle, South) of the state are exluded to retain reservoir settings in the montane, sub-alpine, and alpine life zones.

Within this area, data were collected from 131 reservoirs between ten and four hundred acres in size. However, certain exceptions were made for those reservoirs that do not meet this criterion, but whose overall characteristics are similar to the reservoirs within the ten to four hundred acre criterion. The reason for selecting reservoirs between ten and four hundred surface acres was that most high country reservoirs fall within this range. Relatively few are larger, and those that are smaller are poorly suited for most major reservoir uses. Therefore, this study represents all of the high country reservoirs in the Colorado Front Range that are suitable for major use except for a few extremely large reservoirs. Detailed data were collected for thirty-six reservoirs presently open for recreation and special emphasis was placed on them.

The Cache la Poudre River drainage was then selected as the major test area for the engineering model. From this drainage, one of the most complex water delivery systems in Colorado, Reservoirs were selected for testing.

Five Colorado Springs reservoirs in the Pikes Peak area were selected as example reservoirs for the entire decision process.

FINDINGS

This section presents a decision making framework and information intended to help identify and organize information for the planner so that meaningful decisions can be made concerning recreation at high mountain reservoirs. The framework, when broken down to its component parts, represents a checklist of factors requiring consideration whenever a proposal is made to provide recreation opportunities at reservoirs. A flow diagram of the decision making process is shown in Figure 2.

The framework is predicated upon the assumption that one or a number of reservoirs exists that can potentially be developed for recreation. The problem of the planner is to decide what opportunities are lacking in a given high mountain area and at which alternative reservoir(s) it is most feasible to provide the needed opportunities.

Figure 3 outlines the essential factors requiring consideration in the decision process. The remainder of the findings section shows the need to consider each factor and how to use the factor in making decisions.

STEP I: Determine Need for Reservoir User Group Opportunities in an Area, and Existing Situations at Potentially Developable Reservoirs.

Two factors are immediately important to the decision

FIGURE 2

FLOW DIAGRAM OF THE DECISION MAKING PROCESS

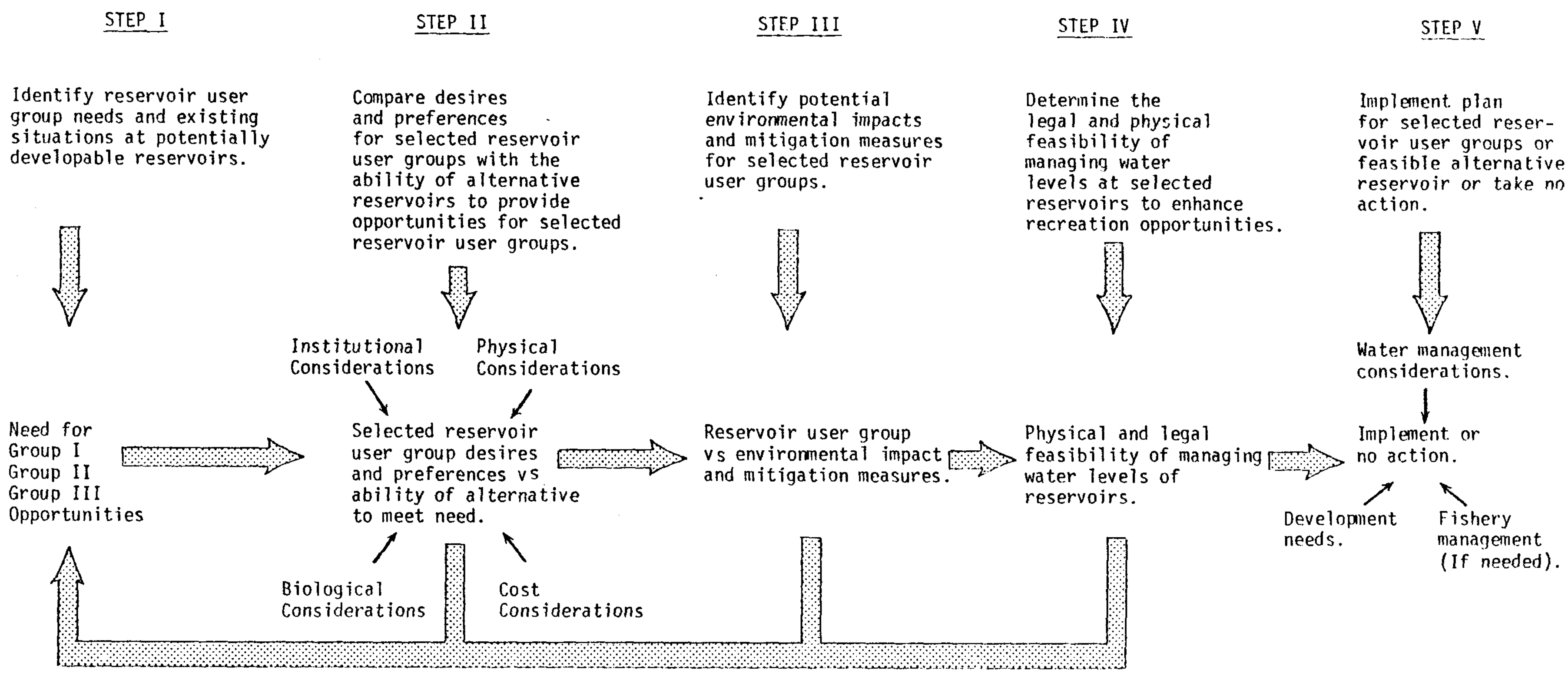


FIGURE 3

ESSENTIAL FACTORS IN THE DECISION MAKING PROCESS

A framework for selecting, planning, and managing for a particular reservoir user group when opportunities for that user group are found to be lacking, and potentially developable reservoirs exist to meet the need.

STEP I

A. Based upon equity considerations, determine the need for reservoir user group opportunities in the area under consideration (e.g., a watershed).

B. Determine the reservoirs potentially suitable for development to meet the need, and define the existing situation at each reservoir (e.g., access type, location with respect to population centers, slope, space, soils, fishery capability, etc.).

STEP II Compare the characteristics of alternative reservoirs with the preferences and desires of the reservoir user group in question, and rank alternatives according to development feasibility based upon:

A. Institutional considerations:
   1. Management policies (e.g., wilderness area).
   2. Legal liability.

B. Physical considerations:
   1. Access type needed.
   2. Driving time from population centers.
   3. Facilities needed.
   4. Slope (flat enough for development).
   5. Space (room enough for development).
   6. Soils (depth to bedrock, erosion potential, etc.).

C. Biological considerations:
   1. Fishery capability (winterkill, refugia, spawning habitats, etc.).
   2. Trees for shading and screening.

D. Development considerations:
   1. Cost of development.

STEP III Evaluate the potential environmental disruptions of mitigation measures.

STEP IV Determine the physical and legal feasibility of managing water levels at selected reservoirs to enhance recreation opportunities.

STEP V Implementation or no action.

making process. First, a tentative decision is required concerning which reservoir user group "needs" opportunities provided in a given area. Second, a determination of the existing situations at alternative reservoirs is required to define such characteristics as access types, space, slope, fishery quality, ownership, drawdown practices, shading and screening potential.

Reservoir User Groups

Four reservoir user groups were identified in the first phase of the present project. Reservoir users were categorized according to their preferences for access type, fishery quality, facility development and degree of use, i.e., crowding (Aukerman 1975). For the purposes of the second phase of this project, the reservoir user groups have been reduced to three groups. A profile of each reservoir user group is given in Figure 4.

The thrust of the first consideration of Step I of the decision making framework is to insure that a full range of recreation opportunities are provided for reservoir recreationists. The importance of a variety of recreational opportunities has been pointed out by other researchers (Shafer 1959; Wagar 1963, 1966; Clark et. al. 1971; Hendee et. al. 1971) and, not surprisingly, was found to be a key factor in the present study. However, specifying that what is needed is a full range of reservoir recreation opportunities may be of little use to the planner when deciding what proportion of an area's reservoir should be devoted to a given reservoir user group. A rule of thumb generated by the present project for Colorado Front Range

FIGURE 4*

USER GROUP PROFILE

GROUP I - Facilities and Access Oritented

1. Reservoirs presently utilized by Group I: Barker, Bell, Branard, Chambers, Chicago, Dowdy, Estes, Evergreen, Left Hand, Manitou Park, Mary's Monument, North, Pinewood, San Isabel, Skagway, West, Wright's.
2. Prefer easy access (paved or maintained dirt roads).
3. Prefer travel time less than two hours.
4. Prefer extensive facility development (toilets, picnic tables, firegrills, trash cans, wood, water, boat ramps, parking sites, camping sites).
5. Accept crowded conditions (averaged 57 users/day in 1973).
6. Of Group I users, 59 percent do not camp at reservoirs, but of those that do camp, 60 percent do so in camper-trailers.
7. Chance to at least catch a fish is important; 55 percent of Group I users are avid-nonconsumptive fishermen, 15 percent are consumptive fishermen.
8. Most important activities: fishing (70 percent), camping (20 percent), relaxing (11 percent).
9. Of all Group I users, 90 percent say reservoir met expectations.
10. Of Group I users, 47 percent will pay $1-2 to use site as is; 47 percent of Group I users unwilling to pay anything.
11. Of Group I users, 50 percent will pay $1-2 to use site with desired improvements; 34 percent unwilling to pay anything.
12. High on-site like for scenery and fishing.

*See Phase I report for more detail on User Group Profile.

FIGURE 4 (Cont.)

GROUP II - Solitude Oriented

1. Reservoirs presently used by Group II: Clear Creek, Chinns, Commanche, Jefferson, Parvin, Peterson, Twin, Lower Urad, Zimmerman.
2. Ease of access unimportant, (accept very poor unmaintained dirt roads, including 4-wheel drive).
3. Prefer travel time less than three hours.
4. Prefer only moderate facility development (toilets, trash cans, picnic tables, firegrills).
5. Prefer uncrowded conditions (averaged 20 user/day in 1973).
6. Over half of Group II users (54 percent) do not camp at reservoir, but of those that <u>do</u> camp, 68 percent do so in tents or under the stars.
7. Fishing quality is generally less important than for Group I users; 44 percent are avid non-consumptive fishermen: 46 percent are casual non-consumptive.
8. Most important activities: fishing (54 percent), camping (23 percent), relaxing (15 percent).
9. Of Group II users, 91 percent say reservoir meets expectations.
10. Of Group II users, 41 percent will pay $1-2 to use site as is; 55 percent are unwilling to pay anything.
11. Of Group II users, 57 percent will pay $1-2 for desired improvements; 40 percent are unwilling to pay anything.
12. Highest on-site likes for scenery and solitude.

*See Phase I report for more detail.

FIGURE 4 (Cont.)

GROUP III - Hiking, and Scenic Oriented

1. Reservoirs presently utilized by Group III: Bluebird, Isabelle, Jasper, Lawn, Long, Pear, Red Deer, Sand Beach, Skyscraper.
2. Prefer foot path access.
3. Prefer travel time less than four hours.
4. Prefer only limited facilities (toilets, trash cans).
5. Prefer uncrowded conditions (averaged 10 users/day in 1973).
6. Majority of Group II users (60 percent) camp at reservoirs, of these individuals camp in tents, under stars.
7. Fishing quality is unimportant (70 percent of Group III users are casual non-consumptive fishermen).
8. Most important activities: hiking (30 percent), camping (22 percent), fishing and relaxing (13 percent each).
9. Of Group III users, 95 percent say reservoir meets expectations.
10. Of Group III users, 43 percent will pay $1-2 to use reservoir as is, 45 percent unwilling to pay anything.
11. Of Group III users, 39 percent will pay $1-2 for improvements; 34 percent unwilling to pay anything.
12. Very high on-site like for scenery and solitude.

reservoirs, based upon actual supply of reservoirs for different user groups and the desires and preferences of these user groups, is that 50 percent of the area's reservoirs should be devoted to Group I users, 25 percent to Group II users and 25 percent to Group III users.

It should be interesting to note that Group II reservoir users are composed partially of dropouts from Group I and III. Group II users have often been overlooked in the supply, planning and management of reservoirs for recreation.

One caution here is that the present study deals only with reservoirs. Any naturally-occurring lakes utilized for recreation within a given high mountain area should also be characterized to the greatest extent possible as either Group I, Group II or Group III (using Figure 4) and their numbers included in the calculated percentages cited above. For example, the area immediately west of Fort Collins, Colorado contains a number of hike-in lakes utilized for recreation, and consequently there seems to be little need to develop reservoirs in this area for Group III users since their needs are probably met by existing lakes. In this case, reservoir planning and management choices would be between Group I and Group II reservoir users.

Existing Situation

As was pointed out earlier, the decision making framework assumes that a potentially developable reservoir(s) exists and the planner wishes to know if a given reservoir user group(s) can feasibly be provided for at the reservoir(s). Thus, the second factor in Step I is an inventory to determine the existing situations at alternative reservoirs, analyzing such factors as access type, fishery capability, drawdown practices, ownership, space and slope considerations, and vegetation for shading and screening (see Figure 3). This is important since it sets the stage for Step II of the decision making process, in which the desires and preferences of a given reservoir user group are compared with the ability of alternative reservoirs (existing situations) to meet the needs of that reservoir user group.

Summary

Step I involves a tentative decision about which reservoir user group(s) lacks opportunities in the high mountain area under consideration and also involves information gathering and organization. Information is obtained and organized concerning the desires and preferences of the tentatively selected reservoir user group; information concerning the existing situations at alternative reservoirs is also gathered and organized.

STEP II: Preliminary Determination of Feasible Recreation Reservoir Alternatives.

Step II involves a comparison of the desires and preferences of a given reservoir user group needing recreation opportunities within an area with the existing situations at alternative reservoirs potentially developable to meet that need. The ultimate goal of this step is to filter out those alternative reservoirs whole existing situations so constrain development potential as to render them infeasible for use by a given reservoir user group. Those reservoirs surviving Step II can be considered preliminarily as feasible for recreation development.

There may be instances in which no alternative reservoir survives the preliminary screening process relative to a given reservoir user group, and in such cases, the planner can return to Step I to derive a second or third-best reservoir user group and then repeat Step II comparing the desires and preferences of the next-best reservoir user group with the existing situations of the original reservoir alternatives. Moreover, the alternative reservoirs screened in the first case as infeasible for development to meet the needs of a given reservoir user group (but some alternative (s) has been found feasible) can be re-evaluated against the needs of another reservoir user group to determine if such alternative reservoirs might be suited to meet the needs of that reservoir user group. The point here is that some alternative reservoirs may not possess adequate characteristics in terms of space, slope, fishery capability, etc., to be considered for development as a reservoir devoted to one user group but may be well-suited for development for some other reservoir user group. Thus, the process allows the planner to pair reservoir user groups with reservoirs having development potential for that user group through a series of reiterations and loopings. The following paragraphs explain the components of the comparison process of Step II and the importance of each component to the various reservoir user groups.

Institutional Considerations

Two factors are considered in this section: management policies and legal liability. Management policies as used here refer to the use of reservoir water and to the use of land riparian to reservoirs. Legal liability refers to considerations required to protect recreationists when providing recreation opportunities.

Management Policies

Ownership is a major determinant of how land and water are used; recreation opportunities are non-existent at many high mountain reservoirs in Colorado because the riparian land is held in private and, in some cases, public ownership. Thus, in deciding between alternative reservoirs, ownership of riparian land is a critical factor and may preclude consider-ation of some alternative reservoirs unless some type of easement agreement can be worked out with the owners. Moreover, even where riparian land is owned publicly and can be utilized for recreation, there may still be constraints upon development. For example, an alternative reservoir located in a wilderness area will prohibit its consideration for development for Group I and Group II reservoir users.

Ownership of water is another important factor when considering reservoir recreation. Rights to use high mountain reservoir water on the piedmont areas east of the Colorado Front Range are owned primarily by municipal, industrial and agricultural interests. These interests, especially agriculture, tend to experience a peak water-demand period on reservoirs which have been drawndown that coincides with peak recreation use periods. Such situations create a problem for recreation; what is needed is knowledge of how to make recreation and other water uses compatible. One of the strongest arguments favoring management of reservoir water levels for recreation is lodged in fishery quality. Research has shown that drawdown and refill practices as presently exercised result in low spawning success, increased winterkill, loss of invertebrates serving as fish food sources, and a general reduction in fish populations (Aukerman et al , 1975).

Thus, when the objective of planning is to provide recreation opportunities for Group I and Group II reservoir users, drawdown becomes an important consideration since these user groups value fishery quality more highly than do Group III users.

Another argument favoring maintenance of water in reservoirs for recreation is that little or no water in reservoirs obviously limits or eliminates recreation use of reservoirs. The effect is basically the same as closure of the reservoir to recreation use. Although we have not yet researched where these recreationists go or what they do when denied use of reservoirs, we can theorize that they are seeking alternative areas which have water but may lack other amenities sought by the recreationist. It is probable that this is one of the contributing factors to overcrowding and overuse of reservoirs presently being managed for recreation. Again, this is only a theory. We have the data to pursue this question and hope, given the resources and time, to find the answer in the near future. Meanwhile, our research does show that even cases of drawdown which are not extreme affect the recreation experience and use of a few recreationists. If we wish to make the recreation experience enjoyable and available to all, then we must consider the needs of these potential users. Furthermore, the primary on-site like of all reservoir user groups is aesthetics. Reservoirs with water drawn out exposing mud flats, fallen trees, and debris are not aesthetically viable.

The water resource engineering component of this project has considered the problem of managing water levels at selected reservoirs while striving to meet downstream water demands. The results of this study are presented in detail in a subsequent section. It is important to note that alternative reservoirs experiencing drawdown conditions are not automatically removed from consideration for development. If that alternative reservoir meets the other criteria, then the river basin simulation model can be used to determine if it is possible to manage the water level of that reservoir during critical periods. The answers and ramifications of the preceding question on drawdown are discussed in Step IV.

Legal Liability

Encouraging public use of reservoirs poses the problems of exposing a larger number of people to water hazards and thus, potentially increasing the number of injuries. It is therefore, very important that users be adequately informed of and protected from hazards which may exist. Even if the best precautions are taken, it is always possible that someone will ignore the hazards and subject themselves to injury or death. In view of this possibility, it is necessary to review potential liabilities and how they may affect management options.

Legal action seeking to obtain compensation for injuries suffered are generally based upon an assertion of negligence. The mere fact that an accident occurred does not raise any presumption of negligence (Heagy v. City and County of Denver, 472 P2d. 757.). In order to establish a prima facie case of negligence, the plaintiffs (those seeking compensation for injury) must prove that the elements of negligence were present. These include: the existence of a duty on the part of the defendant; a breach of that duty; a causal connection between defendant's breach of duty and plaintiff's injury; and injury to the plaintiff (Prosser 1964). An important factor is the duty owed to the injured party.

The highest level of duty is owed to an invitee. A public invitee is a person who is invited to enter or remain on land as a member of the public for a purpose for which the land is held open to the public (Restatement of Torts, 332). Under this definition, it would appear that all reservoir user groups (Group I, Group II and Group III) qualify as invitees. An owner of land is subject to liability to his invitees for physical harm caused to them by his failure to carry on his activities with reasonable care for their safety, if, but only if, he should expect that they will not discover or realize the danger, or will fail to protect themselves against it.

Thus, where a danger is apparent and the victim ignores the hazard, there is no liability. This principle is illustrated in the case of Dumond v. Mattoon where a man drowned in a reservoir which was open for fishing, boating, waterskiing and swimming (207.N.E.2nd. 320, 1965). The victim drowned, however, in an open intake area near the pumping station which was enclosed by a concrete wall. The construction of the intake area was such as to not invite public use; thus, the victim was no longer an invitee, and the dangers should have been apparent. There was no liability.

The legal term for ignoring apparent dangers is contributory negligence and is defined as "Conduct on the part of the plaintiff, contributing as a legal cause to the harm he has suffered, which falls below the standard to which he is required to conform for his own protection" (Restatement of Torts, 463). In most jurisdictions, when contributory negligence has been established, the plaintiff will be denied recovery even though the defendant's negligence may have also played a substantial role in causing the injury (Van der Smissen 1975).

The case of Heagy v. City and County of Denver illustrates the application of contributory negligence as well as other aspects of negligence theory. In this case, a fisherman died when his boat was swamped by high winds on Eleven-Mile Reservoir in Park County, Colorado. Plaintiffs alleged that the city had been negligent in not providing adequate rescue facilities. The accident occurred in October, after the normal recreational use season, there was only one patrolman present, and he was working on a special maintenance assignment. The patrolman attempted to rescue the victim, but the severe weather conditions prevented him from reaching the victim before the victim died. In its decision, the court held that the plaintiffs had failed to establish a duty on the part of the defendants to provide rescue facilities, and that, even if it was assumed that there was a duty, the plaintiffs failed to establish a breach of duty. In other words, plaintiffs presented no evidence to show that equipment or rescue procedures other than those used would have been more successful under the adverse weather conditions.

Furthermore, the court held that contributory negligence also would have prevented recovery since "It was undisputed that the deceased deliberately defied the ominous weather conditions for two hours." This most certainly was negligent and would have banned plaintiff's recovery even if the defendants had been negligent in the first instance (472.P.2nd.757).

It should be noted that a different standard of care is generally applicable for water hazards open to the public where swimming is not encouraged than in an area where it is.

In areas where swimming is not encouraged, normal hazards are generally held to be apparent. This is illustrated by an Ohio case wherein a boy drowned after he fell into a pond maintained by a city in a public park (Sailor v. Columbus, 23 Ohio L Abs. 417. 1936). The court stated, "We are unable to hold as a matter of law that a nuisance is created by the maintenance of a pond in a public playground without the erection of guards or barriers or without the supervision of guards, or without the posting of signs or signals of warning. Neither do we believe that a nuisance is created or maintained when a walk is constructed around the shore of a lake, in close proximity to the water, without any wall or railing." This finding has significance for high country reservoirs since swimming is not usually encouraged due to the cold temperature of the water.

A similar finding was reached in Robbins v. Omaha (100 Neb. 439, 160 NW 749. 1916) where a boy drowned in a lake located in a public park. The court stated that a lake in a park, whether artificial or not, did not itself constitute a nuisance and that the city was no more negligent in maintaining an artificial pond unfenced and unguarded than it would be in leaving a river front so exposed.

However, there are exceptions to the general rule established in the preceding cases. In Williams v. Morristown (32 Tenn. App. 274, 222 S.W. 2nd 607. 1949), the court ruled that a reservoir was an attractive nuisance and awarded damages to the parents of a girl who fell in an drowned. The reservoir was owned by a city and was unfenced, and there were no warning signs.

A higher standard of care is imposed in areas where swimming is encouraged. In addition to being required to exercise reasonable care, the landowner or proprietor has the duty to have in attendance some suitable person with the necessary apparatus to effect rescues and save those who may meet with accidents when the character and conditions of the area are such that deep water and other hazards may cause danger to bathers (8A. L.R., 2nd, 1958). The need for this protection is illustrated by the case of Ward v. United States (208 F. Supp. 118. 1962) in which the Federal Government was found liable for the drowning of a teenage girl in Lake Hasty near John Martin Reservoir in Bent County, Colorado. The girl's drowning was caused at least in part by several boys repeatedly dunking her. The swimming area was leased to the Southeastern Colorado Recreation Association, and the lease stipulated that the Federal Government would not be liable for any damages which occurred on the property. The court nevertheless found the government liable and based this liability upon the fact that no lifeguards were present. The court stated that "...when it is reasonably probable that the antics flowing from the unleashed energy and extravagance of youth may result in serious bodily injury, as in swimming areas, a basis exists for finding that the negligent lack of supervision is the proximate cause of injury: (Ward v. U.S., 208 F.Supp.118, 1962). A similar decision was reached in the case of Longmont v. Swearingen (81 Colo. 246,254P.1000, 1927) in which the City of Longmont was found liable for the drowning of a boy in a swimming pool that it operated. The court ruled that the proximate cause of death was the fact that no lifeguards were present at the time of the tragedy.

In view of the fact that many reservoirs of the Colorado Front Range are government owned, it is necessary to review the doctrine of governmental immunity. The doctrine has been successfully invoked in many cases to shield a government entity from liability for an injury caused by an alleged negligence. The doctrine stems from the cliche that "the king can do no wrong" but its basis in modern times has been fear of fiscal uncertainty along with potentially undesirable deterrents upon governmental functions.

However, in recent years there has been a pronounced trend toward abrogating the doctrine both through judicial and legislative actions (Van der Smissen 1975). In Colorado, the legislature enacted the Colorado Governmental Immunity Act in 1971. This act applies to all public entities including the state, counties, cities, schools, etc., and states that the operation of swimming and park and recreation facilities are not shielded by government immunity (Colo. Rev. Stat., 1973, 24-10-101 et. seq.).

The Federal Government is clearly subject to liability for injuries caused by an act of negligence. In 1946, Congress passed the Federal Torts Claims Act which provides that "The United States shall be liable, respecting the provisions of this title relating to tort claims, in the same manner and to the same extent as a private individual under the same circumstances." (28U.S.C., S2074).

Thus, provision of recreation opportunities by both private and public entities involves a duty to protect the recreationists that might utilize the reservoirs. Such a duty is to carry on and allow activities with reasonable care for the safety of the visitors, but only if the entity providing the recreation opportunity expects that the visitors will not discover or realize the hazard or will fail to protect themselves against such hazards. Such duties should be identified in cooperation with an attorney representing the entity providing the recreation opportunity especially if such activities as swimming are to be provided.

It seems possible that the provider of a recreation opportunity could minimize such liability problems if reservoirs with hazards such as cliffs or rock outcrops were eliminated from consideration as feasible alternative reservoirs. If such reservoirs are not eliminated as infeasible for recreational development, then it would seem prudent to take every precaution to identify and warn the visitor of hazards at the reservoir. Such actions would be advisable at any recreation reservoir but especially at reservoirs with extreme hazards.

Physical Considerations

Access Type

The distribution systems allowing access to high mountain reservoirs of the Colorado Front Range vary from paved and well-maintained dirt or gravel roads to primitive and four-wheel drive roads to hiking trails. Group I reservoir users prefer the easy access afforded by paved and well-maintained unpaved roads. Group II reservoir users prefer road access of some type, but good maintenance does not seem to be needed since Group II users utilize even primitive and four-wheel drive roads. Group III reservoir users prefer hiking-trail access to reservoirs.

Thus, if the planning objective is to provide Group III opportunities in an area, alternative reservoirs having paved-road access or well-maintained-road access would be screened out as infeasible for such development. However, there may be instances in which an alternative reservoir has road access but can be converted to a hike-in situation by such actions as blocking the road at some point to prohibit vehicular access. If this is possible, then the alternative reservoir might be thought of at this point in the decision-making process as feasible for Group III development.

A reservoir having hike-in access should not necessarily be judged as infeasible for Group I or Group II development since it may be possible to construct a road to the reservoir. However, with all other things being equal, a reservoir with some type of road access would rank higher than a trail-access reservoir for Group I or Group II development because of the potential cost involved in constructing a road to the trail-access reservoir.

Cost of development will be addressed later, but it can be seen that cost will play an important role in ranking feasible development alternatives.

In summary, feasible alternative reservoirs for Group I development should have access allowed by paved roads or at least well-maintained unpaved roads. Group II alternative reservoirs judged as feasible should have road access of some kind, but the access should not be so easy that Group I reservoir users begin to take advantage of the opportunity in great numbers. Such a situation could result in increased demand by Group I reservoir users to meet their preferences and desires concerning facility development, etc., and could destroy the solitude factor sought by Group II reservoir users. Finally, reservoir alternatives for Group III development should have hiking-trail access since an important part of the recreation experience for Group III reservoir users is hiking and walking in natural surroundings.

Travel Time

Few Colorado Front Range reservoirs are located more remotely than fifty air miles from some population center of the Front Range corridor. (Table 1 presents the high mountain reservoirs inventoried in this study and their distances in air miles from given population centers.) However, the character of the distribution systems of roads and trails causes travel times to these reservoirs to vary from one hour to four or five hours.

In general, Group I reservoir users prefer travel times of one to two hours, and Group II reservoir users prefer travel times of not more than three hours. Group III reservoir users, since part of their excursion takes place on foot, will accept travel

TABLE 1

DISTANCE (APPROXIMATE AIR MILES) OF RESERVOIR FROM FOUR COLORADO POPULATION CENTERS

From Fort Collins:	
Within 20 miles:	Milton-Seaman, Pinewood
Within 30 miles:	Hourglass, Red Feather, Shagwa, Snake, Twin, West, Lake Estes, Estes Park, Lawn, Mary's, Buttonrock, Bellaire, Comanche, Dowdy, Letitia, Nakomis, Parvin, Erie, Fox Acres, Halligan, Hiawatha.
Within 40 miles:	Barnes Meadow, Chambers, Long Draw, Eaton, Panhandle, Peterson, Beaver Park, Bluebird, Brainard, Gold, Isabelle, Pear, Long, Left Hand, Sand Beach, Red Deer, Tumbleson, Glacier.
Within 50 miles:	Joe Wright, Zimmerman, Albion, Barker Meadows, Goose, Groen Lakes, Gross, Island, Silver, Skyscraper, Jasper, Kossler, Lakewood, LosLagos, Manchester.
From Denver:	
Within 20 miles:	Evergreen, Hiwan.
Within 30 miles:	Barker Meadows, Gross, Kossler, Lakewood, Manchester, Beaver Brook 1&2, Crystal Lake, Harris Park.
Within 40 miles:	Beaver Park, Brainard, Buttonrock, Gold, Isabelle, Left Hand, Long, Longmont, Tumbleson, Albion, Glacier, Goose, Green Lakes, Island, Jasper, Mammoth Creek, Silver, Skyscraper, Altura, Cabin Creeks, Chicago Creek, Chinns, Clear Creek, Georgetown, Green Lake, Loch Lomond, Urads, Perry Park, Baker, Jefferson, Bayou Salado, Michigans, Wellington.
Within 50 miles:	Lake Estes, Estes Park, Pinewood, Mary's, Bluebird, Pear, Sand Beach, Red Deer, Lininger, Aspen, Glen Park, Monument Res., Manitou Park, Terryall, Northfield 1,2,4, Rampart.
From Colorado Springs:	
Within 20 miles:	Aspen, Bigtooth, Crystal Creek, Glen Park, Lake Moraine, Monument Res., Mesa #1, N. Catamount, S. Catamount, Northfield 1,2,4, Rampart, Palmer, Wilson (C.S.#3), Bighorn (C.S.#7),, Mason (C.S.#4), McReynolds (C.S.#5), C.S.#2, Lake George, Cripple Creek 1,2, Burgess #1, Penrose-Monument, Pringtime, Skagway, Bison, Perry Park.
Within 30 miles:	Wright's, Manitou Park.
Within 40 miles:	Florence.
Within 50 miles:	Tarryall, Wellington.
From Pueblo:	
Within 30 miles:	Florence, San Isabel
Within 40 miles:	Stratton, Penrose-Rosemont, Pringtome, Bison, Skagway.
Within 50 miles:	Bigtooth, Lake Moraine, Crystal Creek, Mesa #1, Palmer, S. Catamount, Wilson (C.S.#8), Craeger, J.M., McKinley, Montez #2,3, Murray, Wolf, Roach, Deweece, Wright's.
Over 50 miles:	Butte, Montez (Moyer), Sierra Blanca, Manitou Park, Monument Lake, North Russell.

time of up to four hours. However, it is uncertain just how absolute these preferences for given travel times may be. For instance, Group I reservoir users might possibly accept travel times somewhat in excess of two hours if there is an assurance of a destination that meets their needs. Likewise, Group II reservoir users might accept travel times greater than three hours if the destination reservoir could be anticipated to provide the solitude this user group seeks. Thus, although there is no hard evidence to support the statement, it seems possible that each user group would be willing to travel somewhat longer than their stated preferences if the reservoir destination could be expected to meet their needs. Some support for this theory may be found in our "willingness to pay data." Recreationists say they would be willing to pay more for a recreation experience at a reservoir meeting their stated need.

Facilities/Space, Slope and Soils

The level of services desired at a recreation reservoir varies between reservoir user groups, and depending upon the selected reservoir user group, alternative reservoirs may be filtered from consideration if adequate space, slope and/or soil conditions do not exist to accommodate the facilities desired. Adequate space with slopes of 8 percent or less with well to moderately-well drained soil of a sandy loam texture appears best suited for handling the types of recreational use anticipated at reservoirs (Montgomery and Edminster 1974). Such situations would do much to reduce land and water disruptions caused by grading, leveling, erosions, etc.

Reservoirs developed to provide opportunities for Group I users will require more level space than reservoirs developed for either Group II or Group III users because of the level of services desired by Group I reservoir users and the fact that Group I reservoirs are likely to have higher visitation rates (57 users/day average) than Group II (20 users/day average) or Group III (10 users/day average). Group I reservoir users desire extensive facility development including parking sites, camping sites, toilets, trash cans, picnic tables, grills, firewood and potable water. Using a standard of 3.5 people per vehicle, Group I reservoirs will require a minimum of fifteen parking sites which are large enough to allow maneuvering of camper-trailers since many Group I campgrounds will require a minimum of fifteen camping sites (3.5 people per camping unit), each with a picnic table, a trash can, a firegrill and firewood, an adjacent parking site plus potable water, if possible, and two toilets easily accessible from all camping sites. Finally, a minimum of five acres (3 camping units per acre) of level space will be required at alternative reservoirs proposed for Group I development so as to allow space to accommodate the desired facilities.

Group II reservoir users desire only moderate facility development which would include toilets, picnic tables, firegrills, and trash cans. A minimum of two acres of level space will be required to accommodate six camping sites, each with a picnic table, firegrill and trash can. One toilet in the campground should be sufficient to handle the expected number of visitors. Group II reservoir users do not require designated parking sites, but since this group comes to the reservoir by vehicle, some pull-off parking or a parking lot will have to be provided.

Reservoirs developed for Group III users will require the least amount of level space and only limited facility development. Approximately one acre of level space should be sufficient to accommodate the expected number of visitors, and one toilet and two or three trash cans are the only facilities needed or desired.

It should be noted that the preceding paragraphs have dealt only with the average number of visitors to be expected at a recreation reservoir and with the minimum amount of space and number of facilities required to accommodate the reservoir visitors. These values will obviously change somewhat if development for peak periods of use is considered. Such factors are not addressed here, but are critical to planning, since above-average visitation for extended periods could lead to deterioration of the area and, consequently, to deterioration of the recreation experience.

Biological Considerations

Fishery Capability

Approximately three-fourths of all reservoir users are fishermen, but the importance of fishing to the entire recreation experience varies among reservoir user groups. For example, 70 percent of Group I reservoir users rated fishing as their most important activity, 54 percent of Group II users rated it as their most important activity, but fishing was rated as the most important activity by only 13 percent of Group III reservoir users. Thus, reservoir fishery capability becomes significantly more important when the planning objective is to provide Group I or Group II opportunities at reservoirs.

Research indicates that most of the reservoirs of the Colorado Front Range can support cold-water fisheries (McAfee 1976). However, drawdown and refill practices tend to mitigate against realization of the full fishery potential of these high mountain reservoirs. Even with drawdown, some reservoirs have better fisheries potential than others. Reservoirs proposed to be developed for Group I or Group II users should be located on a perennial stream which could provide refuge during drawdown, spawning habitat, and protection against potential winterkill. Drawdown, should be timed so as not to interfere with fish spawning since current drawdown practices cause fall-spawning fish to utilize the pre-impoundment channel for spawning, and refill following drawdown can drop silt into this channel, smothering fish embryos present there. Moreover, drawdown and refill should also be timed so as to guard against drying or freezing of the reservoir substrate, which can lead to loss of fish-food organisms. Detailed below are a number of considerations required when evaluating a prospective Group I or Group II reservoir from the standpoint of recreation fishery capability.

In addition to the factors discussed in the previous paragraphs, other characteristics of the reservoir and its surrounding environment may be important in determining the level of fishery capability. The characteristics that are discussed in the following paragraphs deal primarily with the productivity of reservoir habitats, since the food chain in a reservoir is nearly as important to fishery potential and capability as refugia, spawning habitat, and absence of winterkill.

Edaphic factors are very important in determining the production potential of a lake or reservoir (Pawson 1939; Sparrow 1966). Solubility, erosivity and chemical composition of the geologic material in the drainage basin are important in controlling the amount and nature of inorganic nutrients in the water and the type of substrate that lines the bottom. Nutrients are essential for the photosynthetic processes which support the food chain, and the composition of the bottom plays an important role in determining the species in and the densities of bottom-dwelling communities. A reservoir such as Idaho Springs, which is in a barren granitic basin, might be expected to be less fertile than one in an area of well-developed soils such as Eaton reservoir (McAfee 1976).

Edaphic effects on bottom-dwelling communities indirectly influence the fish populations, since some taxa of invertebrates are more available to fish than others. Thus, a reservoir such as Eaton, which has a large percentage of burrowing Tubificidae that are often unavailable to fish, might be expected to support fewer fish than a reservoir such as Comanche reservoir, which has many available Tendipedidae.

Other factors are less significant than the basic edaphic character of the watershed but may still be important in determining the nature of the water and bottom substrate. The type of terrestrial vegetation influences the amount, type and distribution of organic detritus in the lake or reservoir basin (Edmondson 1957) and may also determine which nutrients are leached from the soil and which are retained by plant growth (Robertson 1954). The presence of environmental disturbances such as the burn in the drainage basin of Comanche reservoir and the floating limbs in a reservoir such as Eaton might also be expected to affect the water. Fredrikson (1971) and Likens et al. (1969) reported that dissolved-ion loss from the soil was increased by clearing of the forest land and burning of the wood. Moreover, the turbid water that is often produced by such disturbances can also reduce the effectiveness of photosynthetic organisms (Murphy 1962).

The morphometry of a lake or reservoir basin also exerts an influence upon the productivity of that body (Rawson 1952). A basin with very steep side slopes will have a small littoral zone, and the productivity usually associated with that area will be greatly restricted (Berg 1938). Steep-sided reservoirs also do not accumulate sediment in places where aquatic plants can grow, but such situations do exist in reservoirs with more-gently-sloping sides (Peltier and Welch 1970). The higher primary productivity value of Idaho Springs reservoir might be a result of the fairly extensive littoral zone at that reservoir (McAfee 1976).

Further, mean depth is often important in determining the efficiency of energy transfer within the food chain. Equal amounts of volumetrically-expressed photosynthesis from two different reservoirs will have equal effectiveness in the food web only if the two bodies of water have similar mean depths (Stewart 1967). This factor might explain why, with other things being equal, productivity is higher in shallow bodies of water than in deeper reservoirs (McAfee 1976).

Climatic factors are another major group of influences that have an effect upon fishery capability. The most important effects of climate are upon temperature of water and upon the duration of temperatures promoting the growth of aquatic plants and animals (Efford 1967; Hall 1964; Rawson 1942; Talling 1966; Wilson 1939). Within the tolerance limits of a species, a higher temperature will usually cause faster growth and onset of maturity and higher rates of production. Thus, reservoirs with climatic conditions that would tend to make the water in the reservoir warmer would be expected to be more productive than reservoirs with climatic conditions that would lead to colder water temperatures.

Another aspect of water temperature, climatic factors and productivity is thermal stratification of the water body. Stratification is largely controlled by climatic factors and is important in determining the distribution of heat, nutrients and plant and animal life within a body of water. Stratification, when it occurs, may limit production by trapping nutrients in the hypolimnion where they are unavailable to the autotrophs present in the epilimnion. Such a situation may persist until the spring or fall turnover when the water of the reservoir is thoroughly mixed.

Climate is also responsible for variations in insolation which may be responsible for variations in photosynthesis (Goldman 1960; Kerekes 1974; Robertson 1954; Russell-Hunter 1970). Differences in insolation become significant even in small regions if one area is consistently cloudy while another is clear. Differences in insolation and productivity may also arise in situations in which one reservoir is located in a steep-sided basin or canyon and receives only an average of ten or eleven hours of direct sunlight in a day while another reservoir might be located in an open area and receives an average of sixteen hours of direct sunlight in a day.

Wind is another important climatic factor influencing productivity of reservoirs. Wind and wind-induced currents are instrumental in transporting and distributing heat, nutrients, dissolved gases and particulate matter both horizontally and vertically within a body of water (Small 1963). Wind also affects the shoreline and its ability to support life (Boyd 1971; Wilson 1939). Pounding by waves may severely limit the number of species which can establish themselves on a shoreline. This situation, much like the effect of steep-sided shorelines, limits the productivity of a reservoir and may mitigate against fishery capability.

In summary, our research shows that the following characteristics of a reservoir and its drainage basin would tend to make it better-suited as a fishery:

1. Adequate and suitable spawning habitat.
2. Refugia to protect fish and invertebrates during drawdown.
3. Absence of winterkill.
4. Timing of drawdown and refill of reservoir to prevent drying and/or freezing of substantial areas of the reservoir substrate and to facilitate fish spawning.
5. Water in the reservoir from a fertile rather than a barren watershed.
6. Terrestrial vegetation which contributes debris to the water and allows many nutrients to be leached from the soil.
7. A basin with a gently-sloping side so that a littoral zone with rooted aquatic vegetation can develop.
8. Shallow mean depth so that a large proportion of the reservoir can support photosynthesis.
9. Morphometry which slows complete circulation of the water mass.
10. A relatively high water temperature within the tolerance limits of the desired species.
11. Absence of consistent high winds which cause waves to pound the shorelines.

It is not advocated that, for an alternative reservoir to be feasible for recreational development, all of the above factors should exist at a reservoir, but research has found these factors to be important in ensuring good fishery capability at a reservoir. Thus, the more of these criteria that can be satisfied in selecting, planning, and managing reservoirs for recreation, the better will be the fishery capability of the reservoir.

Complete stabilization of the reservoir would almost certainly improve sport fishing in any of the Front Range reservoirs of Colorado. However, given the existing legal and political situation surrounding water use in Colorado, stabilization of some reservoirs may not be possible at this time. As was mentioned previously, the present research project has as one of its objectives a determination of the physical and legal feasibility of stabilization of water levels at certain reservoirs to benefit recreation, and more will be said about the success of this effort in later pages.

Another objective of the present research effort is to determine if there are other methods besides the stabilization of reservoir water levels that might be employed to improve the potential of the fishery in reservoirs. One method that is explored is the use of artificial substrates to provide fish shelter and habitat for fish-food organisms. The following discussion deals with the potential use of such artificial substrates in high mountain reservoirs of the Colorado Front Range.

Artificial Substrates

Artificial substrates for fish food production may be considered as one alternative or supplement to water stabilization.

Artificial substrates have been used extensively in marine and warm-water fisheries to provide cover for game and forage fish. Artificial substrates have also been used as colonization surfaces for study of macroinvertebrates and microorganisms.

Artificial substrates might be built and installed to provide cover and attachment places for benethic and periphytic macroinvertebrates. If designed to remain in the photosynthetic zone of the reservoir during drawdown and refilling periods, these substrates could escape desiccation and might significantly increase the food available to the fish community.

Before attempting to influence fish food production in high mountain reservoir by use of artificial substrates, the following questions need to be answered.

1. What type of substrate should be used?
2. Where should the substrates be placed?
3. What density of substrates would be necessary to significantly change the food supply in a reservoir?

Following is a literature review undertaken to find answers to these questions.

Three main types of information were found:

1. Descriptions of artificial substrates used for water quality sampling and for attraction of warm-water and marine fishes.
2. Discussions of the reliability of substrates for sampling, including good and bad points, differences between various types of substrates, and factors affecting substrate efficiency.

3. Results of studies of natural substrates in their own environments.

Description of Substrates

Fish attractors. Warm-water anglers have always known that game and pan fish tend to concentrate in areas where cover is available. Fishery managers have exploited this tendency by placing artificial cover in lakes and reservoirs, thereby increasing the probability of success of anglers fishing near the shelters.

Many types of artificial fish cover have been used successfully in warm-water fishing areas:

1. Brush shelters
   a. Forshage (1973) weighted Christmas trees at their bases and arranged them in circular clusters of five to ten trees each.
   b. Virginia Commission of Game and Inland Fisheries (1957) piled brush under pole or plank tables which were 1.2 m from the bottom and measured 3.1 m square.
   c. Brush bundles measuring 1.2 by 1.2 by 1.9 m were installed by Wilbur (1970).
   d. Shelters consisting of large hemlock trees weighted down by rock-filled 275 liter drums were successful (Pierce 1967).
   e. Manges (1959) utilized two types of brush shelters:

one consisted of a log frame with brush held inside by cross poles, while the other was a floating-log shelter with 275 liter drums at each corner.

2. Other shelters

   a. Anderson (1964) and Charles (1967) found that car bodies deposited in the water gave good results.

   b. An evaluation by Wilbur (1970) revealed that each of the following could be used with various degrees of success:

      1. Clay drainage pipes bundled with plastic.
      2. Reefs made from limerock, concrete blocks and sand.
      3. Old car tires.
      4. Water hyacinths in a crib.

   c. Coastal pelagic fishes were attracted and concentrated by use of bright white tent-shaped structures suspended in the water (Kilma and Wickham 1971).

No mention was made of invertebrate colonization of any of these structures except the limestone reefs (Wilbur 1970). However, colonization of most barren underwater surfaces occurs rapidly (Moon 1940); for this reason, barring toxic effects, some sort of invertebrate fauna could be expected on most of these substrates.

Water quality samplers. Water quality samplers are placed in areas such as deep rivers or fast-flowing streams where sampling of the actual substrate is difficult. The macroinvertebrate communities which establish themselves on the artificial substrates can be observed and used as indicators of the quality of the water.

Water quality samplers which have been developed include the following:

1. Scott (1958) used a cube of 0.6m mesh hardware cloth containing sticks, stones, and other types of stable substrate.
2. Various other hardware cloth baskets have been tried by Dickson et al. (1971), Anderson and Mason (1968), and Wenen and Wickliff (1940).
3. A 17.5 cm diameter by 27.5 cm long chromium plated Bar-B-Q basket was filled with 2.65 cm diameter limestone by Mason et al. (1967).
4. Hester and Dendy (1962) developed a sampler consisting of .3 cm masonite cut into squares of two sizes (7.15 and 2.5 cm) placed alternately on a bolt and held in place by two nuts.
5. Hester and Dendy plates were modified in several ways by adding more plates and varying the spacing between plates (Fullner 1971).
6. Turner (1947) used boards 30 by 15 by 2.5 cm set 5 cm apart by means of brass bolts, nuts, washers and screws.
7. Moon (1940) placed square iron frames laced with netting on the bottom of the water body to be sampled.
8. Five-cm glass squares with roughened surfaces were paired with wood blocks during a study by Cooke (1956).
9. Hilsenhoff (1969) shaped galvanized iron to form a cylinder 12.7 cm in diameter. He put hardware cloth inside and

mounted the sampler on concrete.

10. Various samplers utilizing microscope slides in different ways have been designed by Bissonnette (1930), Cooke (1956), and Yount (1956).

All of the above devices are colonized by macroinvertebrates to a greater or lesser degree, and most would be candidates for a substrate designed for fish food production.

Discussion of Substrate Characteristics

The individuals who developed and used the artificial substrates listed above made many observations of their good and bad points and relationships to the physical and biological surroundings. There is also some information on comparisons between two or more substrates. Some of the results are outlined below:

1. Good and bad points
   a. Dickson et al. (1970) found that basket-type samplers collected macroinvertebrates generally considered as fish food.
   b. Hilsenhoff (1969) found that debris accumulation in the sampler was a problem; he also observed that most insects quickly left a sampler when it was disturbed.
   c. Mason et al. (1973) showed that baskets touching the bottom accumulated greater amounts of sediment than those at the surface.
   c. A major difficulty encountered by Manges (1959) was in marking brush shelters for recognition from the surface.

e. Twenty-three m. annual drawdown and steep shoreline made installation and maintenance of brush shelters difficult because desirable locations were not inundated during ice cover (Pierce 1967). In addition, drawdown caused an annual exposure of the structures, which was considered undesirable.

2. Relationships to physical and biological surroundings

a. Mason et al. (1967) found that exposure of a limestone-filled basket sampler for six weeks at a 1.5 m depth was adequate to collect macroinvertebrates that cling or adhere to rocks in a large river. They also observed that samplers placed in the euphotic zone collected more and a larger variety of invertebrates.

b. Anderson and Mason (1968) discovered that a basket sampler collected more organisms in warmer water.

c. Scott (1958) showed that brush boxes in fast water supported more organisms than those in slow water.

d. Manges (1959) concluded that placement of brush shelters with regard to physiographic features (i.e., in coves rather than on main channel shorelines) was of more importance than depth, spacing, or nature and slope of the bottom.

e. Mason et al. (1973) found that some species of macroinvertebrates were most responsive to the depth of water quality samplers, while some were affected more by length of sampler exposure.

f. Basket samplers placed in two ecologically-similar areas by Dickson et al. (1971) yielded significantly different results due to the patchiness of macro-invertebrates in aquatic environments.

g. Vogele and Rainwater (1975) found that spotted bass preferred brush shelters, largemouth bass preferred them only during the nesting period, and smallmouth bass showed no preference for shelters.

h. Black crappie utilized brush shelters to a greater extent than did any other species, and shelters in deeper water (2.6-3.2m) were used by more fish than those in 1.5 m of water (Virginia Commission of Game and Inland Fisheries 1957).

i. Other studies showed that brush shelters produced a greater concentration of game fish than other types of fish attractors (Wilbur 1970), that larger brush units were more attractive to game and pan fish (Manges 1959), and that fish attractors at or near the upper level of the thermocline were utilized more than those within the thermocline (Charles 1967).

j. Cooke (1956) concluded that the method of exposing the substrate and the type of substrate varied with the type of habitat and organisms studied and with the anticipated effect of substrate materials on the population.

3. Comparisons of substrates:

a. Mason et al. (1973) found that baskets with 5 cm limestone spheres collected the same number but different types of invertebrates than did baskets with porcelain spheres. They also found that hardwood multiplates collected more invertebrates than similar porcelain multiplates and that baskets collected more and a greater diversity of invertebrates than either type of multiplate.

b. Fullner (1971) showed that a basket sampler provided about 0.3 m^2 of surface for colonization by macro-invertebrates, while the Hester-Dendy multiplate had only .17 m^2. He also concluded that plates collect Chironomidae better than baskets but do not collect as many Trichoptera and Ephemeroptera.

Most of the substrates discussed above were tested and used in environments different from those in high mountain reservoirs. However, the observations give some identification of the types of problems which may be encountered and the many variables which must be considered before artificial substrates are used to enhance food production in high mountain reservoirs.

Natural Substrates

Many studies of natural aquatic substrates and the invertebrate fauna that inhabit them have been completed. Again, must of the work has taken place in environments other than high mountain reservoirs. Following are examples of the many kinds of information which are available, and which might be helpful in making decisions concerning uses and placement of artificial substrates:

1. The diversity of macroinvertebrates increases from less stable substrates to those that combine stability and protection.
2. *Scirpus* (a rooted aquatic plant) does not support a wide variety of invertebrates, but it supports a greater number than either *Potamogetan* or *Cladophora*.
3. Substrate preference is species specific.
4. The relationship between rate of oxygen consumption and substrate is a possible cause for selection of a particular bottom type by a given macroinvertebrate.
5. Macroclimate of chemical gradients is very important in determining species distribution.
6. A concentration zone occurred in the upper profundal and lower sublittoral regions during summer; the total number of invertebrates per unit area of bottom declined sharply above and below this zone.
7. The bottom type with the most organic matter had the fewest macroinvertebrates.
8. The density of invertebrates was lowest among loose small stones and small stones mixed with gravel.
9. The 0.5 m depth was most productive; the 1.9 m depth was least productive.

In addition, studies done in many natural environments have shown that fish often practice preferential feeding and may also only feed in certain areas or at certain depths in a body of water.

No counterparts to the above statements were found for the cold-water mountain reservoir of our study area. However, the ecological principles are the same. There are many factors that help determine where invertebrates live and whether they will be consumed by fish; these must be considered if artificial substrates are to attract fauna which will be utilized as food by fish in mountain reservoirs.

Conclusion

Artificial substrates have been used successfully as fish attractors and as water quality samplers. Workers who have used artificial substrates in these ways have noted the following important variables:

1. Different substrates attract different types of macroinvertebrates and microorganisms.
2. Substrates vary in density of colonization of invertebrates.
3. Substrate efficiency in invertebrate community development and fish attraction varies with placement in the body of water and with physical and chemical properties of the water.
4. Some species of fish are attracted to substrates; others are not.
5. Substrates are subject to disturbances from debris, waves and other movements.

Studies done in natural habitats indicate many factors which should be considered in any effort to produce fish food on artificial substrates:

1. Density and species of macroinvertebrates on a given substrate vary with organic matter content, stability, and physical characteristics of the substrate, as well as with depth of the substrate and the chemical gradients surrounding it.
2. Some types and shapes of plants support greater numbers and diversity of macroinvertebrates than others.
3. Fish species vary in their food preferences and feeding habitats.

Although much of the information in this review was collected from warm rather than cold water ecosystems, it shows that many elements must be considered in designing and installing an artificial substrate to increase food supplies for fish in high mountain reservoirs. The most important of these factors are listed below:

1. The substrate must be colonized by macroinvertebrates which fish will consume as food.
2. The substrate must be attractive to the fish and placed where they will utilize it.
3. The substrate must be designed and installed so that it does not accumulate debris or receive a great deal of wave action.

These provide starting points for further research to determine what types of substrate and which areas of placement are best suited to the biota and physical and chemical conditions of high mountain reservoirs. After this is accomplished, density of substrates needed to significantly influence the size of the food supply in the lake can be determined experimentally, and an alternative management technique may be available.

Shading and Screening

Although the present research effort did not deal directly with shading and screening at campgrounds, the investigations of others (Lime 1971; Cordell & Sykes 1969; Cordell & James 1972) indicate that these factors are important aspects of visitor satisfaction. As general guidelines, Cordell and James (1972) have suggested that canopy closure of 60 to 80 percent produces adequate shading. Shading is present at most mountain reservoirs in Colorado except in the alpine above tree line and in the parks. Vegetation 3 to 7 feet high provides adequate screening. Screening factors may not be widely found in the Colorado Front Range, but some screeming from adjacent camping sites would appear desirable when planning recreation opportunities at high mountain reservoirs.

From the standpoint of aesthetics, shading and screening are probably important to all reservoir user groups since aesthetic recreation areas are universal desires (Aukerman 1975). However, the screening factor is especially significant to Group II reservoir users because of their solitude orientation.

Cost Considerations

Cost information may be used in at least two ways in the decision making process. First, cost of development and maintenance may serve as the final preliminary screening mechanism for alternative reservoirs proposed for development to meet the needs of a given reservoir user group. For example, the amount of grading, leveling, road building, maintenance, etc., required at a given reservoir may prove too costly in view of budget to be considered a feasible alternative. Where budget it not a problem, such an alternative would at least be ranked lower in development potential than an alternative where the degree of grading, road building, etc. is less. Thus, cost information can be utilized to eliminate alternative reservoirs as infeasible due to the high cost of development and maintenance, and to budget constraints. Such information can also be used to rank development alternatives when budget constraints are not a problem.

Cost figures for development and maintenance have not been given due to regional and local differences, and constant changes in cost figures. Each agency or individual should provide the latest figures for its decision making, planning and development of reservoirs for recreation.

One possible way to defray the expense of developing and maintaining sites is to charge user fees. Our research shows that approximately 1/2 of all reservoir users would pay up to $2 a day for recreation use of reservoirs. Importantly, a larger percent of Group I users would be willing to pay than would Group II or III. Group I users are the ones demanding additional and more expensive facilities, and might expect to have to pay more. Yet research and management practice indicates that what people say they will pay and what they actually pay are often two different things. If the site needs are met, users may rapidly accept much higher fees than they said they would pay. Our research set out to determine this, but the idea had to be abandoned due to our inability to get cooperation from water owners to allow us to use or purchase water for research purposes.

Summary

Step II is intended to be a preliminary screening process to identify those alternative reservoirs that are feasible for development to meet the needs and desires of a given reservoir user group. Feasibility is based upon institutional, physical, biological and cost considerations. Moreover, infeasible alternatives relative to one reservoir user group can be re-evaluated in relation to the desires and preferences of a second or third best reservoir user group, and in doing so, each reservoir user group can be paired with alternative reservoirs suitable for development to meet the needs and desires of that reservoir user group.

Preliminary determination of alternative reservoirs feasible for development to meet the needs of a given reservoir user group provides the basis for evaluating these reservoirs against potential environmental disruptions that research has shown to be associated with that reservoir user group. Step III identifies these potential environmental disruptions and discusses mitigation measures that may be required when developing a reservoir for a certain reservoir user group so as to minimize the potential for adverse environmental impacts to land and water.

STEP III: Evaluation of potential environmental disruptions and mitigation measures possibly needed at reservoirs visited by a given reservoir user group.

All recreational use will result in some alteration of the natural environment. However, the degree of potential environmental disruption varies with the reservoir user group involved, site design considerations, and the existing situations at the prospective reservoirs. This section is not intended to screen out alternative reservoirs proposed to meet the needs of a given reservoir user group since such environmental considerations are at least implied in components of Step II. Rather, this section is meant to identify the potential adverse environmental impacts of each reservoir user group and to present the mitigation measures that may be required to reduce such effects. Two phases in the life of a recreation area--the construction phase and the actual recreational use phase--and two components to the environment--the land and the water components--are of immediate concern here.

Environmental disruption is potentially most severe at Group I reservoirs due to the number of visitors likely and to the extensive development required. During the construction phase, grading and leveling for the necessary facilities will result in such adverse environmental impacts as loss of ground vegetation, felling of trees, soil compaction and increased wind and water erosion potential. Such eventualities can lead to increased water runoff during snowmelt and rainfall, and to possible increases in suspended material and silting in nearby bodies of water. Thus, care should be taken during construction to preserve as much of the natural setting as is possible to maintain aesthetics and environmental quality in general.

Impacts during actual recreational use can closely parallel the conditions created during construction. Further vegetation destruction, soil compaction and forest litter and soil loss can result from utilization of parking spurs, camping sites, toilets, potable water faucets and the many pathways to and from these facilities. Observation at Group I reservoir campgrounds, most without traffic management, reveals that bare ground and erosion are common and that what ground cover exists consists of the hardier grasses and forbs such as agropyron, fireweed, senecio and yarrow. There is little promise of establishing vegetation around, and to or from, intensively used facilities. Hardened surfaces, barriers or signs are appropriate to direct traffic, preserve extant vegetation and soils, and facilitate plant succession.

Recreational use can lead to other adverse effects upon the natural and man-made environment. Human browse extending up to eight feet on nearby trees is a problem often found in Group I reservoir user campgrounds. This could possibly be eliminated or at least reduced through provision of firewood for visitors. Vandalism of picnic tables and toilets may sometimes be a problem in Group I campgrounds. Controlling vandalism requires supervision and/or an educational program. Littering, which is a universal problem, can hopefully be reduced by the provision of adequate numbers of trash cans and a regular trash collection schedule.

Water quality degradation in bodies of water near Group I reservoir user campgrounds can take several forms. For example, erosion from upland campgrounds and roads during construction and recreational use can cause increased suspended material in nearby bodies of water, depending upon the size and slope of the eroding area, its distance to water, and precipitation amounts and duration. If sediment loading is excessive, decreased dissolved oxygen concentrations may result either from the sediment itself, if the material is in a chemically-reduced state or from reduced photosynthesis, if the water becomes turbid due to suspended material. Such increased cloudiness in water might also lead to reduced fish feeding and decreased fishing success. Depending upon the fertility of the eroding soils, excessive nutrients may be carried to the water body enriching the environment and causing algae blooms and allied problems. Finally, material that eventually settles out of suspension may adversely affect the water environment through blanketing and smothering of bottom flora and fauna.

However, disruption on such a large scale is unlikely at Group I reservoirs of the Colorado Front Range. Although the level of development at Group I reservoirs is large when compared to Group II and Group III development, it is still relatively limited in scope when compared to some other recreational developments at very large reservoirs of the Front Range area and the piedmont to the east. Thus, increases in suspended material through land erosion at Group I campgrounds is likely to be of short term and limited significance and is nost likely to result in the rather severe impacts discussed above. Good soil and vegetation conservation practices and proper site design should serve to keep suspended sediment problems to a minimum.

A water quality impace that may become a problem due to the recreation use of Group I campgrounds is bacterial water quality degradation . Research indicates that increased bacterial concentrations in water may occur due to recreational use, but such increases should not be a problem to domestic water suppliers since such increases are not likely to result in a need for increased treatment of water for domestic use (Rosebery 1964; Wagenet and Lawrence 1974; Aukerman and Springer 1975). However, such increases in bacterial concentrations are important if recreationists utilize the raw water for domestic purposes, since the presence of such bacteria means that pathogenic organisms might also be present in the water. Thus, the recreationist utilizing such water for drinking and bathing, risks sickness if pathogenic organisms are in the water. The sources of these organisms in water might be improperly working septic tank toilets (Johnson 1975) or land surfaces immediately adjacent to the water body (Aukerman and Springer 1975). Well-stationed toilets in sufficient number, preferably with concrete vaults, and barriers to keep vehicles well away from the water will do much to reduce the potential for bacteria water quality degradation. The latter consideration is important since many Group I reservoir users camp in motorized campers (Aukerman 1975) with self-contained toilets, and it is known from prior research (Aukerman and Springer 1975) that some motorized campers flush their sewage holding tanks directly into water or onto the ground. Barriers, along with the presence of other campers and an educational program, can minimize such occurrences.

In conclusion, it should be noted that the above factors will not ensure raw water of drinking or bathing quality. Most untreated water in Colorado even in remote areas, is not safe for drinking or bathing without boiling or the addition of purifying chemicals. However, such measures to minimize water quality degradation can ensure that recreational use remains a compatible use of wildland watersheds.

The environmental disruptions to be exptected at reservoirs developed for Group II users will be somewhat the same as those at Group I reservoirs, although on a smaller scale. Depending upon the existing situation, roads may have to be graded and the space for required facilities may have to be leveled; Such actions during construction may again result in loss of ground vegetation and possible loss of trees. Soil erosion can result, producing sediment loads in the water, depending upon the size of the disturbed area, its slope, distance to water and precipitation factors. Such adverse effects can be reduced by taking care to preserve as much of the vegetation and soils as possible. In this case, screening vegetation where extant should be preserved, especially to enhance the feeling of solitude sought by recreationists at Group II reservoirs.

The vegetation likely to persist during the recreational use phase will be the hardy forbs and grasses as at Group I campgrounds, but some moderately-hardy species such as vaccinium and stonecrop may also be present in appreciable numbers. Bare ground and erosion is likely to evolve because of recreational use and might necessitate hardened surfaces or barriers to direct traffic and preserve vegetation and soils.

Human browse on nearby trees in a Group II campground may become a problem; however, such occurrences were not found to be as prevalent in Group II campgrounds as in Group I campgrounds. Likewise, vandalism to facilities is not expected to be a great problem in Group II campgrounds as in Group I campgrounds. However, littering is as prevalent in Group II campgrounds as in Group I campgrounds; the provision of trash cans should reduce this problem.

Water quality degradation due to suspended sediment from land erosion is likely to be of short-term and limited importance if proper soil and vegetation conservation steps are taken. Moreover, bacterial water quality is likely to be maintained at acceptable levels if toilets are provided along with barriers to keep vehicles away from water.

Development of campgrounds for Group III reservoir users is likely to generate limited, if any, environmental disruption. Toilets and trash cans are the only facilities desired, and putting such facilities in place is unlikely to cause significant vegetaion or soil disturbance. Thus, soil erosion and possible water quality degradation during construction are unlikely to occur.

Although some vegetation trampling might occur in Group III campgrounds during the recreational use period, observation indicates that such instances have not resulted in bare ground and erosion. Hardy plant species persist at Group III campgrounds as the most abundant vegetation but can be expected to be accompanied by more fragile species such as paintbrushes and American bistort.

Research has revealed that wildland use by Group III type campers (backpackers) is not likely to result in bacterial water quality degradation even without the provision of toilets (Aukerman and Springer 1975). However, toilets are desired by Group III reservoir users and are needed as added assurance that such incidents do not occur, especially as a result of peak campground use.

The most significant adverse impact associated with Group III reservoir users is potential erosion of access trails. Hardening of trail surfaces and waterbars to channel water off the trails and onto more porous adjacent soils may be required to minimize the trail erosion problem.

In summary, development of high mountain reservoirs to provide recreational opportunities can potentially result in some adverse environmental impacts. However, such occurrences can be minimized through rational site design, and planning the construction of campgrounds to preserve vegetation and soils and to avoid extensive erosion and water quality degradation through sediment loading. Provision of sanitary facilities and barriers can also do much to control human waste deposition and maintain acceptable bacterial water quality levels. Such measures can assure that recreational use of watersheds is and continues to be compatible with other uses.

If the potential for environmental disruptions relative to a given reservoir user group is considered minimal, or if mitigation measures are believed capable of reducing such disturbance, the feasible alternative for a given reservoir user group may be advanced to Step IV of the process. This step deals primarily with the physical and legal capability to control drawdown at reservoirs selected for development to meet the needs of a given reservoir user group. It is the final step in deciding upon appropriate reservoir user groups and feasible alternative reservoirs before final implementation or no action.

STEP IV: Determine the physical and legal feasibility of managing water levels at selected reservoirs to meet recreational needs and enhance recreation opportunities.

Research has found that drawdown at reservoirs may not appreciably detract from the experience of reservoir recreationists (Aukerman 1975). In fact, some recreationists have suggested that drawdown is a positive factor in fishing since fish are concentrated in smaller pools making fishing easier and more successful. However, in the long run, drawdown and refill as presently practiced at high mountain reservoirs could deplete the recreation fishery resource altogether. Drawdown is also presently depleting or eliminating all types of recreation use of reservoirs. Better management of water levels during recreational use periods and during critical times in the life history of fish could do much to enhance the aesthetics and recreation experience of reservoir recreationists, and to promote long-term fishery capability.

Thus, Step IV is intended to evaluate the physical and legal feasibility of managing water levels at selected reservoirs to enhance the recreation opportunities of a given reservoir user group. Such management is of special concern where the planning objective is to provide recreation opportunities for Group I or Group II reservoir users since it is among these two reservoir user groups that fishing activity and fishing success are most important.

It is Step IV in which the feasible alternatives derived from Step II and evaluated against the potential adverse environmental effects outlined in Step III are evaluated for the final time. In the process explained in the following paragraphs, feasible alternative reservoirs proposed to meet the needs and desires of a given reservoir user group are evaluated to determine if water levels can be managed in any of the alternatives while still meeting downstream water demands on time. If the answer is positive for one or a number of alternative reservoirs, then the planner advances to Step V of the framework. If the answer is negative, the planner has a number of options open to him. First, he could decide to take no action to provide recreation opportunities for Group I or Group II reservoir users, the planner might re-evaluate the alternative reservoirs against the desires and preferences of Group III reservoir users if there is a need for Group III opportunities in the area. Third, the planner could proceed to Step V (retaining as the planning objective the provision of opportunities for Group I or Group II reservoir users) and make arrangements with the appropriate authorities to begin an annual stocking program. Or if budget allowed the planner could make arrangements to install artificial substrates in the selected reservoir to enhance fishery capability with or without a stocking program. Fourth, if the original planning objective was to provide recreation opportunities for Group III reservoir users, the planner could again proceed to Step V, without the ability to manage reservoir water levels, and could plan for development of Group III opportunities since fishery capability is of little importance to this reservoir user group. In fact, in planning for Group III development, Step IV could be passed over completely as non-essential were it not for the fact that these reservoir users, like the other two reservoir user groups, prefer an aesthetic recreation area; stabilizing water levels at reservoirs provides a more scenic and aesthetic environment.

Physical Feasibility

The previous steps have described analyses that can be conducted on reservoirs on an individual basis. That is, prior to comparison of several reservoirs as to their suitability for recreational use, reservoirs can be studied individually in order to evaluate their characteristics. This approach, however, is inadequate for determining the feasibility of actually maintaining recreation-conducive storage levels in selected reservoirs. The reason is that these reservoirs, in conjunction with others not selected for recreational use, are indirectly linked together through their common supply of water to downstream agricultural, industrial, and municipal users. To at least some extent, then, the entire river basin "system" must be considered, including both water supply and water demand components.

River Basin Simulation Model

Though it may be possible to "decompose" the large basin-wide system into smaller, quasi-independent parts, the larger scope of this aspect of the problem suggests the need to use a computerized mathematical model for simulating flow and storage allocation within the system. Such a model has been applied to this study. It is a generalized river basin simulation model called SIMYLD, developed by the Texas Water Development Board. The model assumes that storage and flow processes can be represented in terms of a network composed of nodes and links (or arcs). The nodes can be storage points in the system (i.e., reservoirs) or nonstorage points (e.g., tributary inflow and diversion points). The links represent the river reaches, canals, pipelines,etc., between the nodal points. Interbasin transfers can be considered in the model, as well as losses due to evaporation and channel seepage. The latter is considered in an iterative manner, as explained in detail in Appendix I of this report.

Several available models were evaluated for possible use in this study, but SIMYLD was finally judged to be the most suitable one. The following advantages of the model can be listed:

1. The model is conducive to planning purposes in that several consecutive years, in monthly time intervals, under various historical or forecasted hydrologic regimes, can be run. The model is capable of simulating a system with a large number of reservoirs (i.e., 30 or more, depending on the computer core storage available), and appears to be quite fast and efficient, as documented in Appendix I.
2. Though it is basically a simulation model, it does have some internal optimizing capability. The planner/manager can supply numerical priority rankings for specifying which reservoirs are most conducive to recreation use. The model will then determine the optimum year-by-year operating policies, according to these rankings, subject to meeting the given downstream water demand for agricultural, industrial, and municipal purposes.
3. Priority rankings can also be attached to various demand diversion points in the system as an indirect way of including the institutional water rights structure. Though the model has this capability, the case study

documented in Appendix I does not include this aspect. For the case study, actual demand in acre-feet per month is assumed to be specified a priori.

4. In addition to priority rankings, the planner/manager can supply "ideal" operating policies for the reservoirs, which the model will then attempt to meet as closely as possible, according to the given priority rankings. In addition, ideal operating policies can be specified for dry, average, and wet months.
5. Environmental and water quality considerations can also be indirectly included in the model. For example, low flow constraints for maintaining acceptable water quality over certain reaches in the system can be included by simply specifying various lower bounds on channel capacity in the model for those reaches of interest. Several bounds can be selected in order to determine the sensitivity of system performance (e.g., meeting recreation use objectives for certain key reservoirs) to adjustment of these bounds.
6. The model is ideal for analyzing tradeoffs among alternative water uses, and for predicting the impacts of new structures in the system, such as reservoirs and canals.
7. In addition to planning purposes, the model could conceivably be used for actual real-time operation of a given system. The model gives monthly operating guidelines, which could provide valuable information to water

commissioners in charge of reservoir operation.

8. The model has a clear input-output format that should be reasonably comprehensible to the manager/planner.

Data Requirements

In order to use the model, the planner/manager must provide the following data and information:

1. Physical characteristics of the system (i.e., reservoirs and channel capacities, reservoir surface area vs. storage volume curves, channel seepage rate estimates, and the node-linkage configuration of the system).
2. "Ideal" monthly operational criteria for the reservoirs, under dry, average, and wet conditions, as a percentage of maximum capacity.
3. Monthly unregulated inflows to the system.
4. Monthly demands, or priority rankings related to the institutional water rights structure (note: it is interesting that the model can determine optimum water exchange and transfer decisions within the system).
5. Monthly net evaporation rates (i.e., less precipitation).

Most of these data can be obtained from the Colorado Water Data Bank, Colorado Division of Water Resources, State Engineer's Office. Other data can be secured from the National Weather Service and the files of the water commissioner for the river basin under study.

Determining the best configuration of the node-arc system is crucial. The reader is referred to Appendix I for a demonstration of how this can be done for a particular case study. If the system is large and complex, with many reservoirs and canals, it may be necessary to break it into parts or "subsystems." Care must be taken to properly account for linkages between subsystems in order to avoid optimum policies for one subsystem that are somehow severely detrimental to another. The subsystems should probably include all reservoirs and irrigation systems that have been historically linked together by a system of water transfers and exchanges. In some cases it may be possible, as demonstrated in the case study, to aggregate or lump together several reservoirs if precise management of their individual storage levels is not necessary. This can result in considerable savings in computer cost and reduce complexity.

The ideal operational criteria for reservoirs conducive to recreation should be obtained from experts in recreational resources, fisheries, etc. Guidelines provided in this report will help the planner/manager identify the key reservoirs.

Historical data on monthly unregulated inflows are available from the Colorado Water Data Bank. For future planning purposes, it may be desirable to synthetically generate equally-likely inflows using the statistical base of the historical record. For real-time operation, inflow forecasting is required using snow pack information, remote sensing data, and possibly, computerized mathematical models.

The monthly water demands are difficult to estimate from historical records, since, for example, it is impossible to know exactly how much water is actually applied to the fields. It is difficult to forecast demands, particularly agricultural demands, since they depend upon climatological factors, land use changes, irrigation technology, and uncertain future regulations concerning nonpoint source pollution. In the case of uncertain demand estimates, sensitivity analyses can be conducted to ascertain the effect of changes in demand or system performance as related to recreation. It is particularly important that the historical uses of water released from the recreation-conducive reservoirs be clearly identified and quantified.

Monthly net evaporation rates are also difficult to obtain, since there is usually a dearth of available pan evaporation data. Once initial estimates are synthesized, gross evaporation rate may be used as a calibration parameter as discussed in the following paragraphs.

Model Calibration

Before the model can be used for planning and management purposes, there should be some attempt to calibrate and verify the model. The principal data for this task would be historical reservoir storage data, although river flow data can also be used as long as all important contributions to that flow are identified. These data are available from the Colorado Water Data Bank. The model user sets the "ideal" operating criteria at these levels, along with high priority rankings, and procedes to adjust uncertain factors such as evaporation and channel seepage (within reasonable bounds) until a "good" fit is obtained between storage and flow levels computed by the model and actual historical records. Some adjustment of the priority rankings may also be required. Goodness of fit is a rather subjective matter, and depends on the intuition and insight of the planner/manager. The reader is again referred to Appendix I for a demonstration of a calibration procedure.

The model user may also want to go further and perform some model verification analyses. For example, one-half of the historical record could be used for model calibration. This calibrated model could then be used to compute storage and flows during the other half of the historical period, which would then be compared to the observed data.

Management Studies

Once the model has been calibrated and verified to the satisfaction of the planner/manager, the management studies can procede. Assuming that the best reservoirs for recreation purposes have been identified, and ideal operating policies specified, the model can now be used to determine to what extent these ideal policies can be met, while satisfying anticipated downstream demands. Though the relative standing of the reservoir priority rankings may stay the same, their absolute magnitudes will most probably have to be adjusted several times until the best operating policies, from a recreation viewpoint, are determined. Figure 5 gives some indication of the sensitivity of model output to adjustments in the weighting factors, for the particular case study discussed in Appendix I.

The management studies should be conducted with the following factors clearly in mind:

1. Possible dam stability and safety problems if the management policy specifies that a reservoir be maintained too full for too long a period.
2. Low flow constraints for water quality considerations, fisheries, and various recreational uses in the river.
3. High flow constraints during periods when flooding can occur from severe thunderstorm activity.
4. Possible operational limitations of high country reservoirs in mid-winter due to ice blocking outlet works and reducing channel capacities.
5. Legal restrictions to carrying out the kinds of water exchanges and transfers specified by the model, which is discussed in detail in the following section of this report.
6. As long as agricultural water demands are properly accounted for, there should be little adverse effect on agricultural water users "outside" of the subsystem defined for the study. For example, return flows should be little affected, unless there are dramatic changes in irrigation technology.

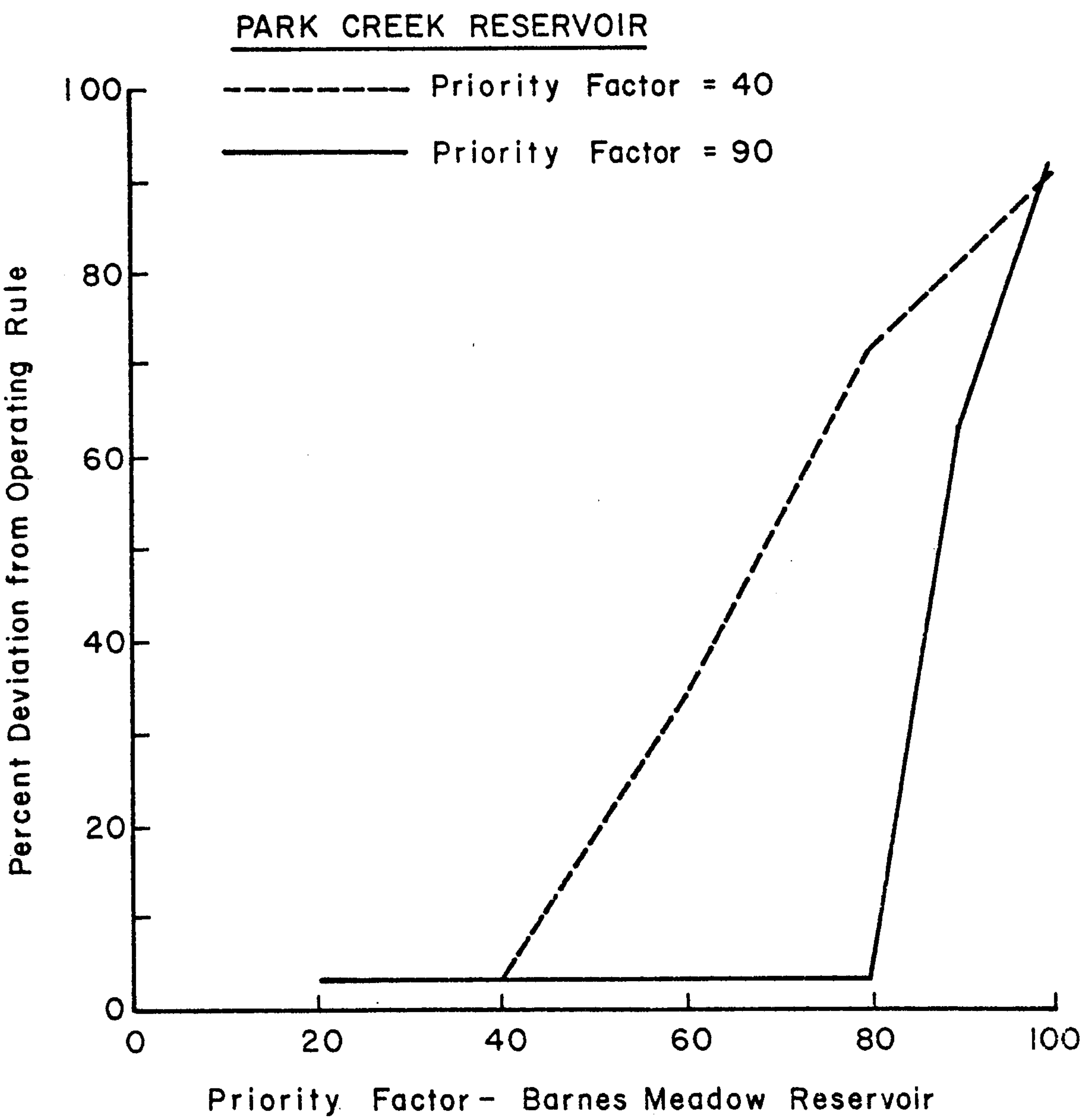


FIGURE 5

SENSITIVITY OF MODEL OUTPUT TO
ADJUSTMENTS IN PRIORITY FACTORS

7. Some consideration should be given to possible difficulties for the water commissioner actually implementing the management policies suggested from the model. They may, for example, require more manpower for operating the reservoirs, the cost of which should be properly considered.

Indications are, from the case study presented in Appendix I, that high country reservoirs can be managed for recreation use least to some extent, without adversely affecting downstream water users. The model results tend to suggest that reservoir filling outside of the current institutional priorities is necessary. Considerable water appears to be unnecessarily held, during peak recreational months, in lower level reservoirs with little recreation potential. Again, these conclusions are based on one limited case study and are highly qualified. It could be argued, however, that the case study selected (a portion of the Cache la Poudre river basin) represents one of the more challenging areas, and gives added weight to the conclusions.

Legal Aspects Associated with Maintaining Water in High Mountain Reservoirs

Most reservoirs in Colorado were constructed to store water which otherwise would not be available at the time of greatest need. Recreational values have been a secondary and usually neglected consideration. In order to evaluate strategies for enhancing the recreational value of high mountain reservoirs, it is necessary to review Colorado water law.

Colorado water law evolved at a time when the only concern was to develop a system which facilitated water use in connection with the economic development of the state. In view of this concern and in consideration of the state's geography, a system of prior appropriation developed. A basic tenet of this system is "First in time, first in right." In other words, the priority of usage relates to the seniority of the water right. Seniority is determined by the decree date, which is simply court recognition of the rank of a water right within the priority system.

Diversion

The basic procedural requirements of obtaining a water right are diversion and application of the water to beneficial use. Definition of these terms has been the subject of a large amount of litigation. The courts have recognized natural overflows during time of high water, and the direct use of water from a stream by cattle as valid appropriations. The Supreme Court held in Town of Genoa v. Westfall that, "The only indispensible requirements are that the appropriator intends to use the waters for a beneficial purpose and actually applies them to that use." This liberal interpretation was not followed, however, in Colorado River Water Conservation District v. Rocky Mountain Power Co., wherein the court held that maintaining a flow of water in a natural stream in order to support a fishery was not an appropriation because it did not entail a physical diversion from the stream. The requirement that a physical diversion take place was codified by the Water Right Determination and Administration Act of 1969, 'Diversion' or 'divert' means removing water from its natural course or location, or controlling water in its natural course or location, by means of a ditch, canal, flume, reservoir, bypass, pipeline, conduit, well, pump, or other structure or device." This restrictive language subsequently gave rise to minimum stream flow legislation which will be discussed below.

Beneficial Use

The Colorado Constitution does not define beneficial use. The Supreme Court has stated, "The term 'beneficial use,' after all, is a question of fact and depends upon the circumstances in each case." As defined by the 1969 Act, "Beneficial use is the use of that amount of water that is reasonable and appropriate under reasonably efficient practices to accomplish without waste the purpose for which the diversion is lawfully made and without limiting the generality of the foregoing, shall include the imooundment of water for recreational purposes, including fishery or wildlife."

Water Storage Rights

There are two basic types of water rights -- direct use and storage. Colorado law provides that a person who desires to construct and maintain a reservoir has the right to store therein any of the unappropriated waters of the state. The amount which can be stored is determined by the capacity of the reservoir and capacity is defined as the amount of water that the reservoir will hold at any one time. The State Engineer has the duty to annually determine the amount of water capacity capable of being safely stored in reservoirs within the state, and it is unlawful to store water in excess of that amount.

A reservoir may be filled only once each year. The courts have held that "Each reservoir shall be decreed its respective priority, and this priority entitles the owner to fill the same once during any one year, up to its capacity, and restricts the right, upon one appropriation, to a single filling for one year." The logic behind this restriction is based upon the fact that "a double filling in effect would give two priorities of the same date and of the same capacity to the same reservoir, on the same appropriation..." There is nothing in the law, however, which restricts the number of appropriations which can be decreed for the same reservoir.

Colorado law also provides that the owners of a reservoir may release stored water into any natural streams and may divert the same out again at any point desired, provided there is due regard to the prior or subsequent rights of others to other waters in said natural streams. The law also provides that due allowance must be made for evaporation and other losses from natural causes, such losses to be determined by the State Engineer. An additional requirement is that water released into a stream not raise the waters thereof above the ordinary high water mark.

Over-Appropriation

The state Constitution also provides that the right to divert water and apply it to a beneficial use shall never be denied. Partly because of this provision, and partly because of the state's semi-arid climate, many rivers and streams have been over-appropriated. In other words, water rights have been obtained on streams which have no unappropriated water remaining. The Poudre River, for example, has water right priorities in excess of 199. There is nowhere near that amount of water available, however, to serve all these rights. During the period 1951 through 1961, priority 100 was served only seven days. The effect of this over-appropriation is that many streams and reservoirs are dried up or reduced to very low levels during the season of peak water use.

Minimum Stream Flows and Lake Levels

One approach to the problems posed by over-appropriation is obtaining decrees for minimum stream flows and lake levels. As was noted earlier, Colorado case law has traditionally been unreceptive to claims for in-stream values and other aesthetic concerns. A major obstacle to court recognition of in-stream values was the general requirement that water be physically diverted from a stream or lake, a requirement illustrated in _Colorado River Water Conservation District v. Rocky Mountain Power Co._ In response to this ruling and public concern for in-stream values, the Colorado legislature enacted Senate Bill 97 in 1973. This legislation eliminates the requirement for a diversion by changing the definition of appropriation to "the application of a certain portion of the waters of the state to a beneficial use." Beneficial use is specifically defined to include appropriation by the State of Colorado of such minimum flows between specific points or levels for and on natural streams and lakes as are required to preserve the natural environment to a reasonable degree. The legislation is apparently limited to natural streams and lakes and would not allow minimum flows or levels with regard to man-made reservoirs.

With authorization provided by Senate Bill 97, the Colorado Water Conservation Board has obtained or filed for minimum stream flows on streams and minimum lake levels on lakes in the state. Obtaining a minimum stream flow decree provides no guarantee that the minimum flow will be achieved. If senior water rights are legally exercised and reduce flow below a minimum level decree which has a junior priority date, there is no basis for the state to take legal action.

Since the minimum stream flow legislation wasn't enacted until 1973, minimum flow decrees are junior to the great majority of water rights, especially along Colorado's eastern slope. The significance of minimum flow decrees is that they are a water right subject to the same protection as other water rights from injury caused by changes in use, diversion and other aspects.

Existing Transfer Mechanisms

Colorado water law recognizes that changing circumstances may require that a water right be changed in its place, timing, or manner of use and/or the point of diversion. Any change in the exercise of a water right, however, must not materially injure the vested rights of either junior or senior water uses. There is no absolute standard which is applied to determine injury; case law indicates that the determination depends upon the facts of each particular case. The facts to be considered cannot include any evidence that the proposed change would produce benefits in excess of the injuries to be suffered; the sole consideration is whether other water users would be substantially injured by the change.

If injury to other users is established, the change may not be approved or conditions may be placed upon the change to prevent injury. Conditions which may be placed on the change include:

--a limitation on the use of the water which is subject to the change, taking into consideration the historic use and the flexibility required by annual climatic differences.

--the relinquishment of part of the decree for which the change is sought or the relinquishment of other decrees owned by the applicant which are used by the applicant in conjunction with the decree for which the change has been requested, if necessary to prevent an enlargement upon the historic use or diminution of return flow to the detriment of other appropriators.

--a time limitation on the diversion of water for which the change is sought in terms of months per year.

--such other conditions as may be necessary to protect the vested rights of others.

As energy development and increased urbanization continue, many water rights will be changed from agricultural to industrial or municipal uses. Even junior minimum flow decrees would have some protection from injury caused by these changes and thus would have some influence on water usage in the state. On streams which are currently not reduced to low levels, obtaining a minimum flow decree would prevent future appropriators from injuring the minimum flow decree. Since most streams along Colorado's Front Range are over-appropriated, the impact of proposed changes in use may be very significant. In those cases the courts are required to impose those conditions which are necessary to prevent injury to vested water rights. Those conditions and limitations may limit or eliminate potential sources of water which might otherwise be available to support minimum stream flows or lake levels.

Exchanges

The ability to divert water stored in a reservoir at any point from the stream in which it was released has contributed to the extensive use of water exchanges. Colorado law provides that, "When the rights of others are not injured thereby, it is lawful for the owner of a reservoir to deliver stored water into a ditch entitled to water or into a public stream to supply appropriations from said stream, and take in exchange therefore from the public stream higher up an equal amount of water, less a reasonable deduction for loss."

Exchanges are made for a number of reasons. One reason is when a ditch company owns a reservoir below any of its ditches. The North Poudre Irrigation Company (NPIC) is a good example. This company owns a reservoir near Timnath, Colorado, which is well downstream from the company's ditches and canals. In order to make use of this water, the company exchanges their water with other companies which have ditches located near the Timnath Reservoir. These other companies, in turn, provide NPIC with water rights they own which are located above the NPIC ditches.

As noted above, exchanges may be adjudicated, and when so recognized by law, the exchanges are protected from injury. Exchanges are often conducted informally, however, and are made on a year-to-year basis. For this reason, water user associations in Colorado have attempted to modify minimum stream flow legislation which they fear would disrupt the exchange system.

The source of their concerns is the fact that an exchange cannot take place if it injures any other water rights, including those that are junior. Thus if a minimum streamflow appropriation is made, an exchange, which had not been adjudicated before the minimum streamflow appropriation was made, could be prevented on the basis that it would injure the minimum streamflow appropriation.

Status of the Poudre River

As was mentioned, the Poudre River is heavily over-appropriated. Water exchanges are made often and many are made informally and on a year-to-year basis. The Colorado Division of Wildlife has recommended a minimum flow of 30 cubic feet per second (cfs), on the river for October through April and 65 cfs for May through September. Concern by water users that these minimum flows might disrupt exchanges ultimately led the Division of Wildlife to withdraw these minimum flow recommendations.

It should be noted that minimum stream and lake level appropriations can only indirectly benefit recreation opportunities in reservoirs. As the language of the legislation indicates, the statute is not directed toward man-made reservoirs. The Colorado Water Conservation Board cannot file for a conservation pool in a reservoir owned, for example, by a municipality or a ditch company. The Board would have to purchase storage space in the reservoir or enter into some type of cooperative arrangement or exchange agreement. Minimum streamflow decrees could benefit the fishery of a reservoir, however, by providing needed flow through and thus prevent stagnation.

Alternative Methods of Providing Water for Recreational Use in High Mountain Reservoirs

Several alternative means of providing water for recreation should be considered in planning for the design and use of existing, new or expanded high mountain reservoirs.

In the case of existing reservoirs, additional water necessary for recreational uses may be acquired through the purchase and transfer of existing rights. However, this alternative is not without its problems. No transfer will be allowed where injury would result to vested water rights. In an over-appropriated river system, such transfers may not reach the desired results. The courts may find it necessary to impose conditions upon the transferred water right so that it cannot be "used" (e.g., to provide a minimum reservoir pool) at a time when it is needed to avoid total reservoir drawdown.

Legal mechanisms, such as plans for augmentation or rules and regulations promulgated by the State Engineer might be available to modify the administration of existing water supplies as to enhance high mountain reservoir use.

In the case of proposed new or expanded reservoirs, water needed for recreational purposes might be obtained through cooperative agreement, by modifications of existing exchange agreements, by expanded use of minimum stream flows, through the use of water quality control laws or water quality management plans, or through cooperative and integrated water quality, water supply, and recreation resource planning.

A detailed discussion of existing legal limitations to providing water for high mountain recreational use and alternatives to existing limitations is contained in Appendix III. A checklist which outlines the major legal questions which should be considered by the recreation planner or manager is set forth on Figures 6 and 7. Use of the checklists in conjunction with the analysis of legal limitations and alternatives in Appendix III should provide the recreation planner or manager with an overview of the legal questions which must be addressed in planning for the use and design of high mountain reservoirs for recreation.

STEP V: Implementation or No Action

In evaluating reservoirs, it is possible to propose development of reservoirs for recreation opportunities which institutional, physical, biological, legal and/or cost (economic or environmental) factors might so constrain as to render all alternatives for recreational development infeasible. If recreational development was found to be impossible, sucn an occurrence obviously would lead to a decision to take no action to provide recreation opportunities at reservoirs.

It is more probable that some alternative reservoir exists with characteristics suitable for development to accommodate some reservoir user group. Thus, the major part of Step V is intended to recap the information organized and evaluated in earlier steps and to provide the basis for final planning on developable reservoirs.

The first need is to re-specify the number of recreationists that can be expected to utilize the reservoir and the number and types of facilities and space that will be required to meet the desires and preferences of the selected reservoir user group. Table 2 serves as a synopsis of the desired facilities and

Figure 6

LEGAL CONSIDERATIONS IN PLANNING FOR THE CONSTRUCTION AND USE OF HIGH MOUNTAIN RESERVOIRS IN COLORADO

1. What are the demands on existing or proposed reservoirs?
    a. Ownership of reservoirs
    b. Ownership of water rights
    c. Nature of storage rights which are decreed to each reservoir
        1) Single fill rights
        2) Historic priority
            a) Appropriation date
            b) Adjudication date
            c) Listing on water rights tabulation--check with Division Engineer
        3) Recent history of reservoir
            a) Drawdown timing--check water commission records
            b) Minimum pool, if any
            c) Minimum stream flow, if any
2. Are there existing agreements or conditions which modify the historic priorities of the existing or planned reservoir?
    a. Formal exchange agreements--check with Water Clerk in Water Court
    b. Informal exchange agreements
        1) Check with Water Commissioner and water users
    c. Conditions attached to water right decrees
        1) Limitation on use
        2) Limitation on time of diversion
        3) Other conditions necessary to protect the vested rights of others
    d. Existing or proposed plans for augmentation
    e. Operating criteria regarding federal reservoirs
        1) Minimum flows
        2) Minimum pools
3. Have municipalities or other water users made any provision for minimum pools or minimum flows in their operating practices concerning their reservoirs
    a. If the reservoir is proposed on federal lands, has the Federal Fish and Wildlife Service been contacted?
    b. If reservoir construction will require dredge and fill operations, has the U.S. Army Corps of Engineers been consulted?
    c. If the reservoir is being financed by federal loans, has the federal agency making such loans considered or attached any conditions concerning reservoir management
    c. Has the state agency responsible for fish and wildlife resources and outdoor recreation been consulted?

4. Has the state filed minimum stream flow claims or received priorities regarding streams or natural lakes near the proposed reservoir?
   a. What are the relative priorities?
   b. Can existing or planned reservoirs make use of decreed minimum stream flows by locating on or adjacent to streams with minimum flows (between decreed points)?
5. Are water rights available for purchase, for transfer and/or exchange in order to provide minimum flows or reservoir levels?
   a. Contact local water users
      1) Conservancy and conservation districts
      2) Large ditch companies
   b. Contact water commissioner and division engineer
   c. Contact realtors and attorneys who deal with water rights
   d. Contact parties to existing exchange agreements
6. Has a regional area-wide planning agency adopted an area-wide water quality management plan?
   a. Has it been approved by the Governor and EPA?
   b. Does it provide for implementation through the regulation of water quantity?
   c. Does it provide for minimum flows or lake or reservoir levels?

FIGURE 7

LEGAL CONSIDERATIONS IN PLANNING FOR THE RECREATIONAL USE AND MAINTENANCE OF HIGH MOUNTAIN RESERVOIRS IN COLORADO

1. What is the nature of planned recreational use?
   a. Swimming encouraged or allowed
   b. Swimming discouraged or prohibited
   c. Other restrictions on use
2. Has the recreational facility been designed to minimize potential liabilities?
   a. What precautions will be taken to discover hidden dangers?
   b. What notice will be given of dangers?
   c. Will intake areas be adequately restricted?
   d. If swimming is encouraged, will adequate supervision be provided?
      1) Lifeguards
      2) Federal government supervision
   e. Are foreseeable dangers apparent?
      1) Are there known hazards to swimmers and divers?
      2) Are signs or other warning devices planned?
   f. Are rescue facilicies planned if boating is allowed?
      . . . if swimming is allowed or encouraged?

required minimum space for each reservoir user group. The Table might be modified depending upon decisions about whether to develop to meet average or peak use.

Closely related to the level of facility development and space required is the need for the formulation of a site design plan and construction plan to minimize vegetation and soil disturbance during grading and leveling for camping sites, parking sites, etc. In cases where budgeting considerations do not allow all desirable development at one time, the planner may have to consider phasing development of recreation opportunities as funds become available, although such considerations are not included in this research.

In cases where it is physically and legally feasible to manage water levels at selected reservoirs, arrangements will have to be made with the appropriate authorities to so manage the water levels at these reservoirs. If it is not physically or legally feasible to manage reservoir water levels, fish and wildlife authorities might be contacted to initiate a fish stocking program if required, or arrangements might be made to install artificial substrates in reservoirs if so warranted.

TABLE 2

DESIRED FACILITIES AND REQUIRED MINIMUM SPACE - BY USER GROUP

	GROUP I[j]	GROUP II[h]	GROUP III
Average # Users/Day	57	20	10
Day-Use	34	11	4
Overnight	23	9	6
Camping Sites[a]	15	6	3
Day-Use	9	3	1
Overnight	6	3	2
Space[b]	5 acres	2 acres	1 acre
Parking Sites	15	6	NA
Day-Use	9	3	
Overnight	6	3	
Space[d]	4500-6000sq.ft.	1800-2400 sq.ft.	
Toilets[e]	2	1	1
Trash Cans[f]	15	6	3
Picnic Tables[f]	15	6	NA
Fire Grills	15	6	NA

[a] = 3.5 people/unit

[b] = 3 units/acre

[c] = 3.5 people/vehicle

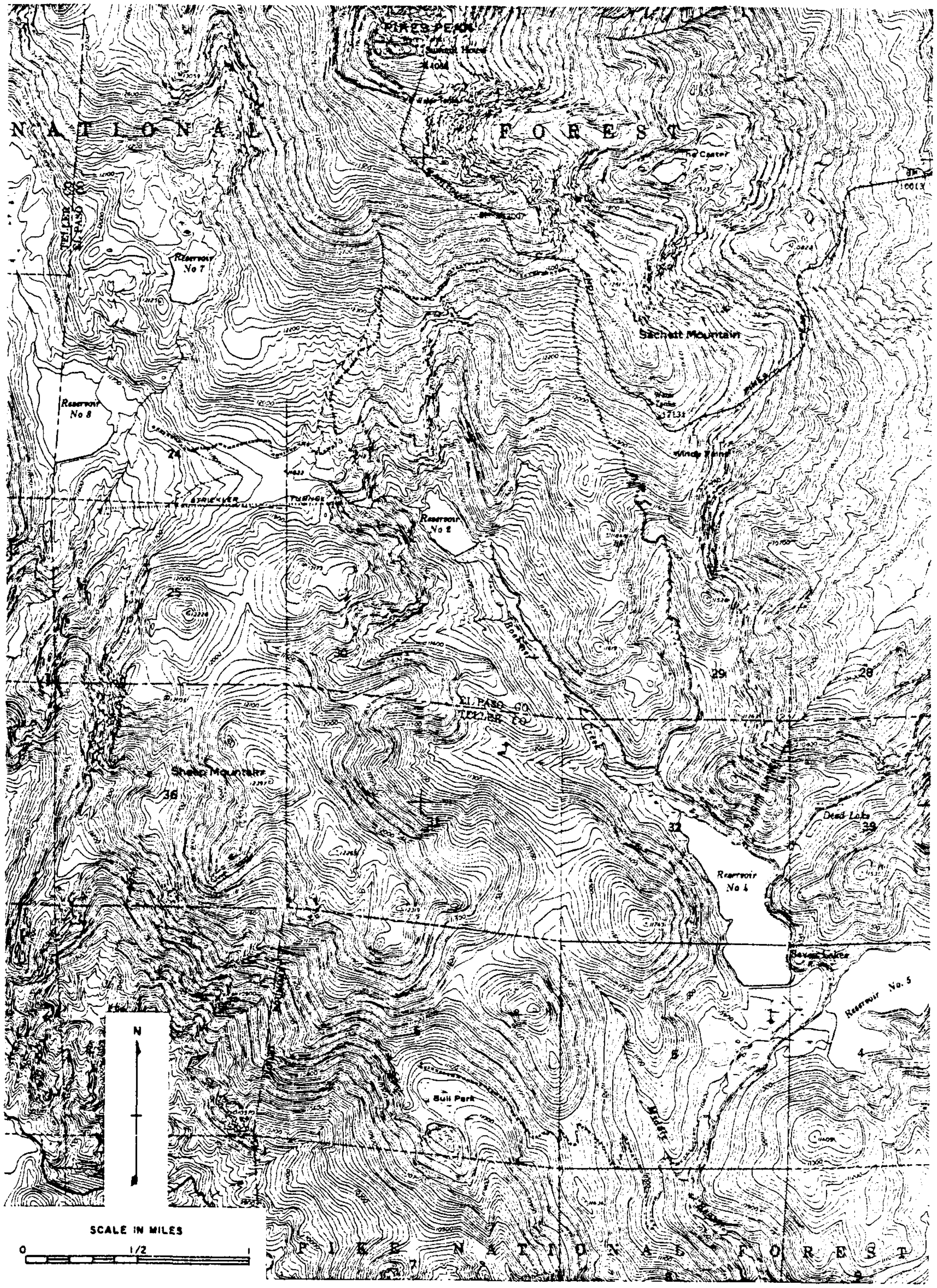
[d] = 300-400 sq. feet parking space (day-use or overnight trailers)

[e] = 1 toilet/50 people

[f] = 1 unit

[g] = potable water (if possible) and firewood are also desired facilities of Group I reservoir users.

[h] = the parking sites of Group II reservoirs do not have to be adjacent to the camping sites, but parking somewhere nearby will be needed since Group II reservoirs must have vehicular access.



CASE STUDY RESERVOIRS
USED IN DECISION MAKING FRAMEWORK

FIGURE 8

EXAMPLE OF THE USE OF THE DECISION-MAKING FRAMEWORK

In order for the reader to more fully comprehend how the process that was described earlier can be utilized in making better informed decisions concerning reservoir recreation, an illustration is presented in the following pages. The reservoirs employed in this example actually exist but are not presently used for outdoor recreation. For the purposes of this example, it is hypothesized that the appropriate authority (a public authority) wishes to develop one or a combination of these reservoirs to provide recreation opportunities. The problem is to decide which reservoir user group(s) needs opportunities in the area and which reservoir(s) has the characteristics best suited to satisfy that need. However, the authors wish to stress that this situation is hypothetical and that the motive for using the reservoirs in this example is only for purposes of illustration and not to generate support for these reservoirs being opened to provide recreation opportunities.

The reservoirs used in this example are Colorado Springs reservoirs numbers 2,4,5,7, and 8. These reservoirs are used for municipal water supply and are located in an area of the Colorado Front Range that is within twenty air miles of Colorado Springs.

STEP I:

Reservoir User Group

The first problem of the planner is to decide what reservoir user group(s) has a need for recreation opportunities within the area west of Colorado Springs. An inventory reveals that there are approximately thirty-three high mountain reservoirs between ten and four hundred surface acres in size within fifty air miles of Colorado Springs (Aukerman, Springer and Judge 1977). Only 21 percent (7) of these reservoirs are open to public outdoor recreation, and those reservoirs allowing public recreation provided for the Group I reservoir user type, all being extensively developed with relatively easy access. Furthermore, at least two large reservoirs, Antero and Eleven-Mile, which are managed by the Colorado Division of Parks and Outdoor Recreation, are located to provide added opportunities for the Group I reservoir user in the area. Clearly, the area to the west of Colorado Springs has a need for recreation opportunities to satisfy both Group II and Group III reservoir users. Thus, in this example, Group I reservoir users will be eliminated from consideration and the desires and preferences of Group II and Group III reservoir users will be evaluated against the ability of the Colorado Springs reservoirs to provide recreation opportunities for at least one of these two reservoir user groups.

Existing Situation

The potentially developable reservoirs used in this example are municipal water reservoirs and are located within twenty air miles of Colorado Springs, Colorado. Three of the reservoirs, C.S.#2, C.S.#7, and C.S.#8, are located in the alpine life zone, and the other two reservoirs, C.S.#4 and C.S.#5, are located in the sub-alpine life zone. All of these reservoirs except C.S. #5 are rated as having outstanding or above average scenery (Aukerman, Springer and Judge 1977). Table 3 presents other existing-situation factors at the five alternative Colorado Springs Reservoirs.

TABLE 3

EXISTING SITUATIONS AT ALTERNATIVE COLORADO SPRINGS RESERVOIRS

	Colo.Spgs.#2	Colo.Spgs.#4	Colo.Spgs.#5	Colo.Spgs.#7	Colo.Spgs.#8
Access Type	4-wheel drive road	light-duty road	light-duty road	4-wheel drive road	4-wheel drive road
Ownership	Colo. Spgs. U.S.F.S.	Colo. Spgs. U.S.F.S.	Colo. Spgs. U.S.F.S.	Colo. Spgs. U.S.F.S.	Colo. Spgs. U.S.F.S.
Drawdown	Variable/ as needed	Variable/ as needed	Variable/ as needed	Variable/ as needed	Variable/ as needed
Fishery Quality	Good	Good	Good	Good	Good
Level Space	Minimal	Ample	Ample	Some	Ample
Shading/Screen	Present	Present	Present	Some	Present
Travel Time (Approximate)	1½ hours from Colo. Spgs.	1½ hours from Colo. Spgs.	1½ hours from Colo. Spgs.	2 hours from Colo. Spgs.	2 hours from Colo. Spgs.

A light-duty road allows access to two of the alternative reservoirs, C.S.#4 and C.S.#5, and four-wheel drive roads make the other three reservoirs accessible. The land riparian to the reservoirs is owned primarily by the U.S. Forest Service and to a lesser degree by the City of Colorado Springs. Rights to use the stored water are owned exclusively by the City of Colorado Springs for municipal water supply, and drawdown of the reservoirs is variable, water being taken as it is needed.

The fishery capability of all the alternative reservoirs is relatively good since all are onstream, possess suitable spawning habitat and experience no winterkill. Other factors listed in Fishery Capability Step II are not considered here because such information was unavailable in many instances. For the most part, ample trees for shading and screening exist at the reservoirs with the possible exception of C.S.#7 where trees are less abundant. Level space exists at C.S.#4, C.S.#5, and C.S.#8, but soils pose a problem at C.S.#4 and C.S.#5. Less level space is existent at C.S.#7, and little space exists at C.S.#2 where the terrain around the reservoir rises quite steeply.

STEP II:

For the purposes of illustration, this example will assume that the planning objective has been tentatively identified as providing recreation opportunities for Group II reservoir users. Thus, the desires and preferences of Group II reservoir users will initially be evaluated against the ability of alternative reservoirs to accommodate such recreational use. Later, the desires and preferences of Group III reservoir users will also be evaluated against the existing situations at the alternative reservoirs to determine if any of the reservoirs could possibly meet the needs of such reservoir users since there is apparently an equal need for Group II and Group III recreation opportunities in the area.

Table 4 provides an evaluation matrix of how close the existing situations at alternative reservoirs may come to meeting the desires and preferences of Group II reservoir users. A blank cell within the matrix means that little or no problem in developing for Group II reservoir users exists at that alternative reservoir relative to a given existing-situation factor. However, an X within a cell of the matrix denotes some kind of problem (e.g.,too little level space, poor fishery quality, difficult access, etc.) exists potentially making difficult the development of that alternative reservoir to provide Group II opportunities.

TABLE 4

GROUP II EVALUATION MATRIX

	C.S.#2	C.S.#4	C.S.#5	C.S.#7	C.S.#8
Institutional Considerations					
Ownership					
Drawdown	X	X	X	X	X
Legal Liability	X				
Physical Considerations					
Access Type					
Travel Time					
Facilities/Space, Slope, Soils	X	X	X	X	
Biological Considerations					
Fishery Quality					
Shading/Screening				X	
Cost Considerations					
Cost of Development	X	X	X	X	

Ownership of riparian land is not a problem at any of the alternative reservoirs since the land is primarily owned by the U.S. Forest Service, an agency which is committed to the concept of multiple use of public lands. Rights to use the water stored in the reservoirs are owned by the City of Colorado Springs and pose somewhat of a problem due to drawdown factors. This problem is not insurmountable since such drawdown might be able to be manipulated to the benefit of reservoir recreation using the approach of the water resource engineers and water lawyers. However, even if water levels in selected reservoirs cannot be manipulated physically and/or legally, it does not pose an undue hardship on feasibility of development for Group II reservoir users since fishery capability is apparently good in all alternative reservoirs even with drawdown. Legal liability might be a problem of C.S.#2 where the steep-sided slopes result in cliffs in some places.

Access types and approximate travel times pose no problems for Group II development at any of the alternative reservoirs. The travel times are all well within travel time limits of less than three hours preferred by Group II reservoir users, and light-duty roads and primitive four-wheel drive roads are acceptable types of distribution systems for Group II reservoir users. However, it is possible that some light improvement of the four-wheel drive roads would make the situation even more attractive to Group II reservoir users.

Adequate level space to accommodate the desired Group II facilities is lacking at C.S.#2 and possibly at C.S.#7. However, a problem of soil suitability exists at C.S.#4 and C.S.#5 since the level space at these two alternative reservoirs is marshy in nature. Such a situation makes these two reservoirs somewhat less attractive as development alternatives due to the potential economic and environmental costs of reclaiming and maintaining this marshy area to provide adequate level space for the desired Group II facilities.

Fishery capability, a factor relatively important to Group II reservoir users, is not a problem at any of the alternative reservoirs, even with drawdown. The reservoirs are all on a perennial stream providing suitable spawning habitat and refugia and mitigating against potential winterkill. Another biological consideration, trees for shading and screening, appears not to be a problem at any alternative reservoir except C.S.#7.

Costs for actual purchase of a minimum of one toilet, six picnic tables, six trash cans and six firegrills plus management (operation and maintenance) costs are assumed to be the same for each alternative reservoir. However, the cost of putting such facilities in place may vary between reservoirs depending upon the degree of grading, filling and leveling required. Thus, development of C.S.#2, C.S.#4, C.S.#5, and C.S.#7 to provide Group II opportunities will likely result in added costs, because adequate level space (2-3 acres) will have to be dozed at C.S.#2 and possibly C.S.#7 and the marshy area of C.S.#4 and C.S.#5 will have to be filled to obtain the required level space to accommodate the desired Group II facilities. Actual figures for budgets and cost of recreational facility development are not included here since such costs vary and since budgets are specific to each agency. Nevertheless, it is possible that the added costs of development at C.S.#2, C.S.#4, C.S.#5, and C.S.#7 could eliminate these reservoirs from consideration as feasible development alternatives given budget ceilings. Without budget constraints, these reservoirs would at least be ranked lower in development feasibility than C.S.#8 whose potential development costs are appreciably less than those of C.S.#2, C.S.#4, C.S.#5, and C.S.#7.

Overall, C.S.#8 appears to be the most feasible reservoir to be developed to provide Group II opportunities. The other alternative reservoirs have problems that make them somewhat less attractive for development to meet the needs of Group II reservoir users. For the purposes of this example the four least-feasible alternatives will be eliminated from further consideration, and the rest of the example will deal only with C.S.#8.

STEP III:

Step III is intended to evaluate the potential for environmental disruption at reservoirs to be developed for a particular reservoir user group and to recommend mitigation measures that may be required to minimize such adverse impacts. Thus, the potential for environmental disruption is discussed in this section relative to Group II development and C.S.#8.

It is probable that almost no grading and/or leveling of terrain to provide the required Group II facilities will be needed at C.S.#8, and the vegetation and soil disturbance that is likely to occur will be associated with putting in required toilet facilities and parking lot. Such adverse impacts during construction can be held to a minimum through careful planning of such development. Moreover, these effects are not likely to result in erosion into nearby water bodies, as the development will take place well away from the nearest waters (100'-150'), and the slope of the terrain is extremely gentle.

Recreational use of the campground at C.S.#8 can result in vegetation and soil disturbance and invasion of the area by more hardy plant species. Hardening of areas around camping sites, toilets and the pathways to and from parking sites, toilets and camping/picnic sites and provision of barriers or signs to channel foot and vehicular traffic can do much to preserve soils and vegetation, to allow plant succession and to prevent any appreciable soil erosion. Moreover, the provision of such barriers or signs, along with toilets and trash cans, can do much to avoid the problems of human waste disposal, littering, and bacterial water quality degradation. Thus, it appears that C.S.#8 can be feasibly developed to provide recreation opportunities for Group II reservoir users while still maintaining an extremely high degree of environmental quality, given the existing situation at the reservoir and the provision of mitigating measures to minimize environmental disruption.

C.S.#8 has been evaluated as the most feasible development alternative to provide needed recreation opportunities for Group II reservoir users, but opportunities are still lacking for Group III reservoir users. As was stated in the initial description of this reservoir recreation decision-making framework, the process allows for re-evaluation of reservoirs, which are found to be inappropriate for one reservoir user group. The re-evaluation process requires comparing alternative reservoirs to the desires and preferences of another reservoir user group that might need recreation opportunities in an area. Thus, before advancing to Step IV, the authors wish to indicate how the decision-making process can be used to pair alternative reservoirs with reservoir user groups needing recreation opportunities in an area.

It was determined in Step I that the area west of Colorado Springs lacks opportunities for both Group II and Group III reservoir users. It is assumed that the planner has determined that C.S.#8 should be developed for Group II reservoir users, but equity dictates that it would be incumbent upon the planner to determine if any alternative reservoir could be developed to provide opportunities for Group III reservoir users. Thus, the planner could at this point re-evaluate the remaining alternative reservoirs against the desires and preferences of Group III reservoir users to determine if one or a number of these reservoirs has existing situations suitable to accommodate such a reservoir user group. Table 5 provides an evaluation matrix for Group III consideration. The blank cells and cells with X's have the same meanings as in Table 4 .

TABLE 5

GROUP III EVALUATION MATRIX

	C.S.#2	C.S.#4	C.S.#5	C.S.#7
Institutional Considerations				
Ownership				
Drawdown	X	X	X	X
Legal Liability				
Physical Considerations				
Access Type	X	X	X	X
Travel Time				
Facilities/Space, Slope, Soils				
Biological Considerations				
Fishery Quality				
Shading/Screening				
Cost Considerations				
Cost of Development				

At first glance, it would appear that the four remaining reservoirs are equal in terms of their development potential for Group III reservoir users, but such is not actually the case. Drawdown is not a critical factor for Group III recreationists since they are not significantly interested in fishery quality (only 13% of Group III users rated fishing as their most important activity). However, it is believed that stable water levels at reservoirs during recreational use periods add to the aesthetic attraction of the area, so the water engineers and water lawyers will be asked in Step IV if it is physically and legally feasible to stabilize the water level of the eventually selected Group III reservoir(s). The same question will be posed for C.S.#8 in relation to Group II development. However, the important point at this juncture is that all the alternatives experience some degree of drawdown, so no alternative can be determined to be better than any other in terms of development feasibility.

The elimination of alternative reservoirs for Group III development comes when access type is addressed. All four reservoirs are accessible by means of some type of road, but two alternatives, C.S.#4 and C.S.#5, are located adjacent to a light-duty road. Since it is almost impossible to block this road to vehicular traffic, it is not feasible to make either of these alternative reservoirs into a hike-in reservoir which is preferred by Group III reservoir users. Likewise, C.S.#2 is located on a four-wheel drive road that cannot be blocked to vehicular traffic since this road is intended to allow access to C.S.#8 for Group II reservoir users. Thus, C.S.#7, located up a four-wheel drive road from C.S.#8, is the most logical choice as the feasible alternative to be developed to provide needed opportunities for Group III recreationists. The example will assume that this four-wheel drive road can be blocked to public vehicular access (Colorado Springs water officials may still require vehicular access to inspect the reservoir and open or close the headgates). Blocking vehicular traffic of recreationists at a point near C.S.#8 would result in a three-quarter mile hike for Group III reservoir users.

The potential for environmental disruption requires evaluation in Step III, and such disruption in relation to Group III reservoir users is potentially low. Little or no vegetation or soil disturbances should result from putting the desired Group III facilities (toilets and trash cans) in place, and thus, soil erosion and water quality degradation are not likely to become significant problems. Observation at Group III reservoir user campgrounds in the Colorado Front Range reveals that some vegetation trampling does occur in and around such campgrounds, but the impact is not so severe as to result in appreciable areas of bare ground or to cause eradication of fragile vegetation, since American bistort and Indian paintbrushes have been found in abundance at even older Group III campgrounds. This, along with the fact that toilets and trash cans should minimize problems of littering and human waste disposal, would indicate that little or no environmental disturbance to the land or water regime is likely to result from Group III reservoir development. Thus, C.S.#7 is probably feasible from the standpoint of environmental quality to be developed for Group III reservoir users.

The most important potential adverse effect of Group III reservoir development has been found to be erosion of the trail systems allowing access to such reservoirs. If the four-wheel drive road to C.S.#7 is converted to a hiking trail and waterbars are provided to channel water onto the more permeable adjacent soils, it appears improbable that erosion due to foot traffic would be a problem. In fact, conditions might improve since foot traffic would not be as damaging to the distribution system as vehicular traffic can be.

By utilizing the critical factors specified in the decision-making framework and by evaluating such factors against the existing situations at alternative reservoirs relative to the desires and preferences of given reservoir user groups, the planner is able to determine which reservoir user group needing opportunities in an area can be accommodated at which alternative reservoir(s). Using this process, it has been determined that Group II opportunities are needed in the area west of Colorado Springs and that C.S.#8 can most feasibly accommodate such a reservoir user group. Since Group III opportunities are also needed in the area, re-evaluation of the remaining Colorado Springs reservoirs indicates that C.S.#7 can feasibly be developed to meet the desires and preferences of Group III reservoir users.

Weighted Decision Process

Another method for identifying reservoirs which are feasible for recreation development is one which weights the individual variables (considerations) in the decision process. The use of a weighting system may have an advantage over the previously explained system because the weighting system defines the degree of importance of one consideration in relation to any other consideration in the decision process. Yet, the use of weights may have a definite disadvantage over the proposed system due to both the complexities and the great margin for error possible in assigning the weights.

Experience has shown that it is not unusual to create a more inaccurate decision process with weights than without.

The present research has found little difference between the end product of the weighted process and the end product of the simpler, non-weighted process previously presented. Therefore, even though we are presenting a weighting system, we are doing so only as an example of how such a system might work; we are at this time recommending the use of the more simplified system.

Further research is needed and is now under way by one of these authors (Springer) into more sophisticated weights and the possible use of a computerized weighting system for identifying reservoirs best suited for recreation development.

The weighting system presented in this report is one developed by the principal investigator (Aukerman) and does not represent the concensus opinion of all of our own investigators. You should critically analyze the weights given if you choose to test or use the weighting system presented. If you do not agree with some of the weights, try some of your own weights and experiment to see if the final reservoir selection is changed by the weight changes.

The weighting system presented in this report is an interpretation (by the principal investigator) of: (1) a set of considerations scientifically studied by the researchers, and, (2) a set of considerations which are either traditionally used by recreation and park planners and managers in decision making, or gleaned from a review of literature.

The weights given the considerations from (1) above have some scientific backing and should be viewed as more valuable guidelines by decision makers than the considerations from (2) above which are more dependent upon opinion.

The (2) type of weighting is not scientific and is error-prone unless a consensus can be found between experienced decision makers, scientific findings, literature, etc. In this study, even where weightings have a scientific base, (type 1) there are "grey zones" where the resource and/or the user vary so greatly that a single weight does not always apply. This is why the weights presented must sometimes be flexible and open to interpretation by the planner or manager attempting to apply them to their own field situation.

A good example of the need for field managers and planners to have some say in the assigning of weights to considerations on their own sites can be seen in assigning weights to the "draw-down" consideration.

On a relative scale of 0-3, 3 would represent elimination of a reservoir from consideration for recreation, and 0 would represent no consideration of the factor as important for recreation in differentiating among reservoirs. Total drawdown during major recreation use times would eliminate a reservoir from consideration for recreation and thus receive a rating of 3. On the other hand, total drawdown outside of the major recreation use period would probably have little effect on recreation use of the reservoir, and this type of drawdown might be assigned a rating of 1. As a third instance, when total drawdown occurs outside of major recreation use periods but during fish spawning periods, killing mature fish, eggs and spawn, it destroys the recreation fishery, making the weighting for drawdown a 3 at those reservoirs important to fishermen. Partial drawdown is an even more complex problem. A single weight may be impossible to assign since the importance of "partial drawdown" may be dependent upon the type of recreation user to be served, the time of year that drawdown occurs, the amount of drawdown, the resource itself, and other factors.

Even if weights can be assigned that are satisfactory for partial or complete drawdown, the problem regarding the importance of drawdown relative to other decision variables still exists. For example, is partial drawdown during recreation use periods as important, more important, or less important than the cost of facilities in selecting a reservoir for recreation? This is impossible to say for any given reservoir without knowing the economic situation of the agency administering the recreation.

Partial drawdown would probably range in importance from 0 (no effect) to 2 (relatively strong effect). This would depend on the recreation user group being served and the recreation fishery desired. At the same time cost of facilities could be weighted anywhere between 1 and 3 depending on the economic situation of the agency developing and managing the facilities and the recreation group involved. It is very unlikely that cost would not be a consideration in reservoir selection (rating

1-3). However, it is quite conceivable that the expense of facility development could eliminate a reservoir from selection (rating 3). Therefore, weights for partial drawdown compared to the weights for cost of development would vary considerably, depending on the requirements of the users and the developing and managing agency.

From these examples, it can be seen that there are multiple problems associated with developing a weighting system which accurately differentiates between all variables which must be considered in selecting reservoirs for recreation. Some of the weights assigned to considerations could be viewed more as ranges than set numbers. From these ranges the planner or field manager must select a weight which best suits his situation.

The important thing to be considered by the potential users of the findings presented in this report is that our research has produced some scientific basis for making weighting decisions for selected considerations. However, the weighted example is only an initial attempt to integrate these considerations into a comprehensive weighted decision process. The weighting for the entire decision process is only experimental, and not ready for field use. It is put forth as a framework or starting point for further scientific study and refinement. Hopefully, the continued research by Springer and/or your own field use and testing will improve upon the selection capability of the weighted system over the non-weighted system or will prove that the weighted system only confounds the decision process for selection of recreation reservoirs.

Table 6 is a list of those considerations which do or do not have some scientific base in our research.

TABLE 6

CONSIDERATIONS WITH OR WITHOUT SCIENTIFIC FOUNDATION

Research Based Considerations	Non-Research Based Considerations
Total Drawdown	Water Quality
Partial Drawdown	Shading
Access Type	Facilities Cost
Facilities	Development Costs - Road Grading, Etc.
Fishery	Maintenance Costs
Legal Liability	Soils
Driving Time	Space
Environmental Impact	Slope
Aesthetics	

Table 7 depicts the weightings given to each consideration for selecting reservoirs for particular recreation users. As was pointed out earlier in this report, our research has identified three distinct recreation user groups utilizing mountain reservoirs. Since each user group has different characteristics, separate weightings have been identified for the considerations found important to each user group. A weighting of 1 means that

TABLE 7

ASSIGNED WEIGHTINGS BY RECREATION GROUP

GROUP I

Weighting of 1

Water Quality
Shading

Weighting of 2

Partial Drawdown
Access
Env. Impact 2-3
Costs:
    Facilities 2-3
    Roads
    Grading & Filling 2-3
Fishery
Soils
Legal Liability
Aesthetics

Weighting of 3

Drawdown Total
Wilderness
Driving Time
Slope
Space
Costs:
    Leveling & Filling 2-3
    Roads 2-3
    Facilities 2-3
    Maintenance 2-3
    Env. Impact 2-3

GROUP II

Weighting of 1

Water Quality
Facility Costs
Shading

Weighting of 2

Partial Drawdown
Access
Env. Impact 2-3
Soils
Costs:
    Maintenance 2-3
    Roads 2-3
    Leveling & Filling 2-3
Aesthetics
Fishery
Legal Liability

Weighting of 3

Total Drawdown
Wilderness
Driving Time
Slope
Space
Env. Impact 2-3
Costs:
    Leveling & Filling 2-3
    Roads 2-3
    Maintenance 2-3

GROUP III

Weighting of 1

Water Quality
Facility Costs
Fishery
Shading
Slope
Space
Soils
Grading
Partial Drawdown

Weighting of 2

Access
Aesthetics
Env. Impact
Solitude
Costs:
    Maintenance
Legal Liability

Weighting of 3

Access
Driving Time

A weighting of 3 eliminates a reservoir from consideration for recreation.

the consideration is relatively unimportant in selecting a reservoir for that recreation user group. A weighting of 2 is highly important for meeting the desires of the users or the needs of the resource. However, a 2 weighting does not eliminate a reservoir from consideration. A weighting of 3 immediately eliminates a reservoir from consideration for recreation.

In some cases specific weightings are not given. What is given is a range. As was explained previously, when this is encountered the responsibility lies with the field manager or planner to select from this range, the specific weighting which seems most appropriate for his situation.

In order to demonstrate how these weighted considerations work selecting reservoirs for recreation, the same set of Colorado Springs reservoirs demonstrated in the "non-weighted selection process" are subjected to the "weighted selection process."

Table 8 demonstrates the weighted selection of reservoirs for Group II recreation users. All those considerations given no weighting numbers are considerations which are deemed unimportant or do not apply to the Colorado Springs reservoirs (see Table 9). Therefore, the first consideration of any importance is "Partial Drawdown." Partial drawdown has been given a weighting of 2 for Group II users (see Table 7). In the case of all of the Colorado Springs reservoirs, partial drawdown does occur and each, therefore, receives a 2 weighting. This factor, then does nothing to help differentiate between the

TABLE 8

WEIGHTED SELECTION PROCESS (EXPERIMENTAL)
COLORADO SPRINGS RESERVOIRS
STUDIED AS POTENTIAL GROUP II RESERVOIRS

	Reservoir #2	Reservoir #4	Reservoir #5	Reservoir #7	Reservoir #8
Drawdown Total					
Partial	2	2	2	2	2
Wilderness					
Access		2	2		
Driving Time					
Slope	3				
Space	3			3	
Soils					
Fishery					
Water Quality					
Shading		1	1		
Costs:					
Facilities	1	1	1	1	1
Leveling & Filling	2	2	2	2	
Maintenance	2	2	2	2	2
Liability	2				
Aesthetics					
Solitude		2	2		
Env. Impact		2	2		
Total Weighting	16	14	14	10	5
	Out because of 3			Out because of 3	Best of Group II Reservoirs
Rank		2	3		1

TABLE 9

GROUP II CONSIDERATIONS RECEIVING NO WEIGHTING
FOR COLORADO SPRINGS RESERVOIRS

Consideration	Reason For No Weighting
Total Drawdown	Does not occur at reservoirs
Wilderness	Reservoirs not located in designated wilderness are
Driving Time	All reservoirs within acceptable limits of Group II users
Soils	No data available
Fishery	Adequate fishery at all reservoirs
Water Quality	Water treated before domestic use
Aesthetics	Outstanding scenery at all reservoirs

reservoirs for Group II recreation. However "access" does begin to distinguish between the capabilities of the reservoirs to meet Group II recreation requirements. Our research shows that Group II users prefer road access, but they do not need or want paved roads; rough, unpaved roads are acceptable. Access at reservoirs #2, #7, and #8 fit the requirements of Group II users. Therefore, access is not an important consideration at these reservoirs. However, reservoirs #4 and #5 have access problems because the roads are of such high quality that they afford easy access to Group I users. Eventually, Group I users could dominate the use of reservoirs #4 and #5. Therefore, reservoirs #4 and #5 receive ratings of 2 for access. Because of the steep slopes surrounding reservoir #2 there is little possibility for recreation development. Since slope is rated 3, reservoir #2 is eliminated from consideration. Likewise, space is weighted 3. Reservoirs #2 and #7 do not have space available for Group II developments. Thus, reservoir #7 is also eliminated from recreation consideration. Shading is not extremely important but might be a problem at reservoir #4 and #5. These reservoirs received a weighting of 1. Cost of facilities is only a minor problem for all reservoirs. Group II users prefer only limited facilities. Thus all reservoirs receive a weighting of 1 and there is no differentiation.

Costs of leveling, filling, and cost of maintenance can be exhorbitant and are given weightings of 2. All Colorado Springs reservoirs should experience the same maintenance requirements, and only reservoir #8 needs no leveling and filling. Due to the steep slopes which create hazards, legal liability is a problem at reservoir #2 and is weighted 2. Solitude and environmental impact both pose major problems at reservoirs #4 and #5, and receive 2 weightings. Solitude is a problem due to the proximity of these reservoirs to the main road. Environmental impact is a problem due to both proximity to the main road and marshy areas present in the areas which are level enough for development.

In the final selection, the lower the total weighted score of all considerations for any given reservoir, the better suited that reservoir is for recreation. From our example, reservoir #8 has an overall weighting of 5 which is by far the lowest weighting of any of the Colorado Springs reservoirs. Thus, reservoir #8 has the greatest potential for recreation development for Group II reservoir users. Reservoirs #2 and #7 were eliminated due to receiving 3 weightings. Reservoirs #4 and #5 could be developed for Group II users, however there would be considerable problems in development. These reservoirs, with a weighting of 14, are a second choice to reservoir #8.

Using the same selection process, but with weights applicable to Group III users, Colorado Springs reservoirs are evaluated for Group III recreation potential (See Table 10). As is the case for Group II reservoirs, partial drawdown is a problem for reservoirs being considered for Group III users. However, it is important to note that the partial drawdown weighting for Group II reservoirs is 2 and for Group III reservoirs, a 1. In the present

TABLE 10

WEIGHTED SELECTION PROCESS (EXPERIMENTAL)
COLORADO SPRINGS RESERVOIRS
STUDIED AS POTENTIAL GROUP III RESERVOIRS

	Reservoir #2	Reservoir #4	Reservoir #5	Reservoir #7	Reservoir #8
Drawdown Total					
Partial	1	1	1	1	1
Wilderness					
Access	2	3	3		2
Driving Time					
Slope					
Space					
Soils					
Fishery					
Water Quality					
Shading		1	1		
Aesthetics					
Env. Impact		2	2		
Solitude					
Costs:					
Facilities					
Roads					
Maintenance	2			2	2
Legal Liability	2				
Total Weighting	7	7 Out because of 3	7 Out because of 3	3	5
Rank	3			1	2

case, partial drawdown is weighted 1 because of the relatively unimportant need of Group III reservoirs to serve fishermen. Since all reservoirs receive a weighting of 1, partial drawdown is not a consideration which differentiates between the reservoirs. Access does differentiate between the reservoirs. In this case the reservoir manager or planner must select between two possible weightings - 2 or 3. Group III reservoir users require hike-in access. In order to provide this type of access to reservoirs #4 and #5, the main road would have to be closed. This would seem to be an impossibility. Therefore, access is weighted 3 for reservoirs #4 and #5, eliminating them from consideration for Group III reservoir developments. Reservoirs #2 and #8 both have road access which would have to be closed for Group III users. However, road closure to either one of these reservoirs would mean closure of access to reservoir #7. This creates a major access problem and warrants a weighting of 2 for reservoirs #2 and #8. Road closure to reservoir #7, which is the most remote reservoir, presents no problem; therefore, access receives no weighting for reservoir #7. Shading and environmental impact are both problems for reservoirs #4 and #5. The reasoning and weighting is the same as for the Group II reservoir example. Maintenance poses the same potential problem for all of the reservoirs still under consideration. Legal liability is again a problem for reservoir #2 due to the hazard of steep slopes.

The following Table 11 outlines the reasons why each of the following Group III considerations received no weighting for any of the Colorado Springs reservoirs.

TABLE 11

GROUP III CONSIDERATIONS RECEIVING
NO WEIGHTING FOR COLORADO SPRINGS RESERVOIRS

Consideration	Reason For No Weighting
Total Drawdown	Does not occur at reservoirs
Wilderness	Reservoirs not located in designated wilderness areas
Driving Time	All reservoirs within acceptable limits of Group III users
Slope	Acceptable for Group III development
Space	Acceptable for Group III development
Soils	No data available
Fishery	Not required by Group III users
Water Quality	Water treated before domestic use
Aesthetics	Outstanding scenery at all reservoirs
Solitude	Available to Group III users
Facility Costs	Outhouses and trash receptical all that is required
Road Costs	No roads required

After tabulating the weighted scores for each of the Colorado Springs reservoirs being considered for Group III recreation, reservoir #7 has the lowest cumulative weight and the greatest potential for Group III recreation development. Reservoirs #8 and #2 are also suitable for Group III recreation but access is a problem which must be overcome for both reservoirs. Reservoirs #4 and #5 are eliminated due to weightings of 3 for the access consideration.

The preceeding example of the "weighted selection process" shows that the weighting system does work, assuming that the assigned weights are reasonable. Clear selections were able to be made for both Group II and Group III recreation users. The fact that the selections were the same as those made by the "non-weighted selection process" supports our previously stated conclusion that, at this time, the weighted system has no obvious advantage over the non-weighted system. Therefore, until further research and refinement can prove that a weighted system is of more value than the non-weighted system, we are recommending the use of the simpler non-weighted system for selection of reservoirs for recreation. Presentation of both systems does give the manager or planner a chance to choose the system with which he feels he might be most comfortable and/or obtain the best results.

In addition, it is hoped, that those interested in a weighting system will find the system outlined herein, useful as a beginning framework in establishing their own weighted decision system.

STEP IV:

The next step after the identification of reservoirs feasible for recreational development in terms of physical, biological, cost, environmental and some institutional considerations is to determine the physical and legal feasibility of managing the water levels of these reservoirs to benefit recreation while still meeting downstream water demands. These determinations are the province of water resource engineers and water lawyers. Such manipulation is most essential in selected reservoirs where fishery capability is impaired by drawdown and refill practices and where the planning objective is provision of recreation opportunities for either Group I or Group II reservoir users; it is also important in striving to provide aesthetic recreation experiences for all reservoir user groups.

An actual run through the system engineering model and through the analysis of results by water lawyers will not be presented in this example since water use and availability data for this reservoir system were not accessible. However, a brief description of what would be asked of the engineers and lawyers is outlined here. An example of the engineering model is given for the Cache La Poudre drainage in the Appendix I.

The assumption is that the planner has decided at this point to provide recreation opportunities for Group II reservoir users at C.S.#8 and for Group III reservoir users at C.S.#7. The engineers and water lawyers would be asked if water levels at C.S.#7, and C.S.#8 could be stabilized at near capacity during the months of June, July, August and September which are peak reservoir recreation months. Water could be drawn from C.S.#2, C.S.#4 and C.S.#5 during these months since these reservoirs would potentially remain closed to recreational use and would have no recreation potential. Management of water in C.S.#7 and C.S.#8 would be of concern since it would be advisable to keep these two reservoirs relatively full through the winter months to minimize substrate freezing and disruption of fish food chains. The fish present in C.S.#7, and C.S.#8 are spring-spawning cutthroat trout, and it is also advisable to time refill of these two reservoirs so as not to reduce spawning success because of silt smothering.

Ideally, water levels in C.S.#7 and C.S.#8 would be managed to keep the reservoirs as full as possible during the summer months (June, July, August and September), but water could be taken from these two reservoirs in fall and early winter (October, November and December). Then, the reservoirs would be allowed to fill gradually through the winter (January, February and March) in order to have them nearly full again by the beginning of cutthroat spawning periods (April to June). Such considerations would be utilized in the water engineering model, and the physical and legal feasibility of managing water in the way described above would be analyzed by water engineers and water lawyers.

STEP V:

If it were concluded by the water engineers and water lawyers that, barring incidents such as drought, water levels in C.S.#7 and C.S.#8 could be managed in the manner specified above, the planner could advance to Step V and begin final planning for recreational development. The numbers and types of facilities desired by Group II and Group III reservoir users must be re-specified in order to derive the needed site design considerations at C.S.#7 and C.S.#8. Moreover, a final judgement would have to be made concerning the number of reservoir users to be accommodated, e.g.,peak use or average use, since this decision will affect numbers of facilities needed and site design considerations to a certain extent. The environmental impact mitigation measures will need to be incorporated into the site design and construction plan, and the planner will have to make contact with the appropriate Colorado Springs water official to arrange to manage the water levels in C.S.#7, and C.S.#8 according to the specifications of the water engineering model.

If it turns out that it is not physically or legally feasible to manage water in C.S.#7 and C.S.#8 in a way that would be beneficial to recreation, the planner could in this case still proceed to Step V to implement development since the most critical factor is drawdown at some reservoirs. Reduction in fishery capability is not a significant factor at either C.S.#7 or C.S.#8, since existing characteristics at these two reservoirs (onstream with spawning habitat, refugia and lack of winterkill) make them relatively good fisheries anyway. If the reservoirs were poor fisheries and fishing was an important activity to the reservoir user group to be accommodated, fishing potential might be enhanced without water management by the provision of artificial substrates to provide shelter, fish food habitat, etc., or a put-and-take stocking program might be arranged with the Colorado Division of Wildlife.

However, in the present example, fishery capability is not an issue at either C.S.#7 or C.S.#8. The only ramification of not being able to manage the water levels of C.S.#7 and C.S.#8, in this example, is the potential reduction in aesthetic appeal of the reservoirs if the water is drawn out during the summer recreational use period. The alternative might be to abandon all consideration of recreational development, and this "cure" might be worse than the "disease" of not being able to stabilize the water levels. The planner is justified in proceeding to develop the reservoirs for recreation even without stable water levels.

SUMMARY:

The authors hope that this example has illustrated how the reservoir recreation decision-making framework can be used to make better informed decisions about reservoir recreation. The steps involved and the factors within each step serve as a rational and logical process to determine what reservoir user groups need opportunities in a given area and what reservoirs within that area have characteristics that make them suitable to accommodate a certain reservoir user group.

SUMMARY AND CONCLUSIONS

The main body of this report is a summary of four years of research. The report summarizes data from the Phase I completion report (Aukerman, 1975), plus detailed information from the three appendices. Four major disciplines are represented, including recreation resources, water resources engineering, fishery biology and water law. The study is truly an interdisciplinary effort to provide new information and to structure the information for making informed decisions for providing water and developing high country reservoirs for recreation.

A decision process for the selection, planning and management of reservoirs for recreation is presented. Built into the process are many factors which need to be considered for both selecting and developing those reservoirs which are best suited for recreation.

The design of the decision process and the identification of the essential factors for the process constitute the first (Objective A) of the project's two main objectives. Institutional, biological, physical, developmental, environmental, and legal considerations were studied. Our research provided the base for selecting those considerations which best differentiate between reservoirs. Those considerations selected formed the framework for a decision process. The decision process was tested in Colorado reservoirs and proved to differentiate nicely between the reservoirs. The decision process is basically a framework for comparing the existing characteristics and management potential of alternative reservoirs to the desires and preferences of a given recreation user group.

Some of the more important considerations included in the decision process are: access, travel time, slope, fishery capability, legal liability, ownership of water rights and riparian lands, facilities, shading, environmental impact, water availability during critical recreation periods, and legal options for obtaining and maintaining water for recreation.

Three of the considerations which are utilized in the decision process (Objective A) constitute the major components of the second objective (Objective B). Water resources engineering, fishery biology, and legal considerations were studied in depth to determine the feasibility of meeting recreation demand on reservoirs.

The water resources engineering component of the study was concerned with meeting recreation demands through timed water delivery without interfering with the water requirements of other downstream water users. A river basin simulation model was developed to help meet this goal.

Testing of the model on the Cache la Poudre River Basin in Colorado clearly shows that by altering management procedures (time and place of storage and release of water) it is possible to provide adequate water for those Poudre River Basin reservoirs important to recreation.

However, the important aspect of the model is not the example or product from the Cache la Poudre River Basin, but the capabilities of the model as depicted by this complex example. We now know that the model has the capability and does simulate historic events. Thus, the model should predict future events. This means that, when calibrated correctly, the model is what the research set out to find, and does give water users, managers and planners the capability of knowing or predicting just when and where water is available in a system for recreation without adversely affecting other water users.

If other river basins throughout Colorado and the Western United States are found to have the same capabilities (as the Cache la Poudre) for providing water for recreation, then a major water source for recreation exists.

Another important question studied in depth by the fishery component of the research was the ability of the fishery in high country reservoirs to meet recreation fishing demand.

All high country reservoirs have potential for fishery development; yet there is little doubt that most can be improved. In order to select those reservoirs which have the greatest recreation fishery potential, our studies identified the components of high country reservoirs which constitute a good fishery. The components identified with a checklist of factors which should be considered in selecting and developing high country reservoirs for recreation fishing. Stabilization or managerial manipulation of water during critical fishery periods is one of the best ways to meet the fishery need. However, where water management is impossible, other means, such as the use of substrates, may improve the fishery. This study presents an indepth review of the state of the art of substrate use in fishery management. Those substrates showing the greatest promise for use in high country reservoirs are recommended for research.

Since approximately three-fourths of all mountain reservoir recreationists are fishermen, the basic research findings of the fisheries research form an extremely important component of the overall reservoir recreation decision process.

The final question addressed by our research was: is it possible, within the constraints of water law, to maintain the water identified by the engineering model in high country reservoirs for recreation? The answer for the Cache la Poudre River Basin is "yes." However, again this answer is only for a single basin and is not the most important contribution of this study. What is important is that the water users, planners, and managers now have a set of legal considerations or questions which provide a framework for obtaining and maintaining water in reservoirs for recreation.

In short, we now know the right legal questions to ask, and either the answers or the sources for finding the answers to the questions. Hopefully, this information will lead to the opening of new recreation opportunities on high country reservoirs.

However, even after demonstrating public demand for reservoir recreation, fishery potential, physical ability to provide water without injury to other users, and a legal potential there is still no assurance that reservoirs will be opened and managed for recreation. Other water users, whether they be public or private, must be convinced that the amount and time of delivery of their water will not be affected, and for that they will have something to gain from recreational use of "their" water.

What is now needed is field implementation of the scientific information and the decision process in order to prove, in practice, that what this research study proposes actually works.

The greatest hope for the future multiple use of reservoirs, which means inclusion of recreation, probably lies in our political system. Political decision makers are now struggling with water plans for Colorado and the entire Western United States. Their decisions will affect the future of this part of the country. Unless these decision makers have accurate information on recreation water needs and potentials for meeting these needs, they can not be expected to make informed decisions. This study was undertaken in part to generate some of the information needed for this decision making. If the type of information presented in this report is not made available and utilized, then we will most certainly be failing to make use of a resource available to us and will probably be jeopardizing a major segment of one of the foremost industries of the state of Colorado - recreation.

Finally, many research reports conclude that more research must be done. When looking at data scientifically, this is always the case. There is certainly a need in this study for further research into every aspect of the study, for the greater the scientific base, the more accurate the decision framework. However, in this report we do not emphasize the research needs. We do wish to emphasize the positive research findings which we feel add significantly to the scientific base necessary for making informed decisions on selecting, planning and managing high country water reservoirs for recreation.

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APPENDIX I

RIVER BASIN SIMULATION MODEL FOR DETERMINING WATER AVAILABILITY FOR RECREATION

John M. Shafer

and

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APPENDIX I

Table of Contents

	Page
Introduction	149
River Basin Simulation Model	144
Description of Case Study	166
Model Calibration	183
Analysis of a Management Strategy for Recreation. . . .	191

INTRODUCTION

Goals

A water resources engineering component has been included in this interdisciplinary project in order to provide a systematic methodology for evaluating, from a hydrologic viewpoint, the recreation potential of high mountain reservoirs along the Front Range of Colorado. More specifically, the goal has been to provide the capability needed by the recreation planner/manager for evaluating the hydrologic feasibility of placing single-purpose (water supply) high mountain reservoirs into a multi-purpose management framework which includes recreational aspects.

The first step, as carried out by the interdisciplinary team, is to select those reservoirs which offer the greatest recreation potential, according to such criteria as distance from population centers, fisheries potential, use intensity, facilities, etc. In addition to the reservoir selections, ideal operating policies from a recreation and fisheries viewpoint may also be suggested. The water resources engineering task is then to determine if, in fact, these desirable storage levels can be realized in the selected reservoirs. These recreation enhancing storage levels must be maintained, while minimizing possible injury to users originally benefiting from the traditional operation of the reservoirs within the context of the total system. If it is not feasible to maintain desirable levels in the originally selected reservoirs, a feedback process may be required where the interdisciplinary team again evaluates the reservoirs in light of the new information, and the engineering component is called upon again. Several iterations may be required. Thus, the problem becomes one of determining which reservoirs should be managed for the inclusion of recreation and to what degree such a multi-purpose operating policy can be exercised.

The specific goal, for this component of the project, has been to develop a systems analysis approach to the resolution of conflicts over water use, through temporal and spatial management of the available water resources. What follows is a thorough documentation of the models, data needs, and procedures for implementing the systems approach. A portion of the Poudre River basin in Northern Colorado has been selected for demonstration purposes, and results from this case study are presented. Great care has been taken to insure that the methods employed in this component of the study are compatible with other facets of the project, so as to synthesize an integrated methodology.

Justification for Use of Systems Analysis Techniques

The use of systems analysis techniques in water resources planning and management has gained wide acceptance in recent years. Due to the large-scale nature of most physical water resource systems, and the corresponding quantity and diversity of data, a systematic treatment of problems becomes somewhat mandatory if such problems are to remain tractable. By definition, the systems approach to problem solving specifies an orderly stepwise solution strategy for these complex problems.

The application of systems analysis techniques to the determination of the feasibility of enhancing reservoir recreation opportunity is especially desirable. Such an endeavor aids the planner/manager in pinpointing data requirements and facilitates the rapid analysis of many alternative management schemes. A general modeling framework can be developed that is not basin specific. This allows the planner/manager the flexibility of analyzing the reservoir recreation potential for different basins through employment of one basic model structure. Once the basic model structure has been developed, there is the added advantage of being able to systematically incorporate new data and information as they become available.

Scope of Study

Within the framework of the overall project objectives, several computerized simulation models were evaluated with respect to the ability of each to provide the desired analysis and also remain compatible with other more qualitative decision models developed in this study. As a result, the research focused on those river basin simulation models that could be incorporated as one component in a more broad-based planning model. The ideal situation is one where the socio-economic and fisheries aspects determine initially which reservoirs are suitable for recreation. Simulation of the physical system would subsequently determine if indeed there is an availability of water to maintain satisfactory recreation storage levels in those reservoirs without altering overall system performance.

Upon selection of the simulation model, a representative study area was defined and the model was applied to a real system of high mountain reservoirs. In order to test the appropriateness and validity of the model, two phases of operation had to be successfully completed. The first step was a calibration and verification procedure to determine if the model could reproduce (within an acceptable range) the historical system performance for the selected case study area. Model verification provides the basis for confidence in the subsequent management analyses and results. The second phase was an actual analysis of the feasibility of altering current operating rules for the case study area, in order to produce a realistic multi-purpose operating policy which includes the maintenance of recreation pools in selected reservoirs.

Finally, the complete documentation of the modeling procedure, data requirements, and results of the test case was undertaken. The test case approach is one of the best methods for describing model operation in that procedures, along with information requirements and interpretation of results, can be fully explored and set forth. A detailed demonstration of the application of modeling procedures provides the prospective user with a useful guide to implementation of the procedures.

Background to Model Selection

Selection of the appropriate simulation model was based on certain objective criteria. These include: flexibility in application, ability to function on large systems for extended time periods, detail of output provided, and data requirements. Also of importance is the amount of computer core storage necessary and the computer time required to make a successful simulation run. In addition to, and underlying the above considerations, are those aspects of the computer program which would provide a measure of trust for the user. The program methodology must not be so obscure as to eliminate even an intuitive understanding of its assumptions, approximations, capabilities, and limitations. Finally, the computer simulation model must be able to reliably predict water availabilities under conditions of intense competition, thereby providing the planner with the information necessary to effect a decision.

The advantages and disadvantages of several computer models were considered before the final selection of the Texas Water Development Board Program SIMYLD as the most appropriate. Those models and corresponding descriptions and limitations are listed as follows:

(1) Evans, Robert G., "Hydrologic Budget of the Poudre Valley." Unpublished Master's Thesis, Colorado State University, 1971.

A hydrologic budget analysis was performed on the Cache la Poudre River basin. A computer program was developed which considers water diversions and application efficiencies of irrigated agriculture in the computation of the hydrologic budget. The model was not designed for

evaluating long-term planning strategies and lacks the flexibility for application to other river basins.

(2) "HEC - 3 Reservoir System Analysis for Conservation - User's Manual." Prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California, July, 1974.

Program HEC-3 simulates the operation of a system of reservoirs for conservation purposes including flood control, water supply, hydropower, recreation, etc. Although it is a comprehensive simulation model, it does not have the capability of considering a set of reservoir operating rules of differing priorities. Also, HEC-3 was designed for large computers and requires a large amount of time for a single simulation run.

(3) Ribbens, Richard W., "Program NW01 River Network Program User's Manual," Unpublished report by the Division of Planning Coordination, Bureau of Reclamation, Denver, Colorado, July 1973.

The Bureau of Reclamation has developed a river network model which is used as a flow and salt accounting model. The computer program provides month by month results of computed flows and salinity of selected nodal points within the network. The model is limited in scope. It is only capable of considering the physical system and alternative management strategies cannot easily be handled.

(4) Thaemert, R.L., "Mathematical Model of Water Allocation Methods." Unpublished Ph.D. Dissertation, Colorado State University, 1976.

A computerized model of a water distribution system was developed based upon the existing water rights structure in Colorado. Functionally, the model allocates surface water, including water held in storage, on a daily basis according to a prespecified distribution criterion. In its present form, the model is not suitable for long-term planning purposes.

RIVER BASIN SIMULATION MODEL

Program Description

The Texas Water Development Board has developed a computerized river basin simulation model which is capable of modeling a multi-reservoir water resources system. The computer program SIMYLD* employs the "Out-of-Kilter Algorithm" to solve a network problem of inter-connected reservoirs, river reaches, pump canals, and gravity flow canals. SIMYLD is capable of modeling the ordered preference of storage and release of water throughout the system. Differentiation between storage preferences and demand preferences is achieved by a ranking procedure which is translated into costs of water transfer from node to node. Using the rankings throughout the system, this simulation or quasi-optimization model will apportion the available water to various storage and demand nodes according to their priority. Such an approach allows SIMYLD to successfully incorporate the institutional framework within the physical modeling of a water resource system. This capability makes SIMYLD the most favorable model of those considered for analyzing the physical potential of enhancing recreation opportunities of high mountain reservoirs.

*"Economic Optimization and Simulation Techniques for Management of Regional Water Resource Systems, River Basin Simulation Model, SIMYLD II--Program Description," prepared by the Systems Engineering Division, Texas Water Development Board, Austin, TX, July, 1972.

Program Methodology

The basic principle underlying the operation of SIMYLD is that a physical water resources system can be transformed into a graphical capacitated network configuration. The real components of the system are represented in the network as "nodes" (storage and non-storage) and "links" (canals and river reaches). Reservoirs, demand points, canal diversions, and river confluences are represented as nodes, while river reaches, canals, and closed conduits are nodal linkages. Basic assumptions associated with the model are listed as follows (Figure 1):

1. All storage nodes and linkages must be bounded from above and below.
2. Each link must be unindirectional with respect to flow.
3. All inflows, demands, losses (evaporation, seepage, etc.) must occur at nodal points.
4. An import node and several spill nodes can be designated for water entering the system across a boundary and for losses from the system, respectively.
5. Spills from the system are the most expensive type of water transfer.

Required or desired reservoir operating policies must be provided by the user. For each reservoir, three separate operating rules can be input which correspond to three different hydrologic states calculated monthly by the model. These states are based on parameters input by the user. Associated with each of these states (Average, Dry, Wet) is a corresponding set of operating

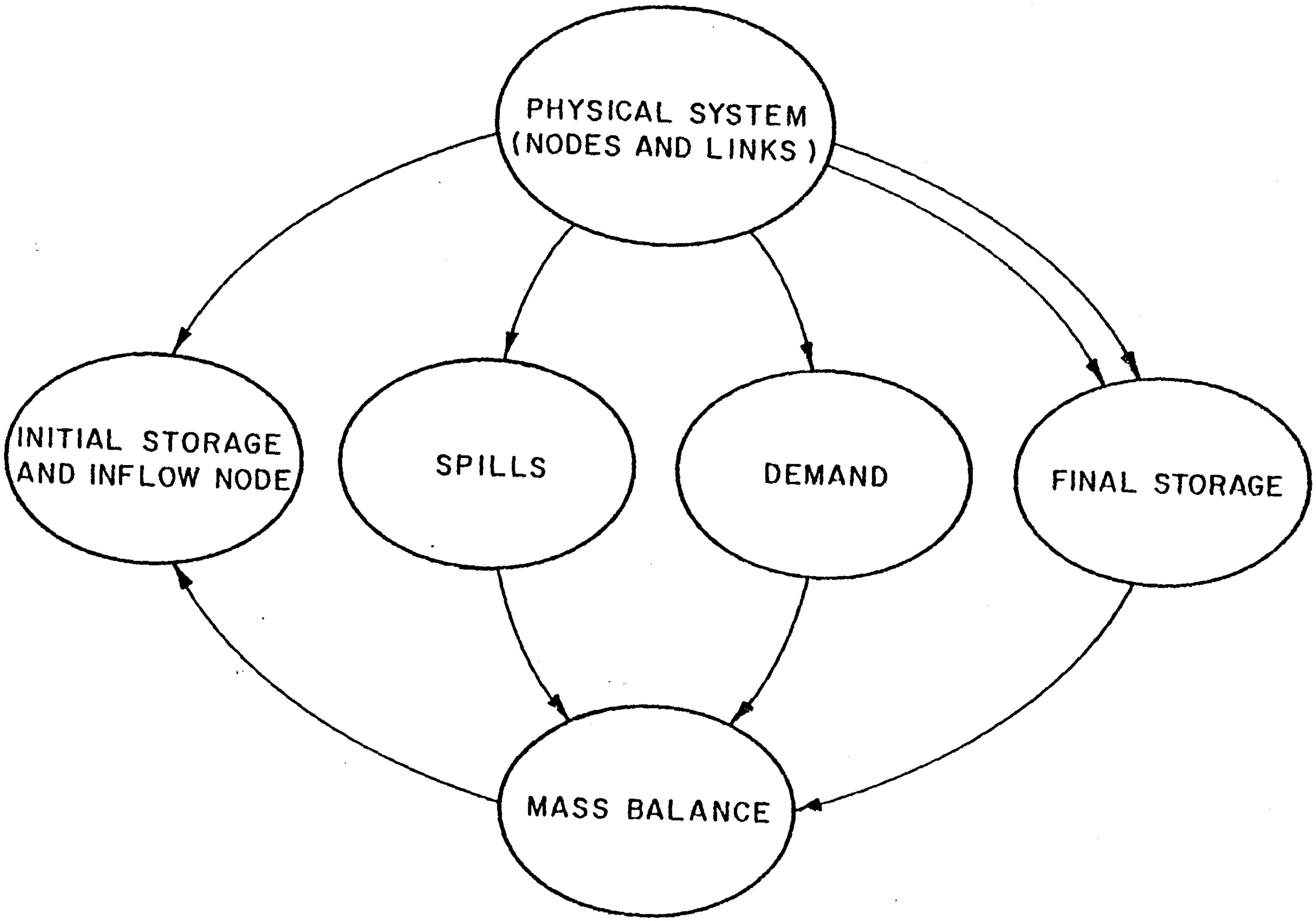


FIGURE 1

SIMPLIFIED FLOW CHART FOR SIMYLD

rules with ranking priorities, along with an additional set of ranking priorities for demand satisfaction. These three hydrologic states are computed by selecting all or some of the reservoirs within the system (user preference) and performing the following analysis:

$$R = \sum_{i=1}^{N} S_{it} + \sum_{i=1}^{N} I_{i,t+1}$$

$$W = \sum_{i=1}^{N} S_{imax}$$

where:

N = number of reservoirs in the system

t = current month of operation

S_{it} = end of month t storage in reservoir i

S_{imax} = storage capacity for reservoir i, which may be less than the actual maximum capacity due to dam stability and safety considerations.

The user also specifies the upper and lower bounds of the average state as fractions of the total subsystem storage capacity:

$$LB = x_1 W$$

$$UB = x_2 W$$

where: x_1 x_2, and

LB = lower bound of average state

UB = upper bound of average state

x_1 = percentage which defines lower limit of average state

x_2 = percentage which defines upper limit of average state

Subsequently the hydrologic states are defined as:

Dry: $R \leq LB$

Average: $LB \leq R \leq UB$

Wet: $R > UB$

Within the confines of mass balance throughout the network, and depending on the particular hydrologic state, SIMYLD sequentially solves the following problem for each month of operation:

$$\min_{q_{ij}} \sum_i \sum_j w_{ij} q_{ij}$$

Subject to:

$$\sum_i q_{ij} - \sum_i q_{ji} = 0; \; j = 1,\ldots,N$$

$$\ell_{ij} \leq q_{ij} \leq u_{ij}; \; \forall \; i,j$$

where:

q_{ij} = flow from node i to node j

w_{ij} = weighting or priority factor per unit flow from node i to node j

ℓ_{ij} = lower bound on flow in link connecting node i to node j

u_{ij} = upper bound on flow in link connecting node i to node j

It should be noted that SIMYLD is defined as a quasi-optimizing model since the network flow problem is solved successively time period by time period, rather than over all periods together. It does, however, compute the optimum deliveries during each time period according to the corresponding priorities, which is an indirect way of linking the time periods.

Data Requirements

The inputs to the model include the following:

1. physical descriptions of the system to be simulated
2. operational criteria
3. monthly unregulated inflows
4. monthly demands
5. monthly evaporation rates

Depending upon the problem size (i.e. number of nodes and number of time periods) a separate data file consisting of flows, demands, and evaporation rates must be created and subsequently attached to SIMYLD for execution.

The card input to SIMYLD is composed of thirteen individual files. Each file is divided into one or more card image records. The following offers a brief description of the information conatined in each file:

- File 1: Contains three records.
    1. The FORTRAN logical unit assignments to the reader, printer, and three tapes.
    2. Title or heading for the simulation.
    3. The system dimensions, such as number of nodes, number of reservoirs, number of links, number of river reaches, number of years to be simulated, number of demand nodes, etc.

- File 2: Describes system nodes (storage and non-storage), as well as maximum and minimum capacities and starting storages.
- File 3: Lists the spill reservoirs in order of preference.
- File 4: Gives reservoir area-capacity tables. For each reservoir there is the capability of inputing up to eighteen matched pairs of surface area versus storage volume data points.
- File 5: Contains the demand rankings or priorities for each node and each hydrologic state.
- File 6: Lists the import node, amount of annual import, and monthly distribution as percentages of the total amount. If a system has no imports this file is left blank.
- File 7: Contains information concerning the reservoirs which contribute to the calculations of the hydrologic states.
- File 8: Lists multipliers to convert output to uniform units. If all inputs are compatible these factors remain unity.
- File 9: Is composed of the operating criteria for each reservoir for each month and each hydrologic state a desired storage level, expressed in percentage of maximum capacity, is input for each reservoir. Along with reservoir operating criteria, priorities for maintaining storage levels are contained in this file.
- File 10: Develops the actual system configuration since it contains link numbers from and to nodes and maximum and minimum link capacities.

- Files 11-13: Compose the junction or nodal data as pertaining to unregulated inflow, demand, and evaporation.

Description of Output

The output from SIMYLD is separated into three summary reports. The first report is an echo of the input information supplied by the user. The number and description of each node along with link capacities and the overall system configuration is also provided.

The second report is an optional detailed annual report giving monthly information node by node. Column headings are completely explanatory and as an example include:

1. Initial storage.
2. Unregulated inflows.
3. Upstream spills.
4. Demand.
5. Surface area.
6. Evaporation loss.
7. Downstream spills.
8. Shortages.
9. System loss.
10. End of month storage.

Note that upstream and downstream spills are identical to controlled releases while losses represent water removed from the system that cannot re-enter (Table 1).

Summaries by node for each year of the entire simulation period compose the third output report. In addition a year by

Table 1. Example Annual Report for Single Node.

SIMULATION YEAR 1 CALENDAR YEAR 1973

RESERVOIR NO 7 HALLIGAN

MONTH	INITIAL STORAGE	URFG INFLOWS	UPSTRM SPILLS	DEMAND	MAX. SURFACE AREA	CAPACITY EVAP RATE	6428 EVAP LOSS	MIN. DWNSTRM SPILLS	OPERATING SHORTAGE	POOL PUMPED INTO	-0 PUMPED OUT	SYSTEM LOSS	END MO. CONTENT	OPER. RULE
1	1014	1101	0	0	119	-.10	-11	133	0	0	0	0	1993	6428
2	1993	780	154	0	155	-.01	-1	0	0	0	0	0	2928	6428
3	2928	1412	109	0	192	.07	13	0	0	0	0	0	4436	6428
4	4436	930	50	0	222	.09	19	149	0	0	0	0	5248	6428
5	5248	1218	0	0	245	.11	27	50	0	0	0	0	6389	6428
6	6389	0	1697	0	258	.04	10	1648	0	0	0	0	6428	6428
7	6428	0	657	0	220	.21	47	3950	0	0	0	0	3088	6428
8	3088	0	4151	0	220	.38	83	728	0	0	0	0	6428	6428
9	6428	0	184	0	257	.25	65	184	0	0	0	0	6363	6428
10	6363	0	85	0	238	.39	93	1647	0	0	0	0	4708	6428
11	4708	0	164	0	207	.15	31	1059	0	0	0	0	3782	6428
12	3782	0	1737	0	217	.17	36	0	0	0	0	0	5483	6428
YEAR TOTALS.		5441	8988	0			412	9548	0	0	0	0		

year report for each node is also printed. Finally, a summary of average flow in each link plus maximum flow in each monthly time period are given.

Discussion

For purposes of conducting the case study the calculation of the hydrologic state was overridden. Instead of selecting one of three possible operating rules for any particular reservoir in any particular month, based on the hydrologic state, the operating criteria have a one to one correspondence with each month. If many years are to be simulated, the above option is not available. However, only three years of data were analyzed in the case demonstration, allowing each monthly reservoir operating rule in each year to be unique. Therefore, instead of considering average, dry, and wet seasons over an extended planning horizon, years one through three possessed independent operating criteria.

There are instances where, due to one reason or another, infeasibilities will occur in the solution of the network algorithm. To avoid this pitfall, the user should pay careful attention to the development of the system configuration. Infeasibilities can be the result of failure to allow an adequate number of spill nodes, minimum canal or channel capacities which are too constraining, or basic data problems.

As SIMYLD is presently running on the CDC 6400 computer at Colorado State University it is capable of handling 30 reservoirs and 40 links over a ten year period. The dimensions can easily be expanded to incorporate larger problems. A simulation of 29 nodes and 30 links over a three year period uses approximately 26 CP seconds, and 124 K core storage.

DESCRIPTION OF CASE STUDY

Selection of Study Area and Multi-reservoir System

As mentioned earlier, the Cache la Poudre River basin in northern Colorado was selected as the river basin to apply Program SIMYLD. As part of Water Division 1, District 3, the Cache la Poudre River basin has as complex a system of interrelated water storage and distribution structures and regulations as anywhere along the Front Range (Figure 2). District 3 is also one of the most productive agricultural areas in Colorado. Consequently, irrigated agriculture has clearly dominated the water use in the area.

Several high mountain reservoirs are located within the boundaries of the basin. In the past, these reservoirs have been used exclusively for storage of water for irrigation, often being completely emptied toward the end of the irrigation season. Attention has been focused on these reservoirs for development of a multipurpose framework allowing the inclusion of recreation. These reservoirs are ideal for study in that they are under common ownership and are not managed for recreation. District 3 is also favorable as a study area since there has been much previous modeling work done there, though under objectives different from this study. Since the Cache la Poudre River is highly over-appropriated, it affords the challenge of modeling a system in great need of comprehensive planning studies.

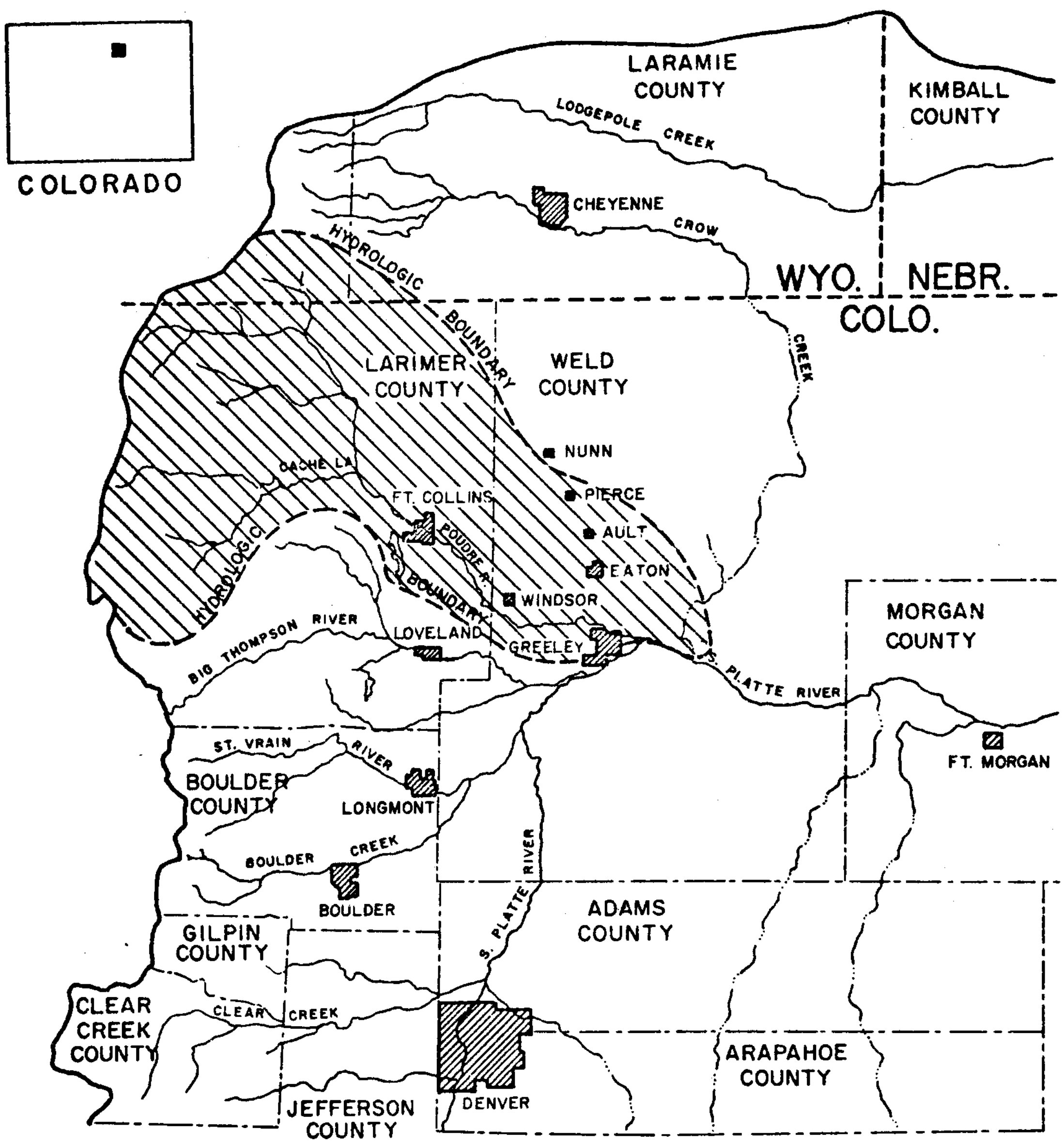


Figure 2. Location of Cache la Poudre River Basin (Evans, 1971)

Due to the interdependence of system components, management of the high mountain reservoirs cannot be analyzed without proper consideration of the demand points for their stored water. However, once the reservoirs to be studied have been identified, along with the various distribution and use subsystems to which they contribute water, a spatial decomposition will isolate this subsystem of water supply, distribution, and use for further analysis. As long as all sources and sinks of reservoir water in the subsystem are considered, a meaningful study of the decomposed subsystem can be carried out even though the entire system is no longer under investigation. This approach allows the problem to remain tractable without great sacrifice in accuracy or detail.

The City of Greeley, Colorado owns and operates six high mountain reservoirs in the Cache la Poudre River basin. Of these six reservoirs, water stored in five is sold on a seasonal basis to the North Poudre Irrigation Company and water stored in the sixth (Milton Seaman) is used for exchange purposes and municipal supply. The first five Greeley-owned reservoirs are Peterson, Barnes Meadow, Comanche, Twin Lake and Big Beaver. These reservoirs, along with the North Poudre Irrigation Company reservoir and canal system, form an autonomous unit in that all water originating in the Greeley reservoirs are delivered to the North Poudre system (Figure 3). This is not to say that the Greeley reservoirs supply only water for North Poudre Irrigation Company. It is true, however, that the only sink

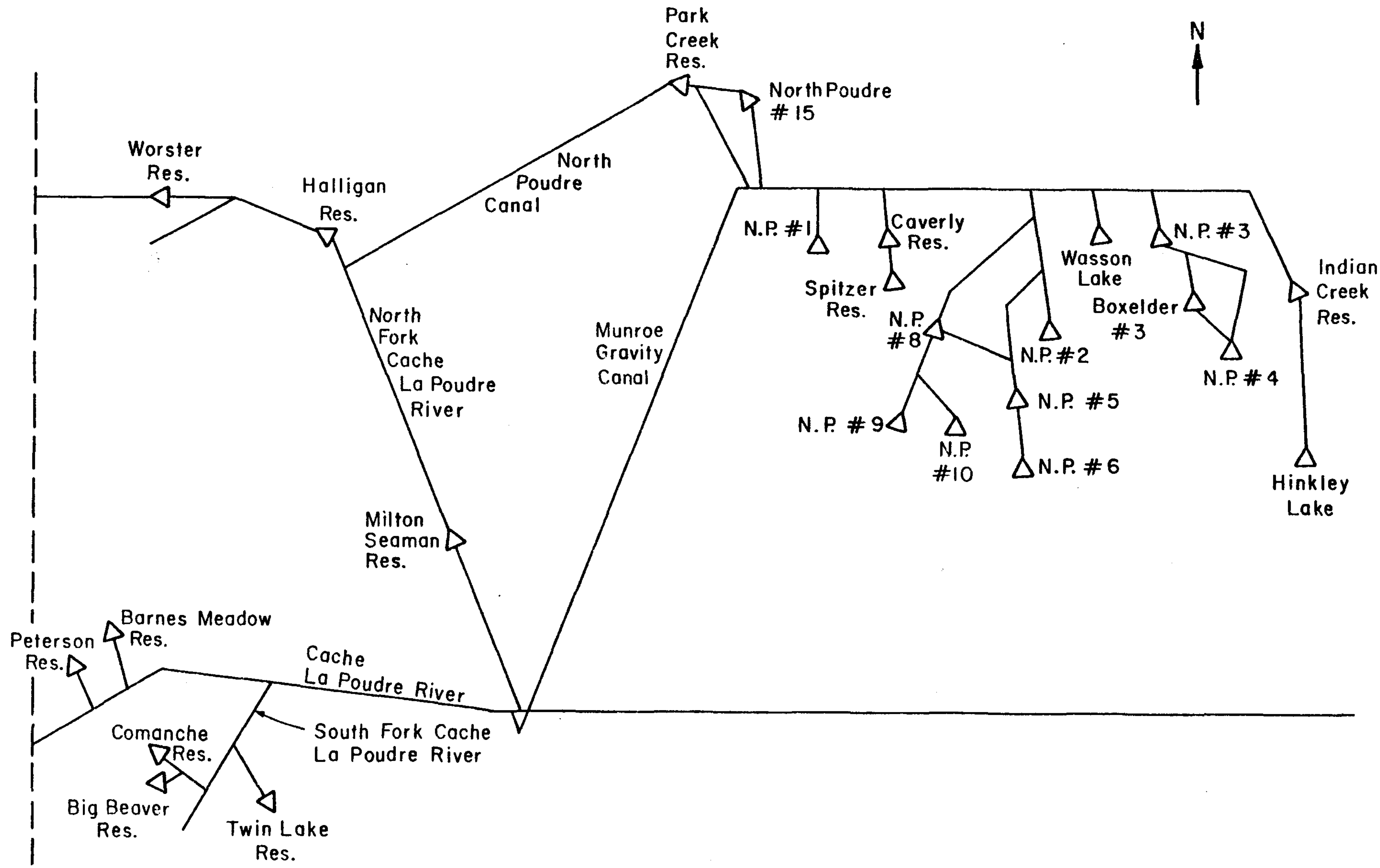


FIGURE 3

RESERVOIR AND CANAL SYSTEM FOR CASE STUDY for water from the five Greeley reservoirs is the North Poudre Irrigation Company system.

System Configuration

Only the demand for intrabasin high mountain reservoir water is of interest for this problem. Therefore, imports are ignored, along with direct flow of river water to irrigation. Since the origin of the reservoir water contributing to demand satisfaction is the only concern, its final destination can be considered a single demand center without introducing any error into the analysis. All of the individual North Poudre Irrigation Company plains reservoirs (North Poudre Reservoir Number 1 and those to the east) provide water to turnouts for application to fields. Of particular importance, however, is the total monthly volume of mountain reservoir water supplied to these reservoirs. Therefore, they can be aggregated into one large plains reservoir whose total surface area and storage volume is equal to the sums of the surface acreages and volumes of the individual plains reservoirs. This maneuver allows the total monthly demand for water from the mountain reservoirs to be lumped together at one demand center (Figure 4).

Once the physical system has been isolated, and all important components identified, it must be translated into a corresponding graphical network of nodal points and likages. Care must be exercised during this translation to insure that the essence of the physical system is captured in its entirety. All nodes

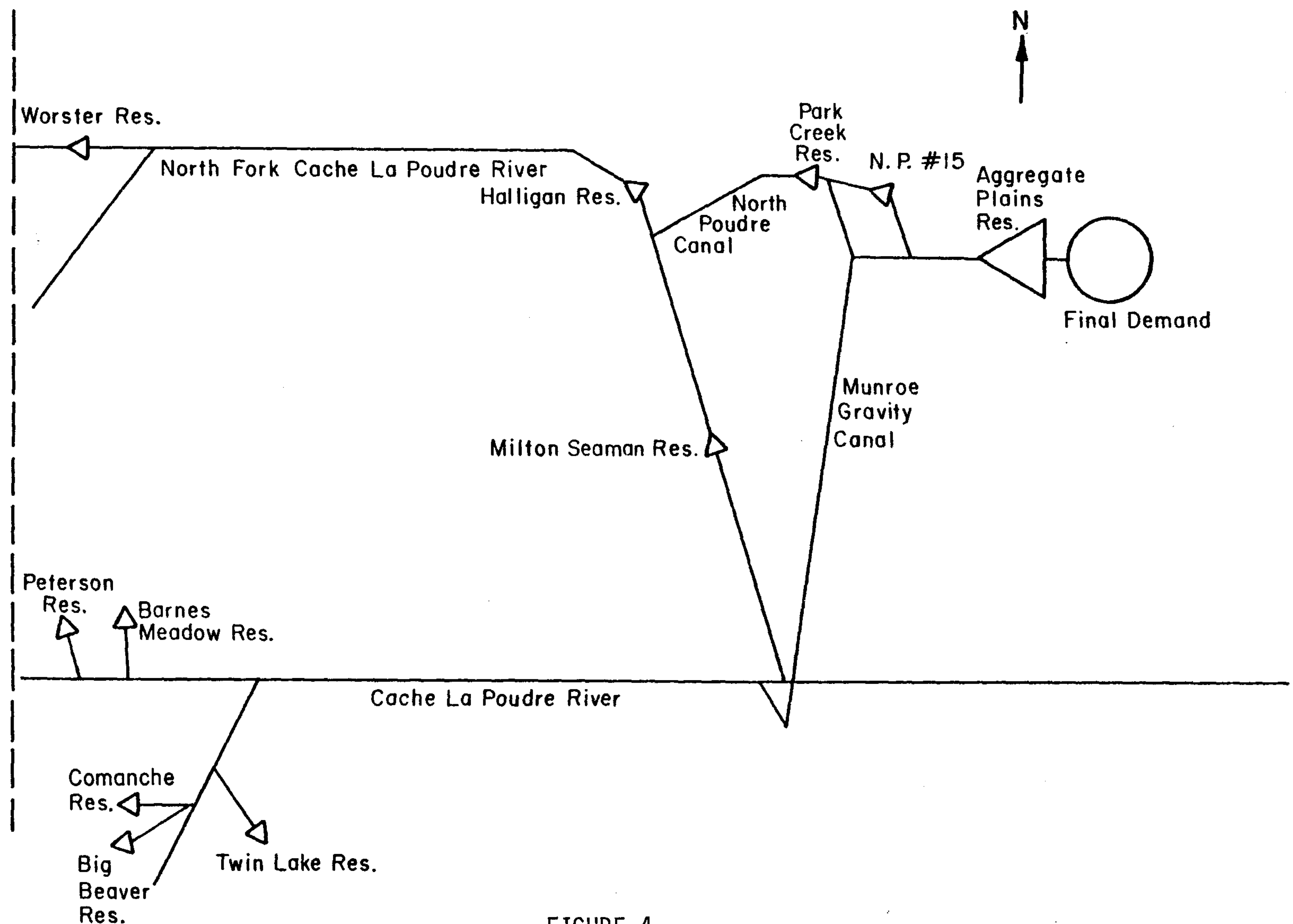


FIGURE 4

CASE STUDY WITH AGGREGATED PLAINS RESERVOIRS and links are then labeled numerically. Reservoirs must be labeled first, followed by non-storage nodes. Links are labeled last, and although they can be labeled in any order, it seems logical and also more systematic if they are labeled in increasing order downstream. After labeling of the nodes and links, spill nodes should be determined (Figure 5).

Data Organization

Data requirements for performance of the case study were met from three main sources:

1. Detailed daily diversion data for all structures in Water District 3 were gathered from the Colorado Water Data Bank and made available through the Division of Water Resources, State Engineer's Office.
2. The Bureau of Reclamation, Denver Office, provided information concerning evaporation rates from reservoir surfaces. These data were subsequently refined in order to better reflect conditions in the study area.
3. The Water Commissioner for District 3 was a valuable source of information for the case study. The Commissioner provided data on reservoir characteristics, channel and canal capacities, and channel losses throughout the system.

The three-year period beginning in November, 1972, and ending October, 1975 was used for the analysis. Although all information necessary for simulating this period is available,

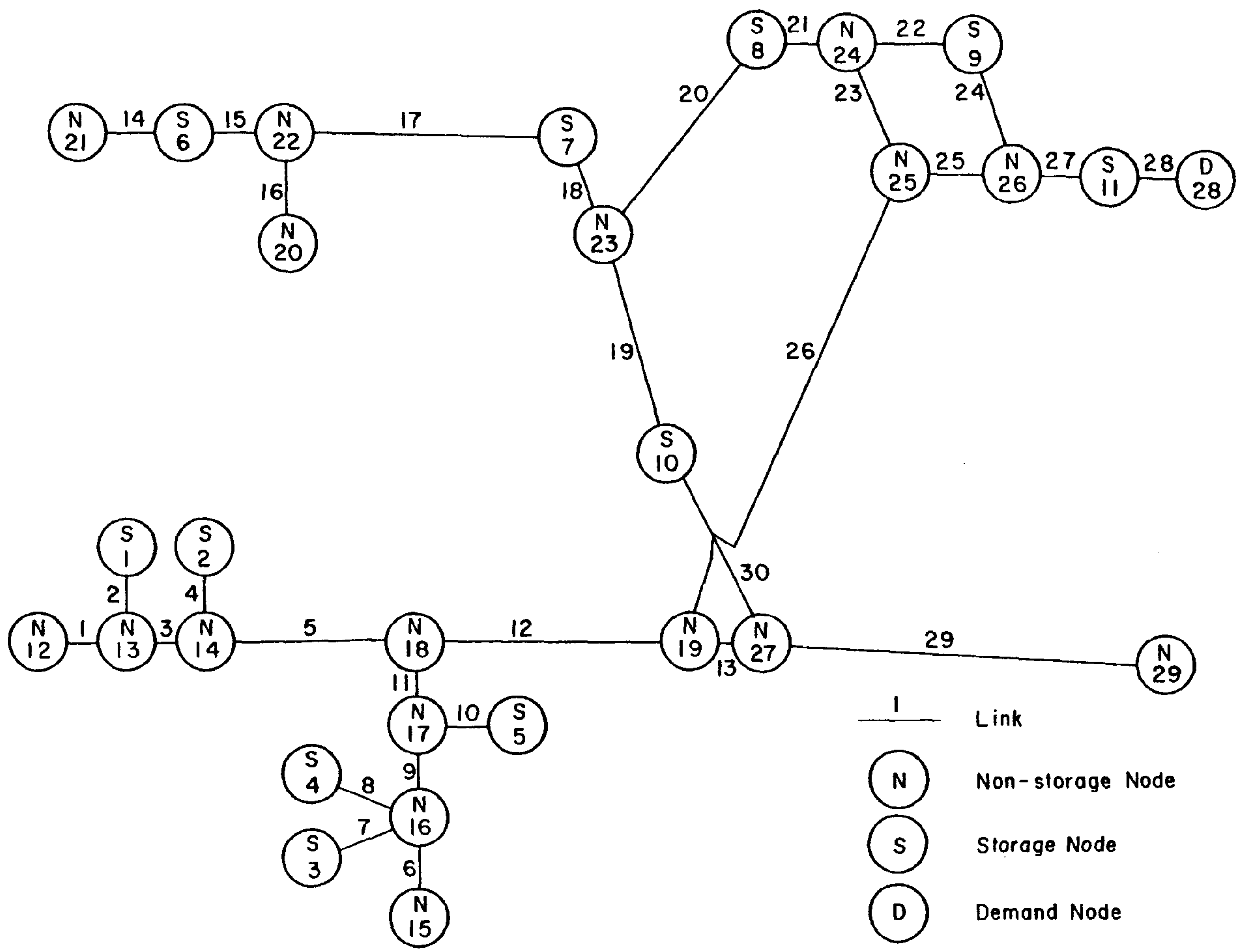


FIGURE 5

LINK-NODE CONFIGURATION FOR CASE STUDY

data for previous years are sketchy and unreliable. Fortunately, these years represent a good approximation of a wet to moderately dry hydrologic trend. The year 1975 was the beginning of a drier than average period of precipitation along the Front Range.

Reservoir Characteristics. The following table lists the reservoirs in the system, their node numbers, maximum storage capacities, and starting storage volumes. Those reservoirs eventually considered for recreational development are marked with an asterisk. Surface area versus capacity curves can be constructed from formulas developed by regression analyses or by plotting points obtained from storage volume versus gage height tables.

Channel Characteristics. In order to maintain consistency in the units, channel carrying capacities were converted from cubic feet per second to acre feet per month. A channel capacity of 5000 cfs for the main stem of the Cache la Poudre River towards the headwaters is equivalent to 300,000 acre feet per month. Likewise, the capacity of the south branch of the Cache la Poudre River is 30,000 acre feet per month; north fork channel capacity is 91,000 acre feet per month; Munroe Gravity Canal capacity is 15,000 acre feet per month; and the capacity of the North

Table 2. Reservoir Characteristics (ac. ft.)

Reservoir Name	Node Number	Maximum Capacity	Initial Storage
*Peterson	1	1409	0
*Barnes Meadow	2	2682	0
*Big Beaver	3	1526	0
*Comanche	4	2629	229
*Twin Lake	5	278	0
Worster	6	3750	71
Halligan	7	6428	1014
Park Creek	8	8500	4222
North Poudre 15	9	5517	4304
Milton Seaman	10	5008	2460
Aggregate Plains	11	34348	0

Poudre Canal is 7,500 acre feet per month.*

Channel losses must also be considered if the analysis is to be as realistic as possible. Depending on the particular conveyance structure, the loss due to seepage will be some percentage of the total monthly volume transmitted. In any one month the expected loss from seepage along the mainstream of the Cache la Poudre River will average around 5 percent of the total volume carried. For example, if in June of one year the main channel conveyed 5000 acre feet, then a loss of 0.05 x 5000 acre feet, or 250 acre feet, could be expected. Therefore, if the downstream requirement is 5000 acre feet, 5263 acre feet must be released. Similarly, a 3.4 percent loss can be expected from the North Fork of the Cache la Poudre River, while a value as high as 20 percent is accepted for the canals.*

*The information in this paragraph was transmitted to the authors through interview with Mr. Jack Neutze, Water Commissioner for District 3.

Evaporation rates. The determination of accurate evaporation rates presented some difficulty during the data organization phase. The rates that were made available from the Bureau of Reclamation were not specific to the immediate geographic region. Even though these evaporation rates were computed from pan evaporation data gathered from different elevations throughout the state, the monthly distribution of the annual total was deemed acceptable. Due to the change in elevation from the plains reservoirs (approximately 5000 ft. to 6000 ft. above sea level) to the high mountain reservoirs (approximately 8000 ft. to 9000+ ft. above sea level), two different gross evaporation rates were used from which net evaporation rates (i.e.,less precipitation) were computed. The monthly distribution of the annual gross evaporation rate for the high mountain reservoirs was adjusted somewhat to better reflect periods of ice and snow cover during winter months and higher wind velocities during summer months (Figure 6). Annual summaries of climatological data obtained from the Office of the State Climatologist, Colorado State University were used to calculate the net evaporation for each month of the 26 month simulation period. The mean annual evaporation for the stations at Grand Lake (elevation 8288 ft.), and Fort Collins (elevation 5001 ft.), were separated into monthly rates according to the distribution percentages previously discussed. The actual monthly precipitation for stations at Red Feather Lakes (elevation 8237 ft.) and Fort Collins were then subtracted from these gross monthly

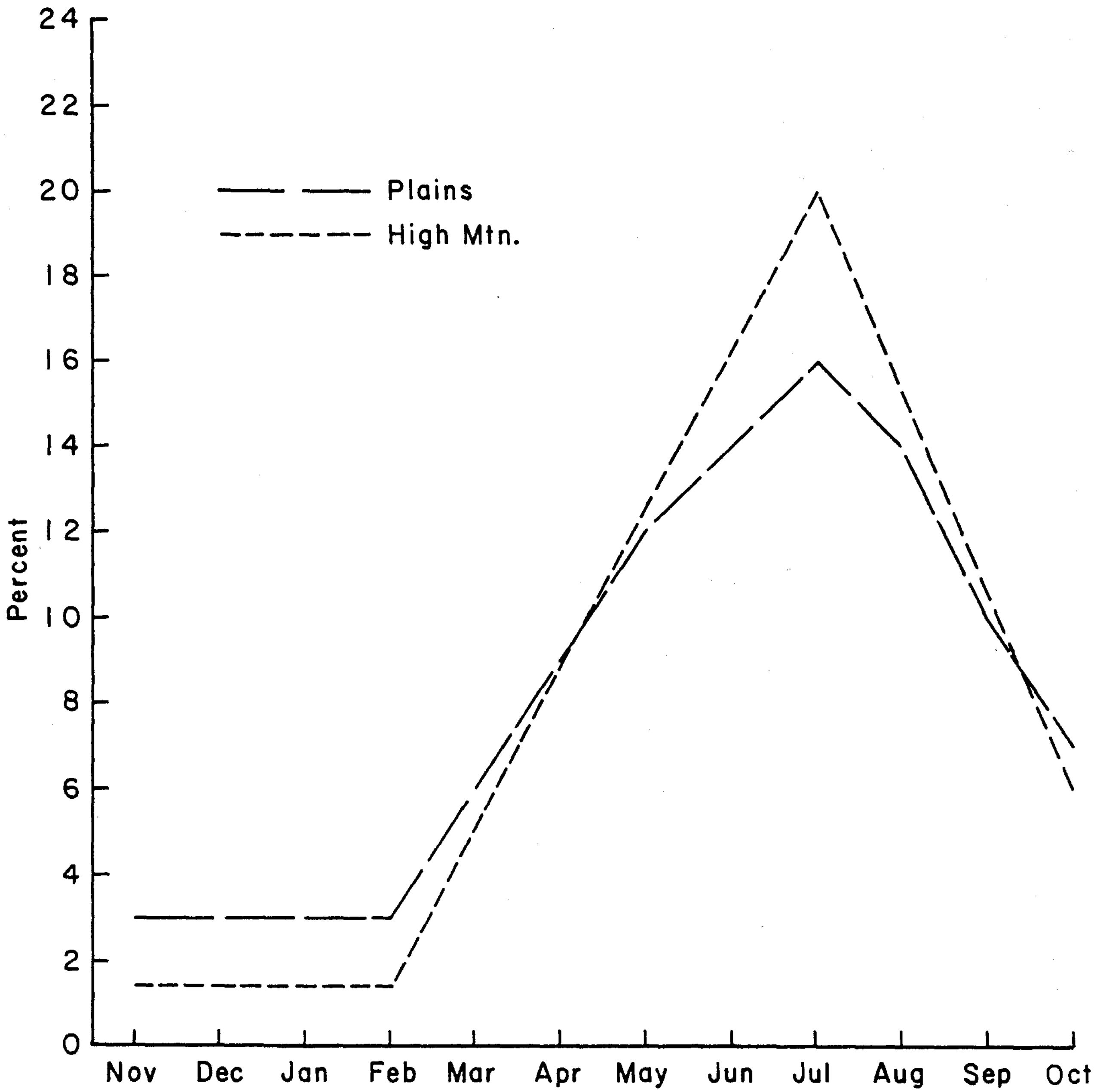


FIGURE 6

MONTHLY DISTRIBUTION OF EVAPORATION AS PERCENT OF GROSS ANNUAL RATE rates. Grand Lake was selected as being the closest representative of the evaporation the study area could expect, based on latitude and elevation, even though it is not in the region. This was necessary because of the dearth of evaporation recording stations. Precipitation data were used from Red Feather Lakes, which is in the study area at the same elevation as Grand Lake. Based on other information pertaining to evaporation rates and an intuitive feeling concerning the actual rates, these net rates are considered acceptable and reasonably conservative for purposes of this study. Figures 7 and 8 display the monthly net evaporation rates for the plains reservoirs and high mountain reservoirs, respectively.

Unregulated inflows. Information obtained from the Colorado Water Data Bank was used to compute unregulated inflows. Each reservoir has several entries in the Data Bank, of which one or more is a daily listing of the amount of water that went directly to storage. These records were used to compile a month-by month summary of unregulated inflows to each reservoir throughout the system. Caution had to be exercised to insure that no double accounting of flows occurred.

Demand for reservoir water. Perhaps the most difficult aspect of the entire study was the determination of the amount of water from the supply subsystem that was delivered to the aggregated plains reservoirs and eventually applied to cropland. Once again, the Colorado Water Data Bank proved an invaluable source of information. A complex accounting of all deliveries to the

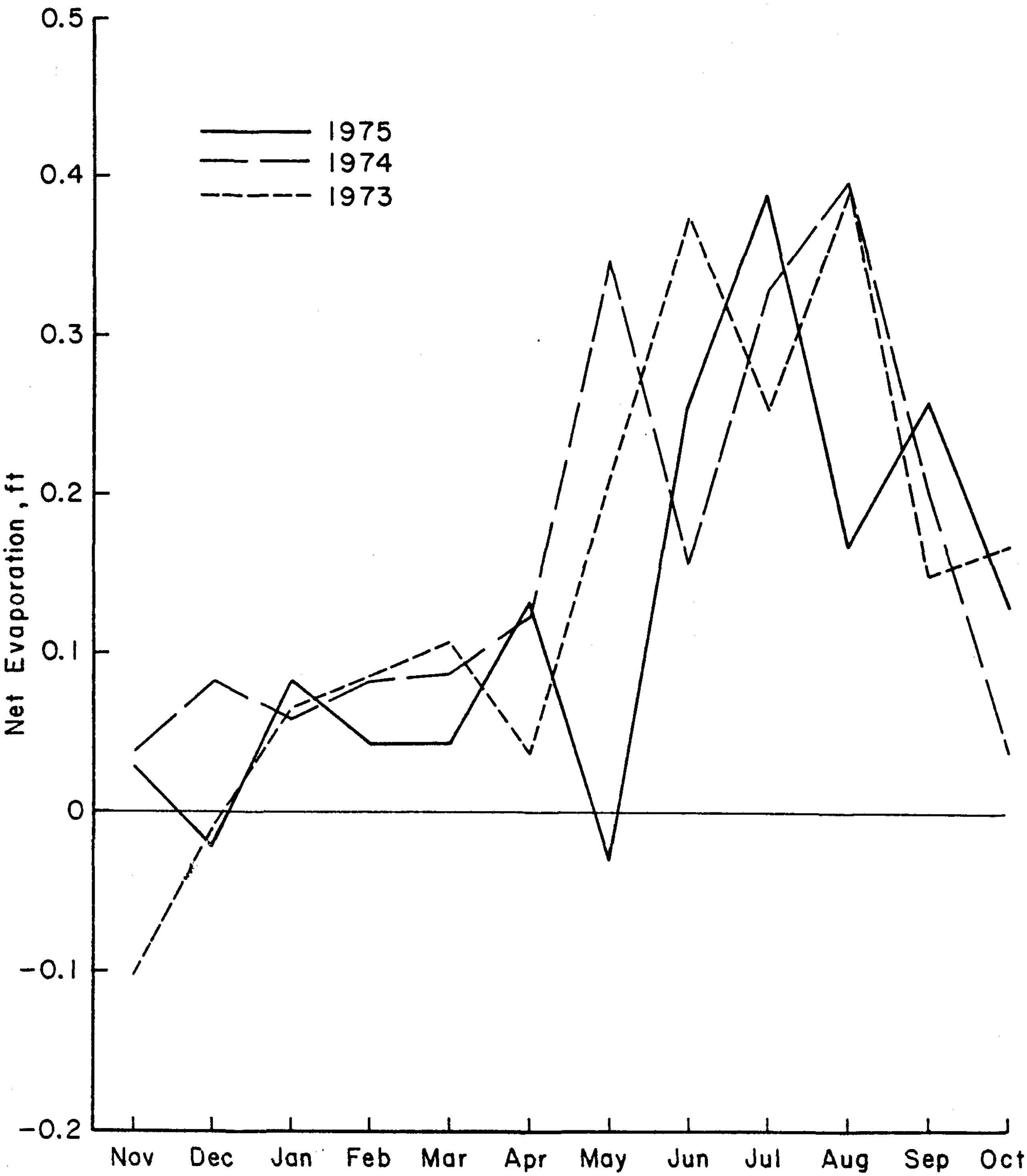


FIGURE 7

NET EVAPORATION RATES FOR PLAINS RESERVOIRS

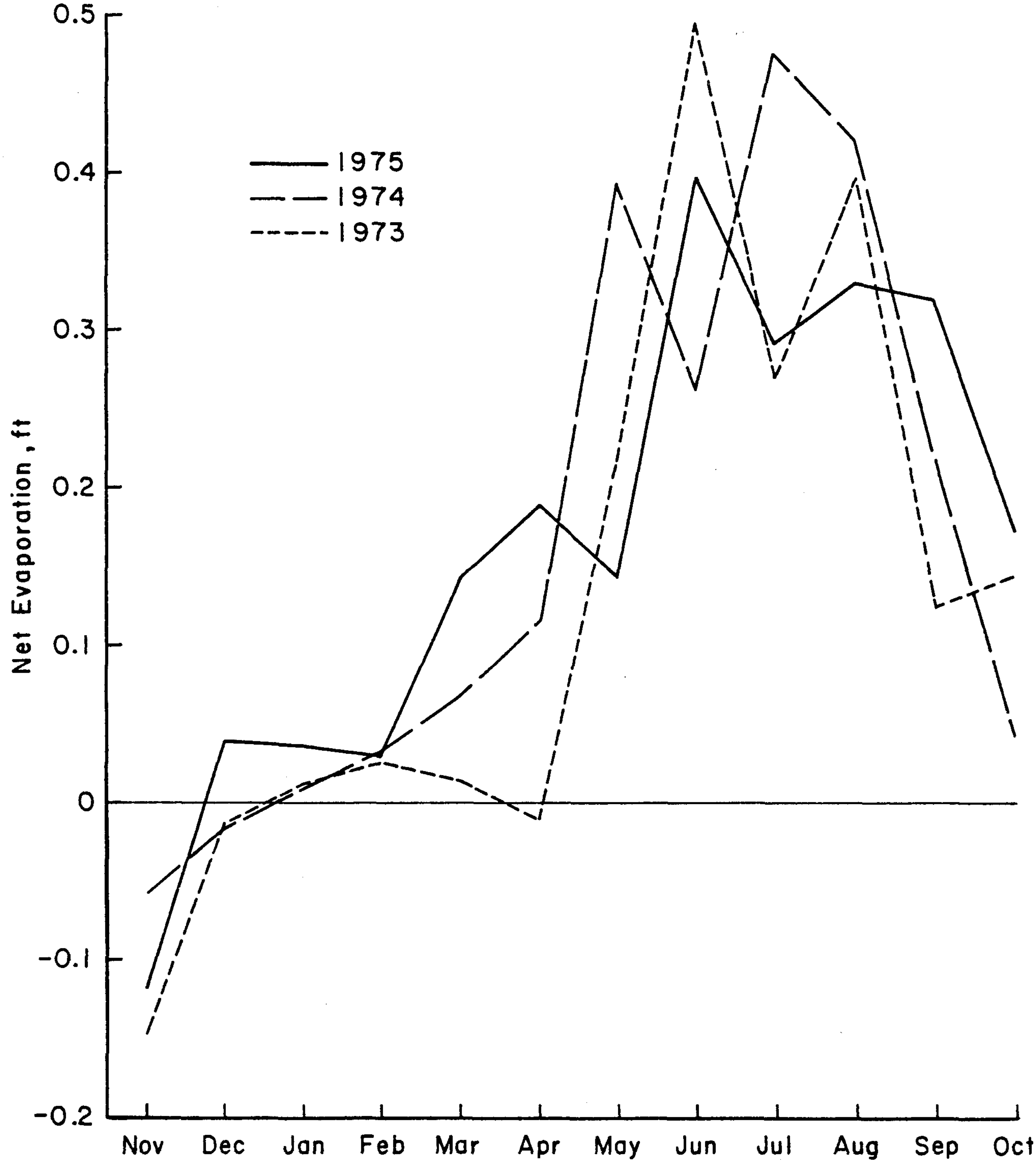


FIGURE 8

NET EVAPORATION RATES FOR HIGH MOUNTAIN RESERVOIRS canal system was undertaken to determine the total monthly amount of water provided by the reservoirs in question. The Data Bank includes tabulated daily flows at the headgates of the Munroe Gravity Canal and the North Poudre Canal which are divided into categories corresponding to the origin of the water (i.e., direct, transbasin, diversion, reservoir, exchange, etc.). Once the total amount of reservoir water delivered to the canal was determined, the amount contributed from the reservoirs in question could be isolated. This amount is the volume gaged at the headgates. Adjustments had to be made for inflows and releases from Park Creek and North Poudre Number 15 reservoirs downstream from the headgates of the canals. This demand for reservoir water had translated to the final demand node of the network. Since this represents the water actually measured at the headgates, losses in the canals were not considered any further. Losses from the river channels, however, must be considered in the simulation. Table 3 is a month-by-month summary of the net volume of water contributed historically from the reservoirs above the aggregated plains reservoir during the 1973 to 1975 period.

TABLE 3

FINAL DEMAND FOR RESERVOIR WATER (ACRE-FEET)

Month*	Year '72-'73	'73-'74	'74-'75
1	0	0	79
2	0	0	0
3	0	0	119
4	0	564	38
5	0	158	0
6	0	1129	273
7	418	4059	2348
8	218	737	0
9	2172	3845	3383
10	9958	7089	9755
11	2357	5657	8889
12	0	44	505
Total	15123	23282	25389

*Month 1 corresponds to November
Month 12 corresponds to October

MODEL CALIBRATION

Procedure

The model calibration phase followed completion of data gathering and organization. A considerable amount of time and patience was required to calibrate SIMYLD. Model calibration is extremely important, however, and the time spent is justly served. Successful calibration is the foundation upon which confidence in future findings is based.

Duplication of the historical release policy of the system reservoirs (except Milton Seaman) was the goal of the calibration phase. The actual gaged end-of-month storage volumes became the operating rules for each reservoir. An acceptance criterion of 5.0% or less deviation of the calculated storage from the historically observed storage in each reservoir for each month was originally imposed. Differing release policies which all met the final demand were simulated by adjusting the priorities set on each reservoir for maintaining storage. Continued adjustment of the priorities eventually led to a release policy which met the demand and also reasonably reproduced the historical monthly storage levels (Figure 4).

TABLE 4

RESERVOIR STORAGE PRIORITIES

	Priority		
Reservoir	'72-'73	'73-'74	'74-'75
Peterson	50	50	48
Barnes Meadow	50	55	45
Big Beaver	50	50	50
Comanche	55	50	50
Twin Lake	50	50	50
Worster	70	46	48
Halligan	60	60	48
Park Creek	70	70	48
N.P. #15	80	80	47

The calibration process was hindered by the fact that the observed storage record was, in some cases, not properly adjusted for evaporation. For example, the record shows that in 1974 Peterson Reservoir filled to 1183 acre feet by June. With no additional inflow and no release made until September, according to the observed data obtained from the Colorado Water Data Bank, the water in storage remained at 1183 acre feet. This example, and others, tend to suggest that evaporation was not accurately accounted for in the actual storage documentation. For the same period of record, using the calculated evaporation rate, SIMYLD computes an evaporation loss of 58 acre feet. The effect of evaporation loss on system performance is significant. Errors caused by the failure to incorporate evaporation in the determination of actual storage volumes accumulate over the simulation period. Unacceptable deviations of calculated storage from observed storage began to regularly occur in 1975. These deviations can, for the most part, be attributed to the discrepancy in evaporation rates and to a slight degree of roundoff error. On this basis, the model was considered calibrated even though some deviations were greater than desired.

Losses from the river channels were also considered. SIMYLD, however, is only capable of computing losses that can be lumped together at nodal points. For this reason, an iterative process was developed for incorporating channel losses into the analysis. One section of the output provided by the program is a month-by-month listing of the total volume of flow (acre feet) in each link. By selecting the proper links the losses can be computed external to the program. These losses are then entered as monthly demands at the first upstream node from the link where the losses occurred. The simulation is repeated with the losses entered as demands. This procedure is followed until convergence is reached. Usually, no more than three iterations are required to gain satisfactory results.

Calibration Results

A separate computer program was written which calculates deviations of calculated storage from the observed according to the formula:

$$x_{i,t} = \frac{100(SA_{i,t} - SC_{i,t})}{SA_{i,t}} \qquad SA > 0 \quad SC > 0$$

$$x_{i,t} = \frac{100(SA_{i,t} - SC_{i,t})}{SC_{i,t}} \qquad SA = 0 \quad SC > 0$$

$$x_{i,t} = 0 \qquad SA = SC = 0$$

$i = 1,\ldots,$ number of reservoirs

$t = 1,\ldots,$ number of months

Where:

$x_{i,t}$ = percent deviation for reservoir i during month t

$SA_{i,t}$ = observed month t ending storage for reservoir i

$SC_{i,t}$ = month t ending storage for reservoir i computed by SIMYLD.

Table 5 lists the complete summary of the results of the model calibration.

Discussion

Milton Seaman Reservoir presented a problem in the analysis in that although it is owned and operated by the City of Greeley, it does not directly contribute to the North Poudre Irrigation Company system. Seaman Reservoir also is considered to have little or no recreational potential by other members of the project team.

The reservoir, however, does contribute slightly to the irrigation system in an indirect fashion through an exchange process. In this analysis, Seaman Reservoir is viewed as an

TABLE 5 SUMMARY OF NODE CALIBRATION

RESERVOIR NAME	YEAR	MONTH	ACTUAL STORAGE	CALCULATED STORAGE	DIFFERENCE	PERCENT DEV.
PETERSON	1973	1	0	0	0	0.0
PETERSON	1973	2	0	0	0	0.0
PETERSON	1973	3	0	0	0	0.0
PETERSON	1973	4	0	0	0	0.0
PETERSON	1973	5	0	0	0	0.0
PETERSON	1973	6	26	25	1	3.8
PETERSON	1973	7	445	437	8	1.8
PETERSON	1973	8	1184	1154	30	2.5
PETERSON	1973	9	1184	1183	1	.1
PETERSON	1973	10	1184	1163	21	1.8
PETERSON	1973	11	0	0	0	0.0
PETERSON	1973	12	0	0	0	0.0
BNS MEADOW	1973	1	0	0	0	0.0
BNS MEADOW	1973	2	0	0	0	0.0
BNS MEADOW	1973	3	0	0	0	0.0
BNS MEADOW	1973	4	0	0	0	0.0
BNS MEADOW	1973	5	0	0	0	0.0
BNS MEADOW	1973	6	0	0	0	0.0
BNS MEADOW	1973	7	0	0	0	0.0
BNS MEADOW	1973	8	0	0	0	0.0
BNS MEADOW	1973	9	0	0	0	0.0
BNS MEADOW	1973	10	0	0	0	0.0
BNS MEADOW	1973	11	1241	1234	7	.6
BNS MEADOW	1973	12	1232	1221	11	.9
BIG BEAVER	1973	1	0	0	0	0.0
BIG BEAVER	1973	2	0	0	0	0.0
BIG BEAVER	1973	3	0	0	0	0.0
BIG BEAVER	1973	4	0	0	0	0.0
BIG BEAVER	1973	5	0	0	0	0.0
BIG BEAVER	1973	6	0	0	0	0.0
BIG BEAVER	1973	7	0	0	0	0.0
BIG BEAVER	1973	8	1359	1333	26	1.9
BIG BEAVER	1973	9	1227	1226	1	.1
BIG BEAVER	1973	10	0	0	0	0.0
BIG BEAVER	1973	11	0	0	0	0.0
BIG BEAVER	1973	12	0	0	0	0.0
COMMANCHE	1973	1	417	418	-1	.2
COMMANCHE	1973	2	430	430	0	0.0
COMMANCHE	1973	3	430	429	1	.2
COMMANCHE	1973	4	430	427	3	.7
COMMANCHE	1973	5	430	426	4	.9
COMMANCHE	1973	6	430	426	4	.9
COMMANCHE	1973	7	430	431	-1	.2
COMMANCHE	1973	8	1918	1916	2	.1
COMMANCHE	1973	9	1801	1800	1	.1
COMMANCHE	1973	10	0	0	0	0.0
COMMANCHE	1973	11	0	0	0	0.0
COMMANCHE	1973	12	172	169	3	1.7
TWIN LAKE	1973	1	0	0	0	0.0
TWIN LAKE	1973	2	0	0	0	0.0
TWIN LAKE	1973	3	0	0	0	0.0
TWIN LAKE	1973	4	0	0	0	0.0
TWIN LAKE	1973	5	0	0	0	0.0
TWIN LAKE	1973	6	0	0	0	0.0
TWIN LAKE	1973	7	0	0	0	0.0
TWIN LAKE	1973	8	276	268	8	2.9
TWIN LAKE	1973	9	211	211	0	0.0
TWIN LAKE	1973	10	0	0	0	0.0
TWIN LAKE	1973	11	0	0	0	0.0
TWIN LAKE	1973	12	0	0	0	0.0
WORSTER	1973	1	136	135	1	.7
WORSTER	1973	2	175	172	3	1.7
WORSTER	1973	3	261	235	26	10.0
WORSTER	1973	4	305	270	35	11.5
WORSTER	1973	5	378	342	36	9.5
WORSTER	1973	6	500	451	49	9.8
WORSTER	1973	7	2945	2916	29	1.0
WORSTER	1973	8	3750	3560	190	5.1
WORSTER	1973	9	3750	3459	291	7.8
WORSTER	1973	10	1436	1436	0	0.0
WORSTER	1973	11	0	0	0	0.0
WORSTER	1973	12	91	89	2	2.2
HALLIGAN	1973	1	2114	2114	0	0.0
HALLIGAN	1973	2	2894	2892	2	.1
HALLIGAN	1973	3	4306	4306	0	0.0
HALLIGAN	1973	4	5233	5232	1	.0
HALLIGAN	1973	5	6428	6428	0	0.0
HALLIGAN	1973	6	6428	6428	0	0.0
HALLIGAN	1973	7	6428	6428	0	0.0
HALLIGAN	1973	8	6428	6428	0	0.0
HALLIGAN	1973	9	6428	6428	0	0.0
HALLIGAN	1973	10	4306	4306	0	0.0
HALLIGAN	1973	11	0	0	0	0.0
HALLIGAN	1973	12	0	0	0	0.0
PARK CREEK	1973	1	4222	4224	-2	.0
PARK CREEK	1973	2	4222	4224	-2	.0
PARK CREEK	1973	3	4222	4218	4	.1
PARK CREEK	1973	4	4222	4210	12	.3
PARK CREEK	1973	5	4222	4200	22	.5
PARK CREEK	1973	6	6194	6164	30	.5
PARK CREEK	1973	7	6145	6145	0	0.0
PARK CREEK	1973	8	7252	7206	46	.6
PARK CREEK	1973	9	5837	5839	-2	.0
PARK CREEK	1973	10	5107	5108	-1	.0
PARK CREEK	1973	11	6593	6595	-2	.0
PARK CREEK	1973	12	7063	6576	487	6.9
N.P. 15	1973	1	4304	4303	1	.0
N.P. 15	1973	2	4304	4303	1	.0
N.P. 15	1973	3	4304	4284	20	.5
N.P. 15	1973	4	4304	4260	44	1.0
N.P. 15	1973	5	4304	4229	75	1.7
N.P. 15	1973	6	4304	4218	86	2.0
N.P. 15	1973	7	5424	5371	53	1.0
N.P. 15	1973	8	5207	5208	-1	.0
N.P. 15	1973	9	4648	4645	3	.1
N.P. 15	1973	10	2795	2510	285	10.2
N.P. 15	1973	11	4192	4192	0	0.0
N.P. 15	1973	12	4192	4144	48	1.1

TABLE 5 CONTINUED

PETERSON	1974	1	34	33	1	2.9
PETERSON	1974	2	60	59	1	1.7
PETERSON	1974	3	60	59	1	1.7
PETERSON	1974	4	60	58	2	3.3
PETERSON	1974	5	60	57	3	5.0
PETERSON	1974	6	60	55	5	8.3
PETERSON	1974	7	1100	1080	20	1.8
PETERSON	1974	8	1183	1150	33	2.8
PETERSON	1974	9	1183	1126	57	4.8
PETERSON	1974	10	1183	1105	78	6.6
PETERSON	1974	11	0	0	0	0.0
PETERSON	1974	12	0	0	0	0.0
BNS MEADOW	1974	1	1232	1225	7	.6
BNS MEADOW	1974	2	1232	1225	7	.6
BNS MEADOW	1974	3	1232	1225	7	.6
BNS MEADOW	1974	4	1232	1222	10	.8
BNS MEADOW	1974	5	1232	1216	16	1.3
BNS MEADOW	1974	6	1415	1387	28	2.0
BNS MEADOW	1974	7	1850	1850	0	0.0
BNS MEADOW	1974	8	2045	2024	18	.9
BNS MEADOW	1974	9	2458	2392	66	2.7
BNS MEADOW	1974	10	2296	2295	1	.0
BNS MEADOW	1974	11	1425	1424	1	.1
BNS MEADOW	1974	12	1341	1341	0	0.0
BIG BEAVER	1974	1	0	0	0	0.0
BIG BEAVER	1974	2	0	0	0	0.0
BIG BEAVER	1974	3	0	0	0	0.0
BIG BEAVER	1974	4	0	0	0	0.0
BIG BEAVER	1974	5	0	0	0	0.0
BIG BEAVER	1974	6	0	0	0	0.0
BIG BEAVER	1974	7	1360	1341	19	1.4
BIG BEAVER	1974	8	1505	1468	37	2.5
BIG BEAVER	1974	9	1505	1435	70	4.7
BIG BEAVER	1974	10	0	0	0	0.0
BIG BEAVER	1974	11	0	0	0	0.0
BIG BEAVER	1974	12	0	0	0	0.0
COMMANCHE	1974	1	302	302	0	0.0
COMMANCHE	1974	2	430	429	1	.2
COMMANCHE	1974	3	430	429	1	.2
COMMANCHE	1974	4	430	427	3	.7
COMMANCHE	1974	5	430	423	7	1.6
COMMANCHE	1974	6	430	416	14	3.3
COMMANCHE	1974	7	1835	1780	55	3.0
COMMANCHE	1974	8	2256	2255	1	.0
COMMANCHE	1974	9	2256	2198	58	2.6
COMMANCHE	1974	10	0	0	0	0.0
COMMANCHE	1974	11	0	0	0	0.0
COMMANCHE	1974	12	0	0	0	0.0
TWIN LAKE	1974	1	0	0	0	0.0
TWIN LAKE	1974	2	0	0	0	0.0
TWIN LAKE	1974	3	0	0	0	0.0
TWIN LAKE	1974	4	0	0	0	0.0
TWIN LAKE	1974	5	0	0	0	0.0
TWIN LAKE	1974	6	0	0	0	0.0
TWIN LAKE	1974	7	125	125	0	0.0
TWIN LAKE	1974	8	276	263	13	4.7
TWIN LAKE	1974	9	276	252	24	8.7
TWIN LAKE	1974	10	0	0	0	0.0
TWIN LAKE	1974	11	0	0	0	0.0
TWIN LAKE	1974	12	0	0	0	0.0
WORSTER	1974	1	175	172	3	1.7
WORSTER	1974	2	223	221	2	.9
WORSTER	1974	3	283	280	3	1.1
WORSTER	1974	4	313	309	4	1.3
WORSTER	1974	5	544	538	6	1.1
WORSTER	1974	6	771	758	13	1.7
WORSTER	1974	7	3750	3719	31	.8
WORSTER	1974	8	3750	3685	65	1.7
WORSTER	1974	9	1701	1702	-1	.1
WORSTER	1974	10	0	0	0	0.0
WORSTER	1974	11	35	33	2	5.7
WORSTER	1974	12	109	105	4	3.7
HALLIGAN	1974	1	0	0	0	0.0
HALLIGAN	1974	2	4075	4075	0	0.0
HALLIGAN	1974	3	6272	6160	112	1.8
HALLIGAN	1974	4	6428	6295	133	2.1
HALLIGAN	1974	5	6428	6273	155	2.4
HALLIGAN	1974	6	6428	6241	187	2.9
HALLIGAN	1974	7	6428	6153	275	4.3
HALLIGAN	1974	8	6428	6114	314	4.9
HALLIGAN	1974	9	5371	5367	4	.1
HALLIGAN	1974	10	3244	3246	-2	.1
HALLIGAN	1974	11	0	0	0	0.0
HALLIGAN	1974	12	750	748	2	.3
PARK CREEK	1974	1	7063	6572	491	7.0
PARK CREEK	1974	2	7063	6640	423	6.0
PARK CREEK	1974	3	7063	6633	430	6.1
PARK CREEK	1974	4	6904	6624	280	4.1
PARK CREEK	1974	5	6747	6614	133	2.0
PARK CREEK	1974	6	6670	6672	-2	.0
PARK CREEK	1974	7	6367	6366	1	.0
PARK CREEK	1974	8	5631	5626	5	.1
PARK CREEK	1974	9	4448	4445	3	.1
PARK CREEK	1974	10	3542	3543	-1	.0
PARK CREEK	1974	11	4840	4836	4	.1
PARK CREEK	1974	12	4800	4802	-2	.0
N.P. 15	1974	1	4192	4133	59	1.4
N.P. 15	1974	2	4192	4110	82	2.0
N.P. 15	1974	3	4192	4093	99	2.4
N.P. 15	1974	4	3786	3784	2	.1
N.P. 15	1974	5	3786	3760	26	.7
N.P. 15	1974	6	5117	5114	3	.1
N.P. 15	1974	7	1360	1357	3	.2
N.P. 15	1974	8	4029	4027	2	.0
N.P. 15	1974	9	4248	4248	0	0.0
N.P. 15	1974	10	4619	4616	3	.1
N.P. 15	1974	11	4083	4082	1	.0
N.P. 15	1974	12	4735	4706	29	.6

TABLE 5 CONTINUED

PETERSON	1975	1	0	0	0	0.0
PETERSON	1975	2	0	0	0	0.0
PETERSON	1975	3	0	0	0	0.0
PETERSON	1975	4	0	0	0	0.0
PETERSON	1975	5	0	0	0	0.0
PETERSON	1975	6	0	0	0	0.0
PETERSON	1975	7	227	226	1	.4
PETERSON	1975	8	1183	1137	46	3.9
PETERSON	1975	9	1183	1123	60	5.1
PETERSON	1975	10	1091	1090	1	.1
PETERSON	1975	11	0	0	0	0.0
PETERSON	1975	12	0	0	0	0.0
BNS MEADOW	1975	1	1341	1341	0	0.0
BNS MEADOW	1975	2	1341	1337	4	.3
BNS MEADOW	1975	3	1341	1334	7	.5
BNS MEADOW	1975	4	1341	1331	10	.7
BNS MEADOW	1975	5	1341	1318	23	1.7
BNS MEADOW	1975	6	1341	1300	41	3.1
BNS MEADOW	1975	7	1980	1925	55	2.8
BNS MEADOW	1975	8	2458	2354	104	4.2
BNS MEADOW	1975	9	2458	2317	141	5.7
BNS MEADOW	1975	10	2458	2276	182	7.4
BNS MEADOW	1975	11	118	118	0	0.0
BNS MEADOW	1975	12	118	114	4	3.4
BIG BEAVER	1975	1	0	0	0	0.0
BIG BEAVER	1975	2	0	0	0	0.0
BIG BEAVER	1975	3	0	0	0	0.0
BIG BEAVER	1975	4	0	0	0	0.0
BIG BEAVER	1975	5	0	0	0	0.0
BIG BEAVER	1975	6	0	0	0	0.0
BIG BEAVER	1975	7	526	522	4	.8
BIG BEAVER	1975	8	1505	1475	30	2.0
BIG BEAVER	1975	9	1170	1170	0	0.0
BIG BEAVER	1975	10	0	0	0	0.0
BIG BEAVER	1975	11	0	0	0	0.0
BIG BEAVER	1975	12	0	0	0	0.0
COMMANCHE	1975	1	172	168	4	2.3
COMMANCHE	1975	2	349	342	7	2.0
COMMANCHE	1975	3	349	340	9	2.6
COMMANCHE	1975	4	349	338	11	3.2
COMMANCHE	1975	5	373	354	19	5.1
COMMANCHE	1975	6	437	406	31	7.1
COMMANCHE	1975	7	647	504	143	22.1
COMMANCHE	1975	8	2256	2070	186	8.2
COMMANCHE	1975	9	2256	1149	1107	49.1
COMMANCHE	1975	10	0	0	0	0.0
COMMANCHE	1975	11	0	0	0	0.0
COMMANCHE	1975	12	111	81	30	27.0
TWIN LAKE	1975	1	0	0	0	0.0
TWIN LAKE	1975	2	0	0	0	0.0
TWIN LAKE	1975	3	0	0	0	0.0
TWIN LAKE	1975	4	0	0	0	0.0
TWIN LAKE	1975	5	0	0	0	0.0
TWIN LAKE	1975	6	0	0	0	0.0
TWIN LAKE	1975	7	17	0	17	100.0
TWIN LAKE	1975	8	278	253	25	9.0
TWIN LAKE	1975	9	0	0	0	0.0
TWIN LAKE	1975	10	0	0	0	0.0
TWIN LAKE	1975	11	0	0	0	0.0
TWIN LAKE	1975	12	0	0	0	0.0
WORSTER	1975	1	134	132	2	1.5
WORSTER	1975	2	143	142	1	.7
WORSTER	1975	3	226	224	2	.9
WORSTER	1975	4	265	262	3	1.1
WORSTER	1975	5	334	333	1	.3
WORSTER	1975	6	480	480	0	0.0
WORSTER	1975	7	1596	1597	-1	.1
WORSTER	1975	8	3750	3708	42	1.1
WORSTER	1975	9	3340	3341	-1	.0
WORSTER	1975	10	1366	1365	1	.1
WORSTER	1975	11	0	0	0	0.0
WORSTER	1975	12	49	48	1	2.0
HALLIGAN	1975	1	2050	2044	6	.3
HALLIGAN	1975	2	3082	3085	-3	.1
HALLIGAN	1975	3	3952	3938	14	.4
HALLIGAN	1975	4	4847	4846	1	.0
HALLIGAN	1975	5	6298	6299	-1	.0
HALLIGAN	1975	6	6428	6428	0	0.0
HALLIGAN	1975	7	6428	6428	0	0.0
HALLIGAN	1975	8	6428	6361	67	1.0
HALLIGAN	1975	9	5584	5585	-1	.0
HALLIGAN	1975	10	4138	4139	-1	.0
HALLIGAN	1975	11	0	0	0	0.0
HALLIGAN	1975	12	718	714	4	.6
PARK CREEK	1975	1	4721	4717	4	.1
PARK CREEK	1975	2	4721	4717	4	.1
PARK CREEK	1975	3	4603	4598	5	.1
PARK CREEK	1975	4	4554	4564	0	0.0
PARK CREEK	1975	5	4564	4564	0	0.0
PARK CREEK	1975	6	5552	4569	983	17.7
PARK CREEK	1975	7	5861	5332	529	9.0
PARK CREEK	1975	8	7037	6407	630	9.0
PARK CREEK	1975	9	6267	6264	3	.0
PARK CREEK	1975	10	4297	2490	1807	42.1
PARK CREEK	1975	11	5045	3225	1820	36.1
PARK CREEK	1975	12	5066	3254	1832	36.0
N.P. 15	1975	1	4735	4733	2	.0
N.P. 15	1975	2	4735	4733	2	.0
N.P. 15	1975	3	4851	4849	2	.0
N.P. 15	1975	4	4851	4849	2	.0
N.P. 15	1975	5	4851	4849	2	.0
N.P. 15	1975	6	4764	4761	3	.1
N.P. 15	1975	7	2795	2797	-2	.1
N.P. 15	1975	8	5207	5203	-1	.0
N.P. 15	1975	9	4164	4165	-1	.0
N.P. 15	1975	10	3600	3597	3	.1
N.P. 15	1975	11	2350	2359	0	0.0
N.P. 15	1975	12	1845	1842	3	.2

equalizing reservoir and is not allowed to influence the operation of the system. Historically, Seaman had a starting storage value of 2460 acre feet. This was set equal to zero in the study and no unregulated flows into it were considered. In this manner it could not unduly influence system performance. The slight contribution made by Seaman to meet demand for reservoir water was subtracted from the total demand, thereby eliminating the error of overestimating the demand. Finally, its ending storage was allowed to go to zero.

The total historical ending storage volume for the system (excluding Milton Seaman) was 7927 acre feet. The total ending storage computed from the calibration is 6053, which is a difference of 1874 acre feet. Based on the calculated net evaporation rates, approximately this amount of evaporation losses were not considered in the observed storage data. Subsequently, a calibration run was made in which evaporation losses were set equal to zero (though channel losses were calculated). In this case, the ending storage was much higher than the historical ending storage. These results indicate that while evaporation was not fully considered in the observed data, some losses were included.

ANALYSIS OF A MANAGEMENT STRATEGY FOR RECREATION

Introduction

The analysis of a predetermined management strategy for the inclusion of recreation was the final phase of this aspect of the study. Upon satisfactory completion of model calibration, reservoir operating rules and storage priorities were changed to reflect the management alternative proposed by other members of the project team. Evaporation rates and the demand pattern remained identical to those of the calibration study. Channel losses had to be recomputed due to changes in the release policies of the reservoirs. Throughout the analysis, demands were given the highest priority to insure that no shortages occurred.

Description of Management Alternative

The management strategy developed for the case study centered around creation of a user Group Type I recreational reservoir out of Barnes Meadow and a Type I recreational reservoir at Twin Lake. These two reservoirs were considered to have the highest recreational potential of the five. Comanche Reservoir and Peterson Reservoir were believed to have some potential as Type II reservoirs, while Big Beaver was declared to have no recreational possibilities whatsoever due to private ownership of riparian lands.

This management alternative is in marked contrast to the traditional operating policy in that storage levels in these reservoirs must be maintained at acceptable levels throughout the year. During the simulation period, these reservoirs historically were drawn down completely (except Barnes Meadow, which was emptied to half its storage capacity in 1973 and 1974) at the end of each irrigation season. This not only tends to discourage water related recreation but also makes it virtually impossible to establish a long term fishery.

The desired monthly storage levels for all five reservoirs were set at 100% of the maximum capacity of each reservoir. Desired storage levels for the remaining non-recreational reservoirs were set at zero for each month, thereby allowing these storage levels to freely fluctuate, based on the operation of the five high mountain reservoirs. The priorities assigned to each reservoir reflect the ordered preference of meeting the operating rules provided. Table 6 lists all the reservoirs and their corresponding rankings. Determination of these priority factors required somewhat of a trial and error approach. A set of initial priority values were selected and the resulting operating policies checked against the ideal recreation-oriented policies selected by the project team. If there was a large discrepancy, the priority factors were appropriately adjusted. Several iterations and adjustments of these factors were necessary before arriving at the ones shown in Table 6.

TABLE 6

STORAGE PRIORITIES FOR MANAGEMENT ANALYSIS

Reservoir	Priority Factors w_{ij}* '72-'73	'73-'74	'74-'75
Peterson	50	50	50
Barnes Meadow	40	40	40
Big Beaver	80	80	80
Comanche	60	60	60
Twin Lake	40	40	40
Worster	75	75	75
Halligan	85	85	85
Park Creek	90	90	90
North Poudre #15	115	115	115
Milton Seaman	200	200	200
Aggregate	150	150	150

*Lower values have higher weight since the objective function of the model is minimized.

It can be seen from these priorities that Barnes Meadow and Twin Lake are given equally the highest consideration for storage maintenance, followed in order by Peterson, Comanche, and Big Beaver. Priorities for the remaining non-recreational reservoirs reflect a desire to maintain water as high as possible in the system for added flexibility. The simulation of this management alternative was performed and the results are discussed in the following section.

Summary of Results

Figures 9 through 16 graphically display the results of the management analysis. Both the historical and the calculated monthly ending storage values are plotted over the 36 month simulation period. Keeping in mind that the same demand for reservoir water was met in both instances, and based on admittedly conservative evaporation rates, the alternative management strategy is clearly viable. Upon initial filling, Barnes Meadow and Twin Lakes reservoirs maintained near capacity storage levels throughout the simulation period, as expected. However, Peterson Reservoir also remained near capacity, as did Commanche. Big Beaver was drawn empty in late 1975 but this was also acceptable. The remaining reservoirs fluctuated between zero storage and in some cases, their maximum capacity.

Carryover storage at the end of the 3 year period should be reasonably consistent with what occurred historically. Total ending storage volume for the system, as a result of the alternative management strategy, is 6438 acre feet. This compares with a value of 6053 acre feet for the calibration phase. Considering the decrease in evaporation from the calibrated value of 5112 acre feet total to a value of 5022 acre feet for the total evaporation calculated for the management alternative, as well as a slight reduction in channel losses (300 acre feet) caused by varying the reservoir operating policies, the management alternative appears to be reasonably consistent with the calibration value.

It is clear from Figures 9 through 16 that the management strategy simply specifies a shifting of stored water from reservoirs not conducive to recreation to those high country reservoirs with greater recreation potential. Notice that large conservation levels are maintained in all high country reservoirs except Big Beaver, which was given a low priority for recreation use. For the three year historical period considered in this case study, it is clear that enough water was available in the system to maintain storage levels in the high country reservoirs, while still meeting the historical demand for water from all of the reservoirs considered.

Obviously, this is a case study only, and in no way proves that recreation-oriented storage levels can be maintained in any reservoirs along the Front Range that appear to have the most attractive features for recreation purposes. The primary value of this study has been to demonstrate that a computerized simulation model is a valuable tool for evaluating multi-purpose management strategies in a river basin.

There are many legal issues that must be dealt with in attempting to implement this kind of a management strategy, since it involves storing water out of established legal priority. However, stored water is simply being transferred to other portions of the system, and should result in downstream water demands continuing to be satisfactorily met. In case of severe drought conditions, water could still be taken from the high country reservoirs to meet pressing downstream agricultural, industrial, and municipal water needs. Since, by definition, the high country reservoirs are at higher elevations, there is much greater flexibility in meeting downstream water demand.

Use of the model in an actual planning context would require some degree of forecasting of future inflows in order to develop current operating policies that are compatible with anticipated flow conditions. This represents a fruitful area for further research.

FIGURES 9-13

COMPARISON OF HISTORICAL STORAGE
LEVELS AND COMPUTED LEVELS FROM PROGRAM
SIMYLD FOR HIGH COUNTRY RESERVOIRS CONSIDERED
IN THE ALTERNATIVE MANAGEMENT STUDY

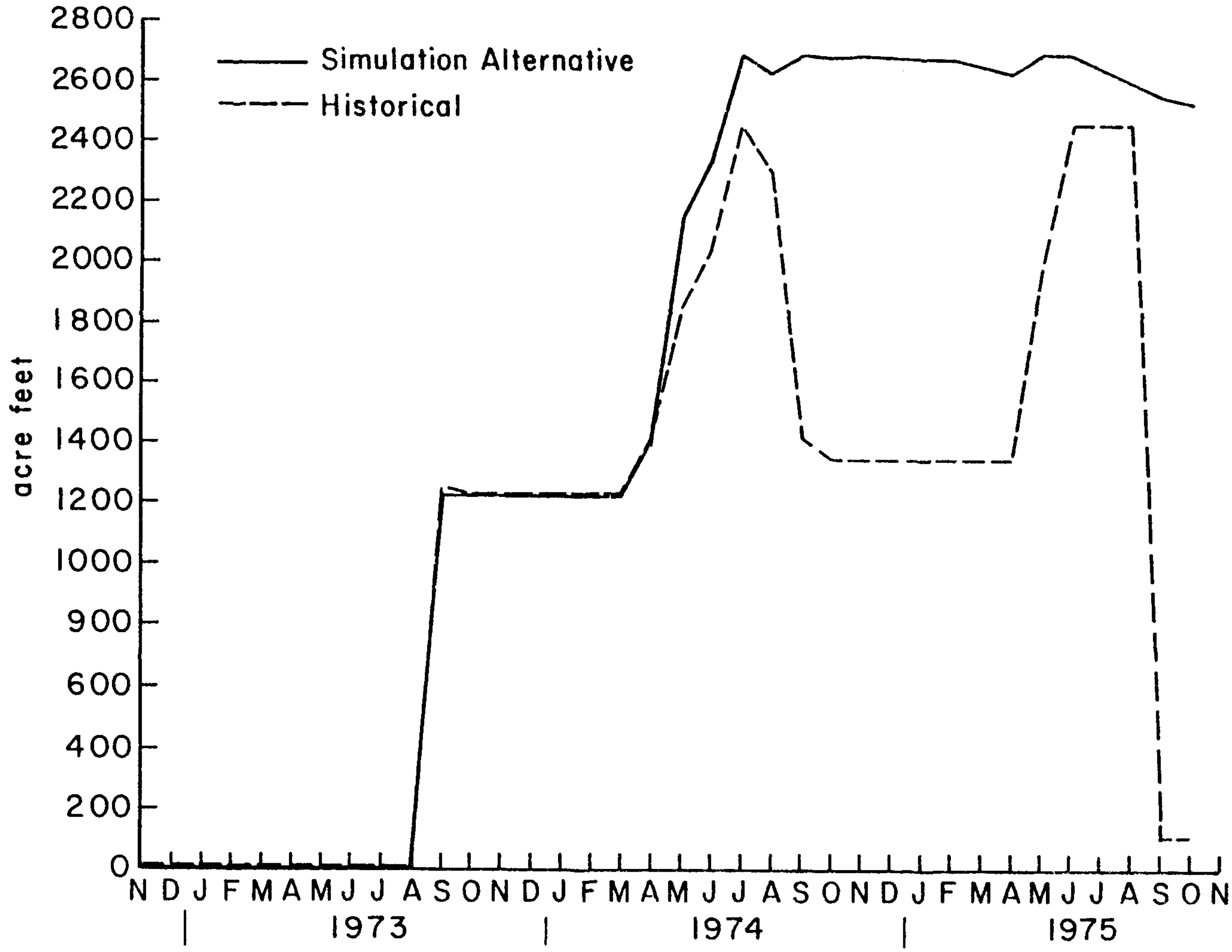


FIGURE 9

BARNES MEADOW RESERVOIR

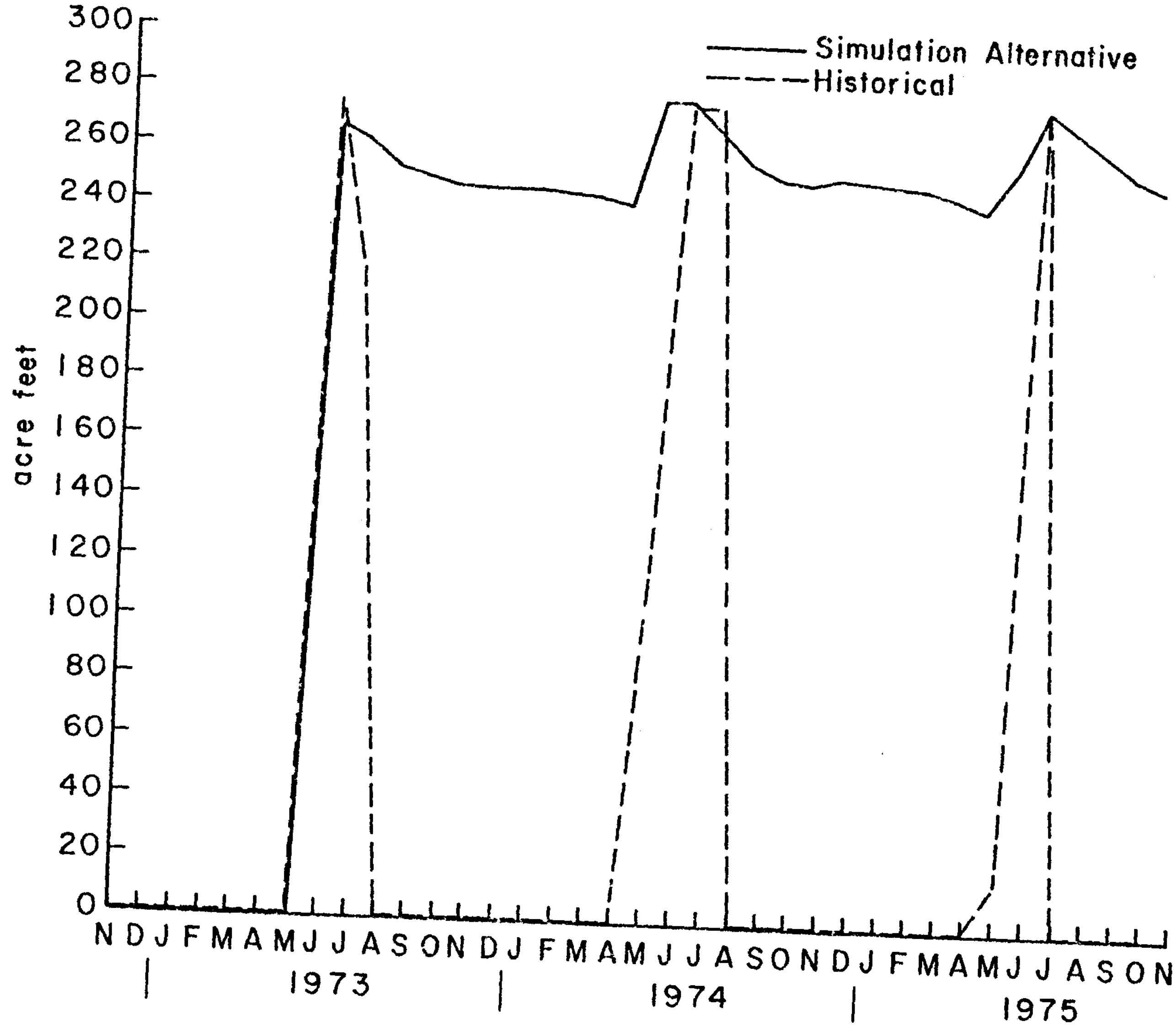


FIGURE 10

TWIN LAKE RESERVOIR

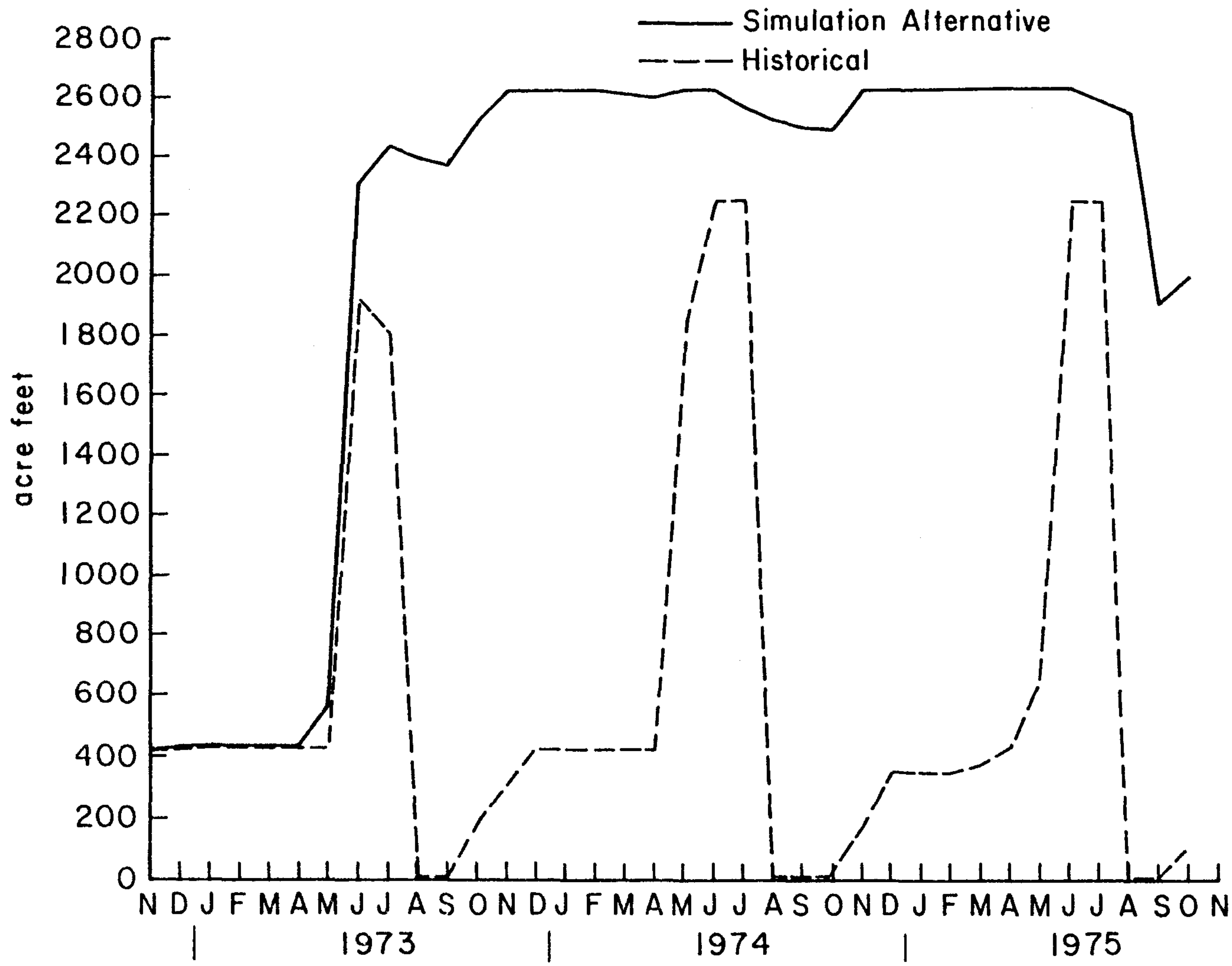


FIGURE 11

COMANCHE RESERVOIR

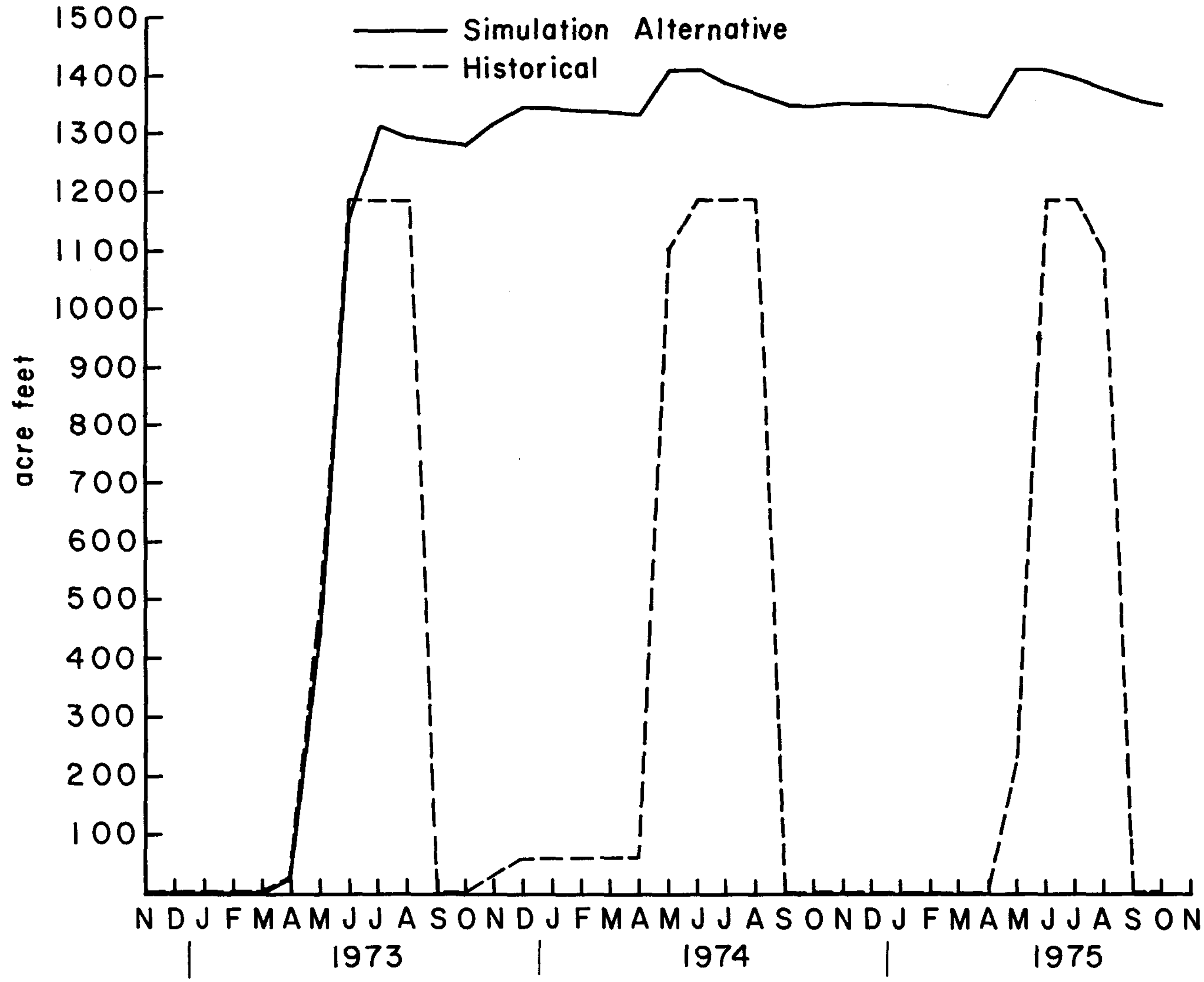


FIGURE 12

PETERSON RESERVOIR

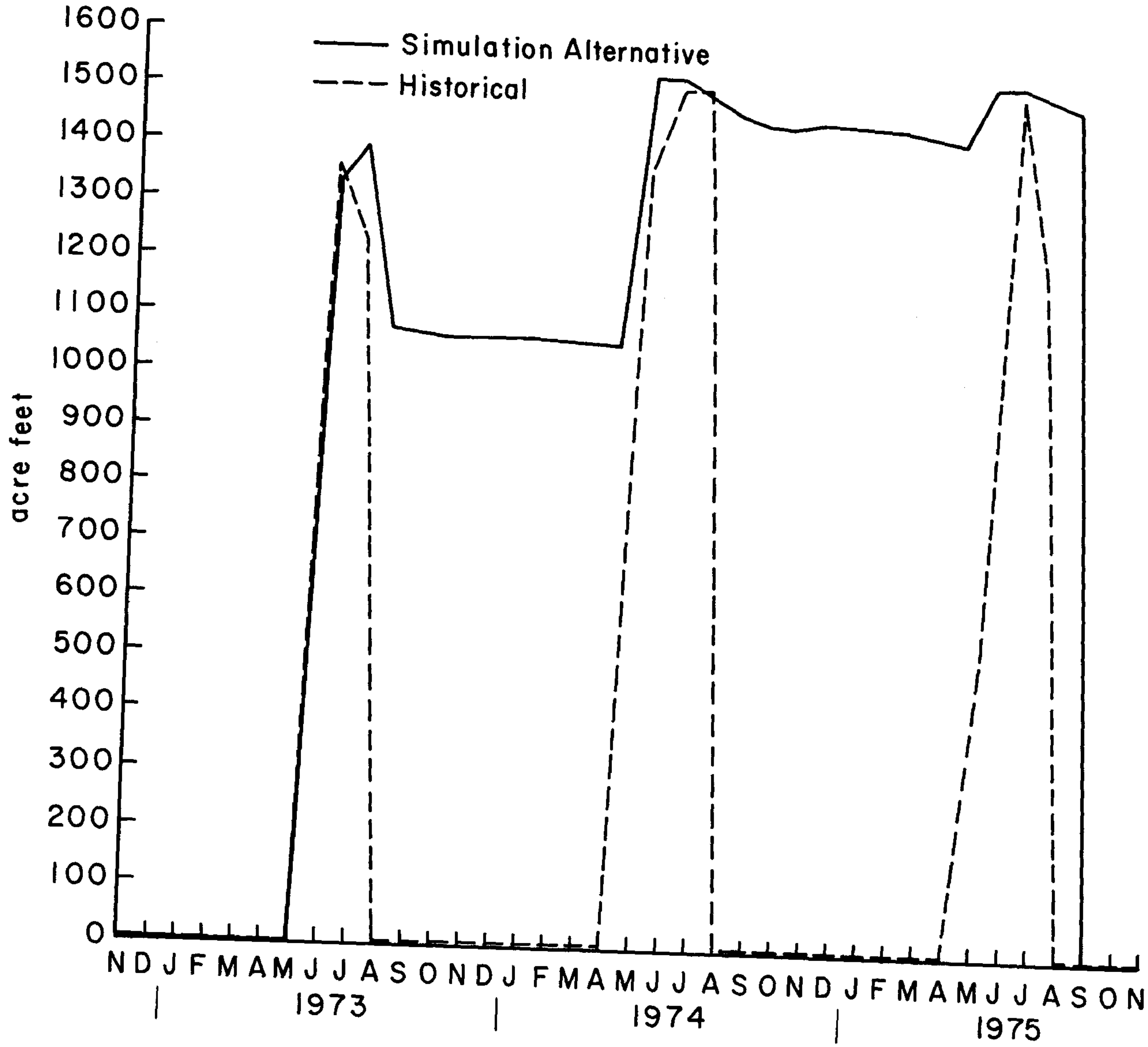


FIGURE 13

BIG BEAVER RESERVOIR

FIGURES 14-16

COMPARISON OF HISTORICAL STORAGE
LEVELS AND COMPUTED LEVELS FROM PROGRAM
SIMYLD FOR PLAINS RESERVOIRS
CONSIDERED IN THE ALTERNATIVE
MANAGEMENT STUDY

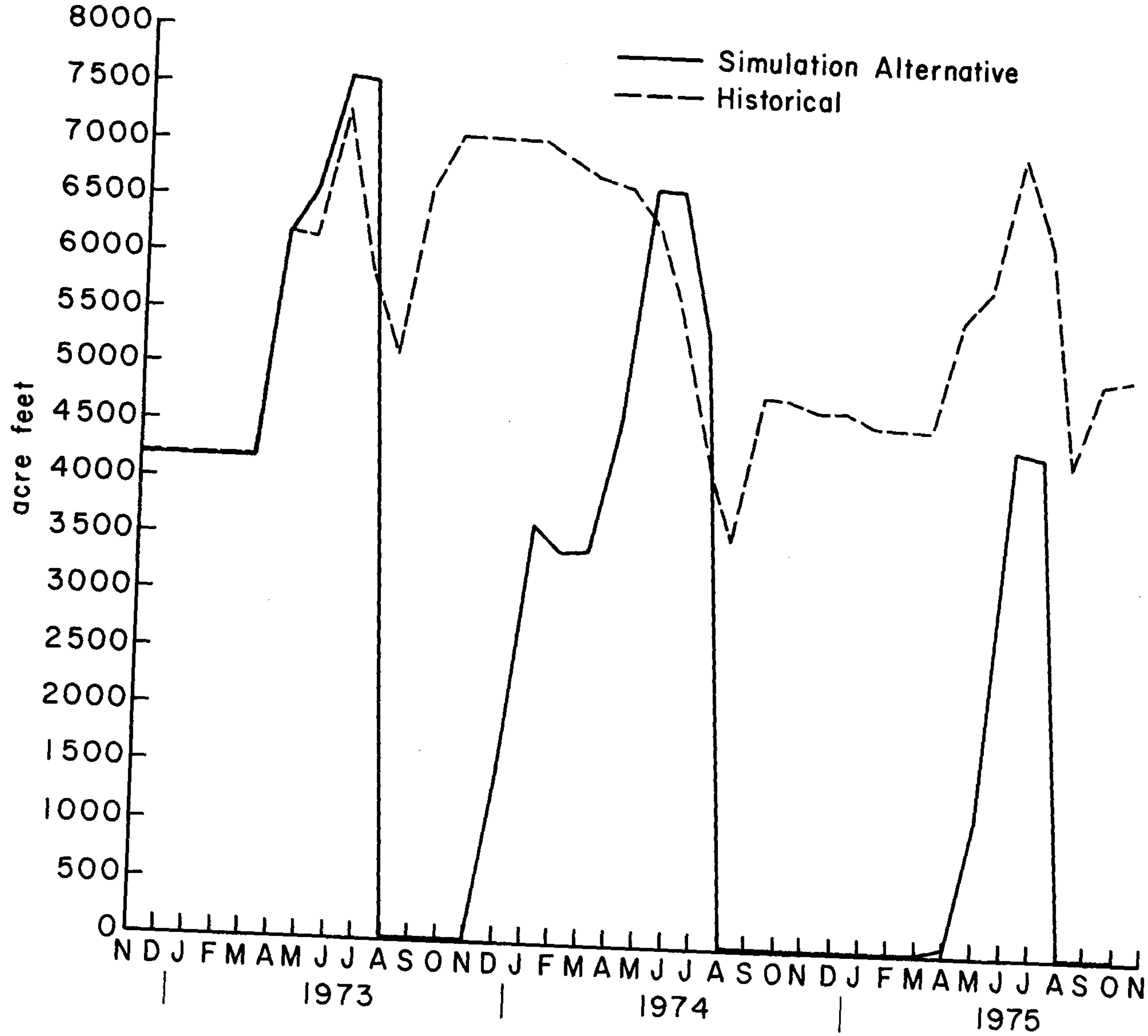


FIGURE 14

PARK CREEK RESERVOIR

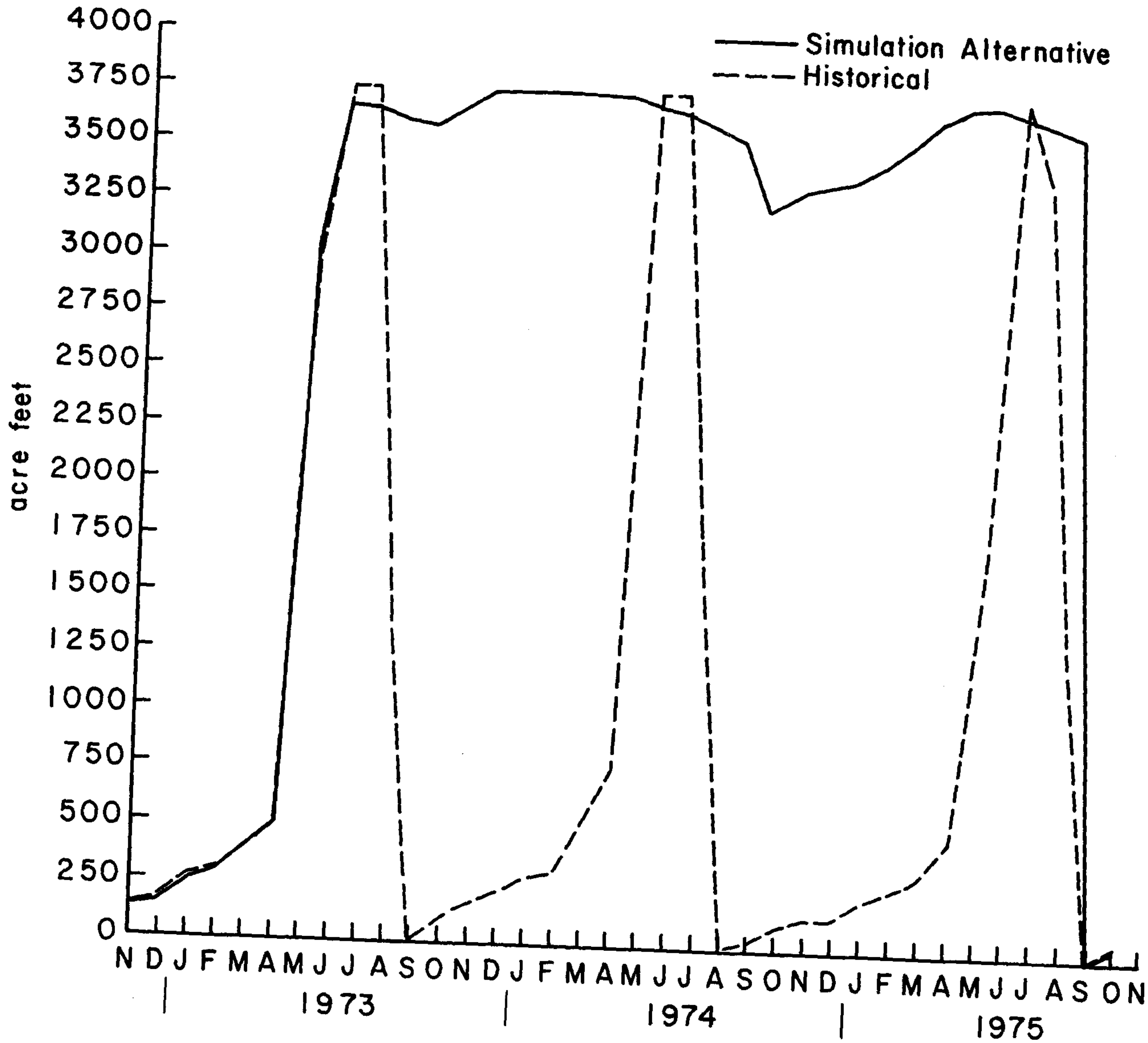


FIGURE 15

WORSTER RESERVOIR

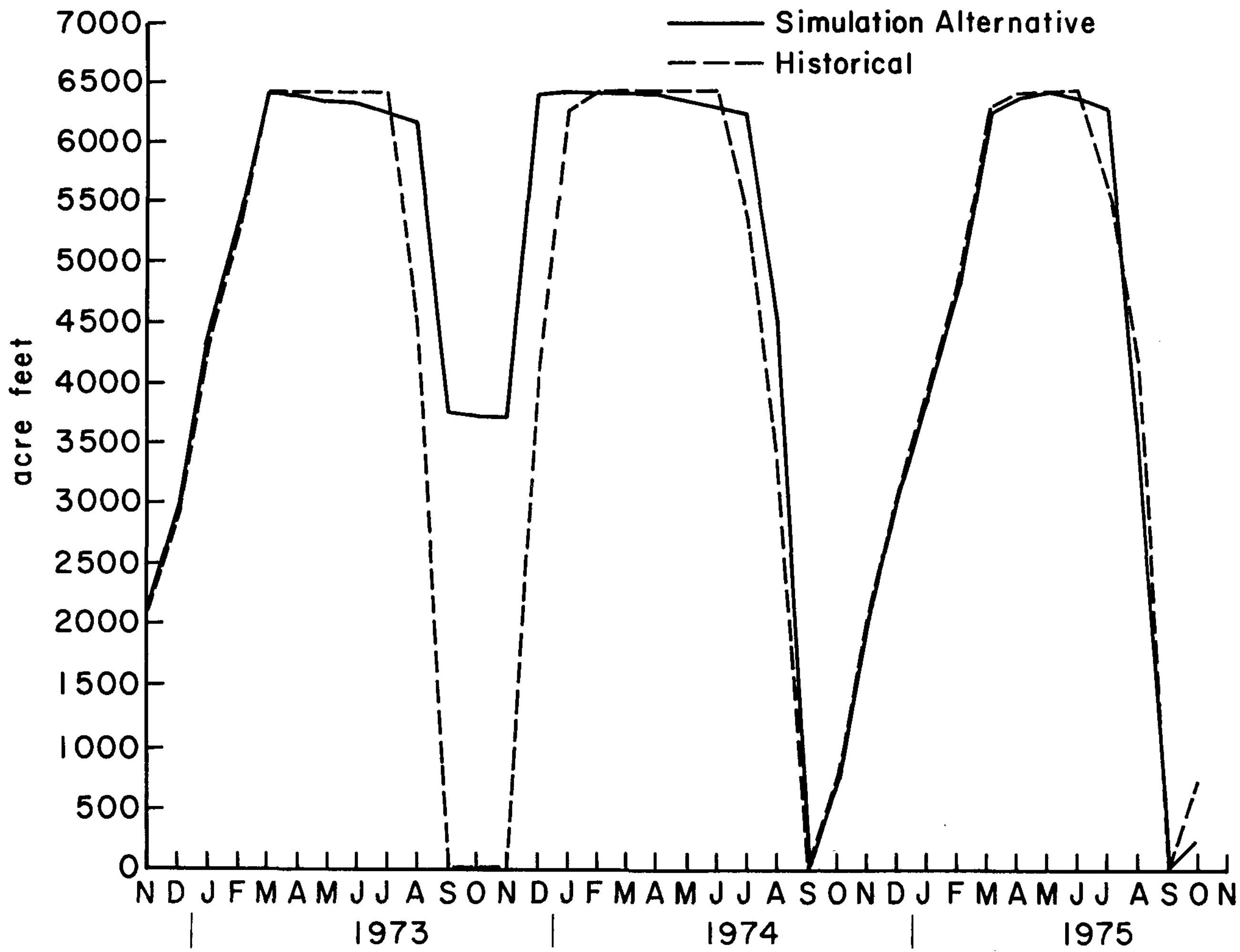


FIGURE 16

HALLIGAN RESERVOIR

APPENDIX II

EFFECTS OF WATER DRAWDOWN ON THE FAUNA IN SMALL COLD-WATER RESERVOIRS

Mary Elizabeth McAfee

and

Clarence A. Carlson

APPENDIX II

Table of Contents

Page

Introduction 209

Study Reservoirs 213

Methods and Materials 223

Results 230

Discussion 251

Conclusions 266

Literature Cited 267

INTRODUCTION

Many mountain valleys in the Front Range area of Colorado contain reservoirs that store water for municipal and agricultural uses on the plains below. These reservoirs are located in the montane, sub-alpine and alpine life zones and most are small (mean surface area 50 ha). Most of the reservoirs have potential for supporting cold-water fisheries and, although this use is incidental to others, many of the reservoirs are actually considered to be sport-fishing "lakes" by Colorado fishermen.

Because the primary function of these reservoirs is to supply water for downstream use, water in the reservoirs is subject to withdrawal at any time. In fact, water is withdrawn to various degrees from many of the reservoirs annually. Annual drawdowns are usually continuous over a short (2-3 wk) period of time in late summer or early fall. Drawdowns result in small water-level changes (1-m drops) to complete water removal, with only the pre-impoundment stream remaining (Figure 1).

Little is known of the effects of such water manipulation on the biota in small mountain reservoirs. Most of the available literature on drawdown deals with large warm-water impoundments (Fraser 1970). There is some published information on drawdown in cold-water ecosystems, such as work by Aass (1960), Martin (1955), and

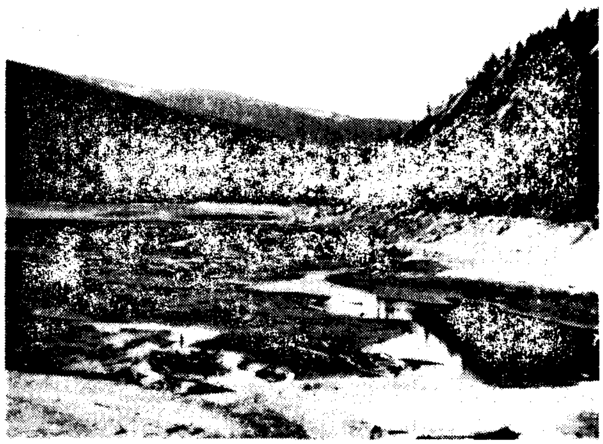


Figure 1. Comanche Reservoir, Larimer Co., after complete drawdown.

Miller and Paetz (1959); however, these studies were primarily conducted on very large hydroelectric reservoirs which were subject to long-term fluctuations. Neel (1963) noted that small reservoirs of all types have received very little study.

Although most work on the effects of drawdown has been conducted on large warm- and cold-water impoundments, some available information may be applicable to small mountain reservoirs. Such data will be cited in the discussion section. Many natural history and ecological studies of the aquatic fauna of mountain lakes can also be used to gain an understanding of small cold-water reservoirs.

The present study was a part of the second phase of a project designed to "provide the scientific rationale necessary for recommending management practices which will lead to increased use of high country reservoirs" (Aukerman 1975). In the initial phase of the study, Wespestad (1975) conducted research to determine the overall effect of drawdown on fish and invertebrate communities in Colorado mountain reservoirs. The biological results were highly variable and somewhat inconclusive. The reservoirs selected for study lacked a common fish species. Further, limited information was obtained on invertebrates, success of fish spawning and fate of young-of-the-year fish. In general, however, the results indicated that drawdown decreased the total fish community and the quantity of benthic food organisms. Neither the mechanisms of the reductions nor the level of drawdown at which the observed effects occurred were identified.

The primary objective of the present study was to further quantify and describe the effects of complete water drawdown on the fish and invertebrates in small mountain reservoirs. The data collected may also serve as a baseline for evaluating possible future drawdown changes. Two reservoirs scheduled for complete water removal were compared with two non-fluctuating (stable) reservoirs. Primary productivity and fish and invertebrate community composition and density were examined. Time, funding, and man-power constraints limited the scope and intensity of sampling. The reservoirs were studied from July 7 to September 20, 1975, and from June 16 to August 23, 1976. Each summer was divided into sample periods. These sample periods were numbered so that a given sample period encompassed the same calendar dates in each year. For example, sample period 2 corresponded to June 21 through June 27.

STUDY RESERVOIRS

The four study reservoirs, Idaho Springs, Urad, Comanche, and Eaton, were located in the Northern Half of the Colorado Front Range (Figure 2). Selection of the study reservoirs was guided by the following physical and biological variables:

1. travel distance not more than 2 hr driving time from base,
2. accessibility by pick-up truck,
3. history of drawdown pattern, and
4. fish community common across all reservoirs.

The two stable reservoirs, Idaho Springs and Urad, were maintained at the expected non-fluctuating levels during 1975. However, unanticipated variations occurred during 1976; these are discussed below. Comanche and Eaton, the drawdown reservoirs studied, were drained completely during both years. Water remained only in small pools and in the pre-impoundment streams after drawdown. The drawdown periods were different during each year of the study (Table 1).

The predominant game fish in all reservoirs was the brook trout (Salvelinus fontinalis), although each reservoir also contained at least one other fish species. Catchable-sized rainbow trout (Salmo

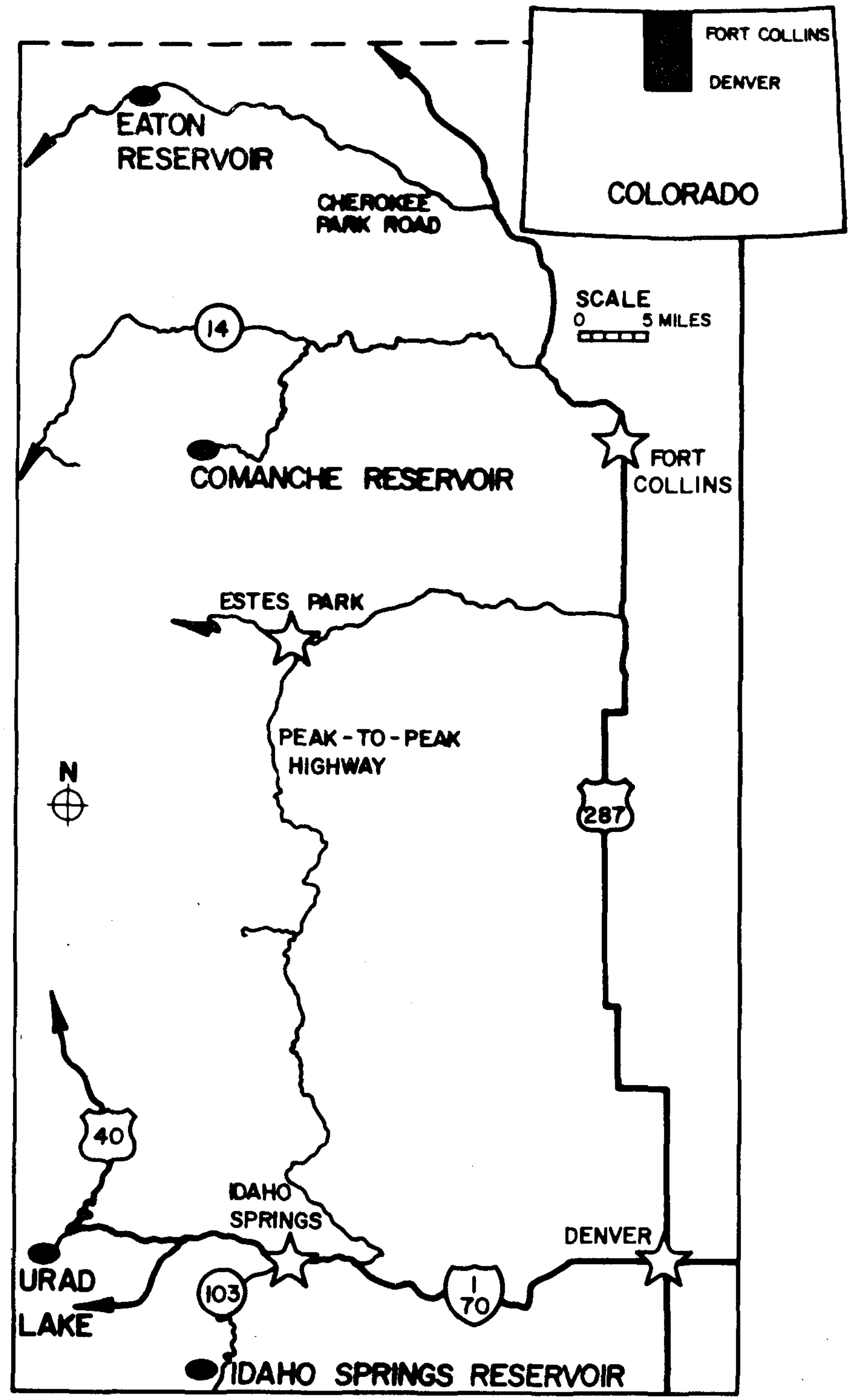


Figure 2. Map of study area for reservoir drawdown project, Northern Colorado, 1975-76.

Table 1. Drawdown periods for four study reservoirs, Northern Colorado, 1975-76.

Reservoirs	Drawdown periods
1975	
Idaho Springs	No drawdown
Urad	No drawdown
Comanche*	Aug. 12-Sept. 1
Eaton*	July 22-Sept. 15
1976	
Idaho Springs	June 22-Sept. 12
Urad	No drawdown
Comanche*	Aug. 28-Sept. 12
Eaton*	July 9-Sept. 5

*Denotes reservoirs normally scheduled for drawdown.

gairdneri) were stocked in Idaho Springs and Urad, but did not influence the analysis because so few of them were sampled.

All of the reservoirs were on a natural stream which was dammed, and were filled in this manner rather than by diversion of water from other areas. Other important physical and biological characteristics of the reservoirs are summarized in tabular form (Table 2).

Stable Reservoirs

Idaho Springs Reservoir was located in a deep, steep-sided valley in the sub-alpine life zone and received drainage from forested areas and barren granitic rock (Figure 3). The reservoir had a gently-sloping shoreline, which supported extensive mats of coarse filamentous algae in some areas. The bottom of Idaho Springs Reservoir consisted of very fine mud and organic detritus, although the shoreline was lined with large boulders.

Idaho Springs Reservoir was built to store water for municipal use in the City of Idaho Springs. However, the water has not been needed, and the position of the valve has not been changed for over 40 yr. Unfortunately, during the summer of 1976, a crack in the dam necessitated tests which resulted in rapid water-level fluctuations and, finally, draining of the reservoir. Results of these manipulations will be discussed later.

Table 2. Major physical and biological characteristics of four study reservoirs, Northern Colorado, 1975-76.

	Reservoirs			
	Stable Reservoirs		Drawdown Reservoirs	
Characteristics	Idaho Springs	Urad	Comanche	Eaton
Elevation (m)	3238	3142	2865	2591
Life zone	Sub-alpine	Sub-alpine	Montane	Montane
Max. surface temp (C)	14	12	14	19
Bottom composition				
littoral	lg. boulders	clay, rocks	lg. gravel, rocks	gravel
profundal	mud, detritus	clay, rocks	mud, organic debris	gravel, organic debris
Max. surface area (ha)	8	5	47	57
Volume (m^3)	493, 400	310, 842	2, 467, 000	4, 625, 625
Max. depth (m)	8.5	15.9	9.8	16.5
Stratification	none	none	none	slight
Fish species*	B, R, C, L	B, R	B, L, W	B, L

*B=brook trout, R=rainbow trout, C=cutthroat trout, L=longnose sucker, W=white sucker.

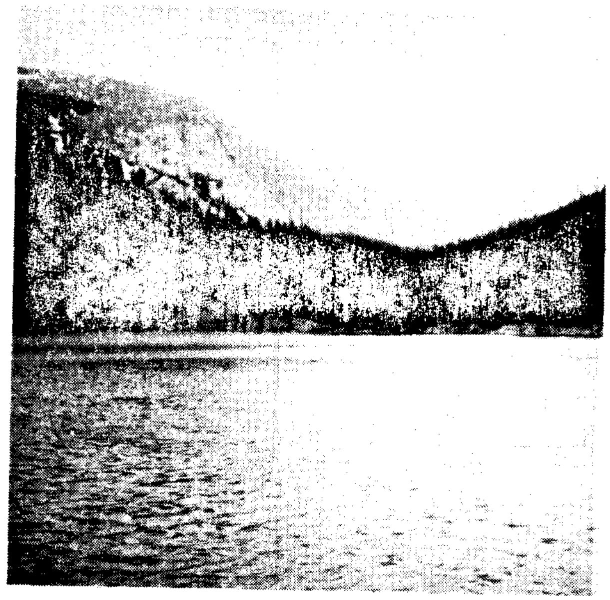


Figure 3. Idaho Springs Reservoir, Clear Creek Co.: a stable study reservoir.

Figure 4. Urad Reservoir, Clear Creek Co.: a stable study reservoir.

Urad Reservoir was in a sub-alpine drainage very similar to that of Idaho Springs Reservoir but was very deep and had extremely steep side slopes (Figure 4). These characteristics limited the percentage of lake bottom which was exposed to sunlight and inhibited growth of macrophytes. The reservoir was lined with a very hard, clay substrate covered with rocks ranging from 44 to 28 cm in diameter.

Urad Reservoir is part of a large molybdenum mining and milling installation operated by American Metal Climax, Inc. (AMAX). As in the case of Idaho Springs Reservoir, this reservoir was constructed to provide storage for water which was never needed. The water level dropped slightly (2 m) during the summer of 1976 because of decreased runoff from the higher mountains. However, this fluctuation must be considered natural, as it was a result of the design of the spillway rather than of human manipulation.

Drawdown Reservoirs

Comanche Reservoir was located in the montane zone and drained areas of heavily-forested mountain land (Figure 5). The reservoir had a very steep shoreline and, therefore, a restricted littoral zone. The bottom was composed of mud and organic debris in the deeper parts, with large gravel and rocks near shore.

Comanche Reservoir is part of a complex system designed to deliver water to various downstream areas for agricultural uses, and

Figure 5. Comanche Reservoir, Larimer Co.: a drawdown study reservoir.

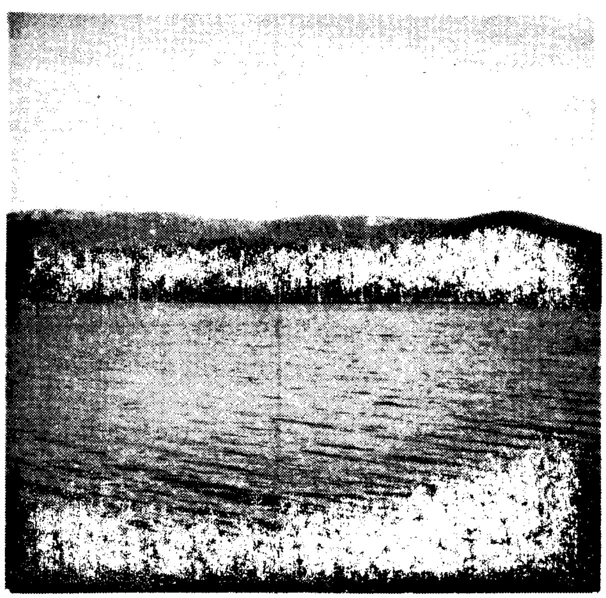


Figure 6. Eaton Reservoir, Larimer Co.: a drawdown study reservoir.

it has been drawn down annually to approximately 1% of its capacity. During this study, the water remaining after drawdown was in the pre-impoundment stream and in pools averaging 1 ha in area and 1 m in depth. In early October of a drawdown year, Comanche Reservoir begins to refill. It reaches half capacity by late autumn and is maintained at that level until spring runoff begins.

Comanche Reservoir is one of a series of lakes connected by a perennial stream. The lakes upstream from Comanche do not fluctuate significantly and have no history of winter-kill. Comanche Reservoir also has a series of beaver ponds, which remain full after drawdown begins, on its inlet.

This reservoir had logs and large limbs floating in its waters at all times. A large stand of timber was killed by a forest fire in the drainage to the reservoir, and this area contributed large amounts of such debris.

Eaton Reservoir was also constructed in the montane zone. This reservoir was surrounded by areas by grassland and sagebrush and also drained areas of forested land (Figure 6). There were no macrophytes growing in the reservoir, partly because the littoral zone was limited by the steepness of the side slopes. The entire reservoir basin was lined with 1/2 to 1-cm gravel, which was mixed with mud and organic debris in the deepest areas.

Eaton has been completely drawn down annually for many years, and the water used for irrigation. After drawdown, water remains in the pre-impoundment stream and in one fairly-large pool which averages 2 ha in area and 3 m deep. After the irrigation season, Eaton Reservoir gains water slowly throughout the winter and reaches half-capacity by the beginning of snowmelt.

Eaton Reservoir is the only reservoir in its drainage, and the small inlet stream is nonexistent at times and sometimes freezes solid during the winter. There were many logs and limbs in the water; these originated in areas of standing timber which were inundated each year during high water.

METHODS AND MATERIALS

Information was collected to determine the relationship of drawdown and specific lake characteristics to the game-fish community in each reservoir and each type of reservoir. Observations were made of reservoir characteristics which were independent of drawdown patterns but assumed to be related to game fish production. These were

1. elevation of reservoir,
2. maximum surface temperature of water,
3. availability of spawning grounds,
4. bottom composition,
5. presence of competing fish species,
6. reservoir basin side slope,
7. presence of allochthonous nutrient sources, and
8. physical and biological characteristics of watershed.

Important variables which were assumed to be related to drawdown included:

1. times and rates of drawdown and refill,
2. amount and character of water remaining after drawdown,
3. primary productivity of reservoir,
4. invertebrate abundance, and
5. fish abundance and condition.

Information on drawdown and refill patterns was obtained from the agency managing each reservoir, and the water remaining after drawdown was observed in the field. Quantitative measurements of primary productivity and of invertebrate abundance and fish abundance and condition were made.

Primary Productivity Determinations

Photosynthetic activity of benthic and planktonic autotrophs was determined and compared by a modification (McConnell 1962, 1963) of the open-water diel oxygen pulse procedure. The objective was to determine if drawdown affected the rate of photosynthesis in the reservoirs.

The oxygen pulse method is based on two facts: that photosynthesis is the basis for production of all living material, and that photosynthetic processes produce oxygen. Photosynthetic oxygen production should be proportional to the quantity of energy made available to the food web in the form of green plant material. Therefore, a body of water with a high capacity for photosynthesis should also be capable of supporting large amounts of primary and secondary consumers. As a result, primary productivity determinations are an indirect measure of the relative ability of bodies of water to produce fish flesh; the more oxygen that is produced by photosynthesis, the higher will be the productivity potential.

Equipment used in the primary productivity determinations consisted of

1. a Secchi disk for estimating photic zone depth,

2. a specially-constructed plastic syringe for obtaining depth-integrated water samples (Kemmerer and Neuhold 1969),

3. glass sample bottles, and

4. chemicals and apparatus for determining dissolved oxygen concentrations with the modified Winkler method (Amer. Publ. Health Assoc. et al. 1966).

Sampling dates were scattered throughout both summers, because windy days were excluded to avoid significant oxygen diffusion errors.

Water samples for dissolved oxygen analysis were taken at sunset and the following sunrise because these are the times of maximum and minimum photosynthetic oxygen concentration. A sample was taken at each of three randomly-selected locations in the reservoirs, excluding coves and inlets. These locations were different at each sampling time. All samples were taken over the depth of the photic zone as estimated by Secchi disk transparency.

Water samples were collected in the syringe, which integrated water from all depths in the photic column and delivered a sample containing the mean oxygen concentration in the column. The concentration of dissolved oxygen in each integrated sample was determined by the modified Winkler method. Sunrise and sunset dissolved oxygen values used in the final analysis were means of the three samples taken at each sampling time.

Gross photosynthesis was calculated according to procedures described in McConnel (1962) and was reported as g oxygen evolved/ m^3 of the photic zone/day.

Invertebrate Sampling

Zooplankton and benthic invertebrates were sampled to determine taxa and numbers present. These organisms make up the bulk of food consumed by most cold-water fish and are very important in determining fish production in a body of water. The objective in studying the standing crop of these organisms in each reservoir was to detect differences and changes caused by drawdown.

Samples were taken in each reservoir as often as practical during 1975 and every second week during 1976. Equipment used for zooplankton sampling consisted of

1. a #12-mesh plankton net,
2. vials of 70% methanol,
3. a stereozoom microscope, and
4. a Sedgewick-Rafter counting cell.

On each sampling date, one vertical net haul was made through the maximum depth of the lake and one through the littoral zone near shore. Each sample was preserved in 70% methanol and returned to the laboratory for analysis with a stereozoom microscope and a Sedgewick-Rafter counting cell. Four subsamples were taken from each sample, and zooplankters were counted and identified as cladocerans or copepods. Data were summarized as number of zooplankters/liter of water sampled.

Equipment used for benthic sampling consisted of:

1. a Peterson dredge,
2. a screen with 1 mm mesh,
3. vials of 70% methanol, and
4. a stereozoom microscope.

The Peterson dredge collected 1/13 m^2 of lake bottom. On each sampling date, one haul was made in an area near maximum water depth, and one was taken from the littoral zone near shore. Each sample was rinsed over a screen. Invertebrates were separated from the remaining debris and preserved. In the laboratory, invertebrates were counted and identified to family. Data were summarized as number of invertebrates/sample.

Fish Sampling

Fish were sampled to determine comparative population densities and conditions and the relationships of these factors to drawdown patterns. Fish were not sampled in Comanche and Eaton reservoirs during 1975 because sufficient data were available from Wespestad's study of the same reservoirs. All other sampling was done once a month. Equipment used for fish sampling included

1. a 38.5-m experimental gill net with 13 to 51-mm mesh gradations,

2. a measuring board graduated in mm, and

3. a scale with 2-g gradations.

Throughout the study, nets were set in the same location in each reservoir; all nets were set on the bottom in habitats that were as similar as possible between lakes. Nets were set for a 12-hr period overnight, and a gill net index (number of fish/38.5 m of net/day) was calculated for density comparisons (Moyle 1951; Moyle et al. 1950).

Captured fish were identified and weighed and measured (total length) to the nearest g and mm. Coefficients of condition ($K = 10^5 \times \text{weight}/\text{length}^3$) were calculated from these data. In addition, stomach contents of selected fish were examined in the field for type and percentage (by volume) of major food items. This information was used to roughly relate fish densities and conditions to the standing crop of invertebrates.

<u>Data Analysis</u>

All data were punched on Hollerith cards for computer analysis. Each card contained a date, sample number, reservoir designation, data type and information collected from each sample.

Each type of data was analyzed separately to determine the relationships between the results and the individual reservoirs, reservoir type (stable or drawdown), and year of the study.

Analysis of variance was used on the primary productivity and fish condition data to determine if the variation in the figures was due to difference between years, between reservoirs, or between reservoir types. Invertebrate data were broken down by year, reservoir, and reservoir type. Data means and 95% confidence intervals were used to compare the results. Gill net indices were compared in a similar manner.

RESULTS

Primary Productivity Determinations

Analysis of the dissolved oxygen data (Table 3) revealed that differences between reservoirs and between reservoir types were not significant ($p = .25$, $F = 2.19$ with 1, 2 degrees of freedom; Snedecor and Cochran 1967). This indicated that drawdown had no effect on photosynthetic activity. Since the estimated photic zone depths in the reservoirs were usually within 1 m of each other, areal figures would not have been significantly different and were not analyzed.

Differences in photosynthetic oxygen production in the four reservoirs may not have been reflected in primary productivity determinations because of experimental error in the following areas:

1. Number of samples obtained: McConnell (pers. comm.) recommended that at least ten samples be taken to obtain a representative value for a given lake. Seven samples were the most taken from one reservoir during this study.

2. Diffusion errors: diffusion of oxygen through the air-water interface can cause a serious error if open water primary productivity determinations are attempted when water is turbulent (McConnell 1963). Although samples were not taken on extremely

Table 3. Primary productivity of four study reservoirs, Northern Colorado, 1975-76 (g oxygen/m^3/day).

Stable Reservoirs		Drawdown Reservoirs	
Idaho Springs	Urad	Comanche	Eaton
.71	1.23	.16	.35
.78	.82	.24	.42
.73	.38	.57	1.31
.27	.00	.00	.19
.36	.19	.54	.36
.47	.21		.42
.90	.00		.45
Averages			
.60	.40	.31	.50

windy days, time constraints made it impossible to wait for complete calm, and diffusion errors may, therefore, have been significant.

3. Variations in insolation: no records were kept of amount or quality of incoming radiation during the day. Therefore, some measurements were made after a day of direct sunlight, and others were made after a day of cloudiness.

The values obtained in this study were small compared to those of other authors who used the same technique (Hallock and Ziebell 1970; McConnell 1963; Odum 1957), and reported values ranging from 4.4 to 18.1 g oxygen/m^2/day. This suggests that photosynthesis in all of the study reservoirs was limited and indicates a relatively low potential for fish and invertebrate production regardless of drawdown variations.

Determination of primary productivity by the open-water diel oxygen pulse method is a fairly new limnological technique, and there are areas of uncertainty concerning its use and interpretation. Despite these limitations, slight differences between the reservoirs appeared in the mean oxygen production values, and possible interpretations of these differences will be presented in the discussion.

Invertebrate Sampling

Results of benthic and planktonic sampling were separated into hauls taken in shallow and deep water on each sampling date (Figures 7-10). The dependent variable is presented on a log scale.

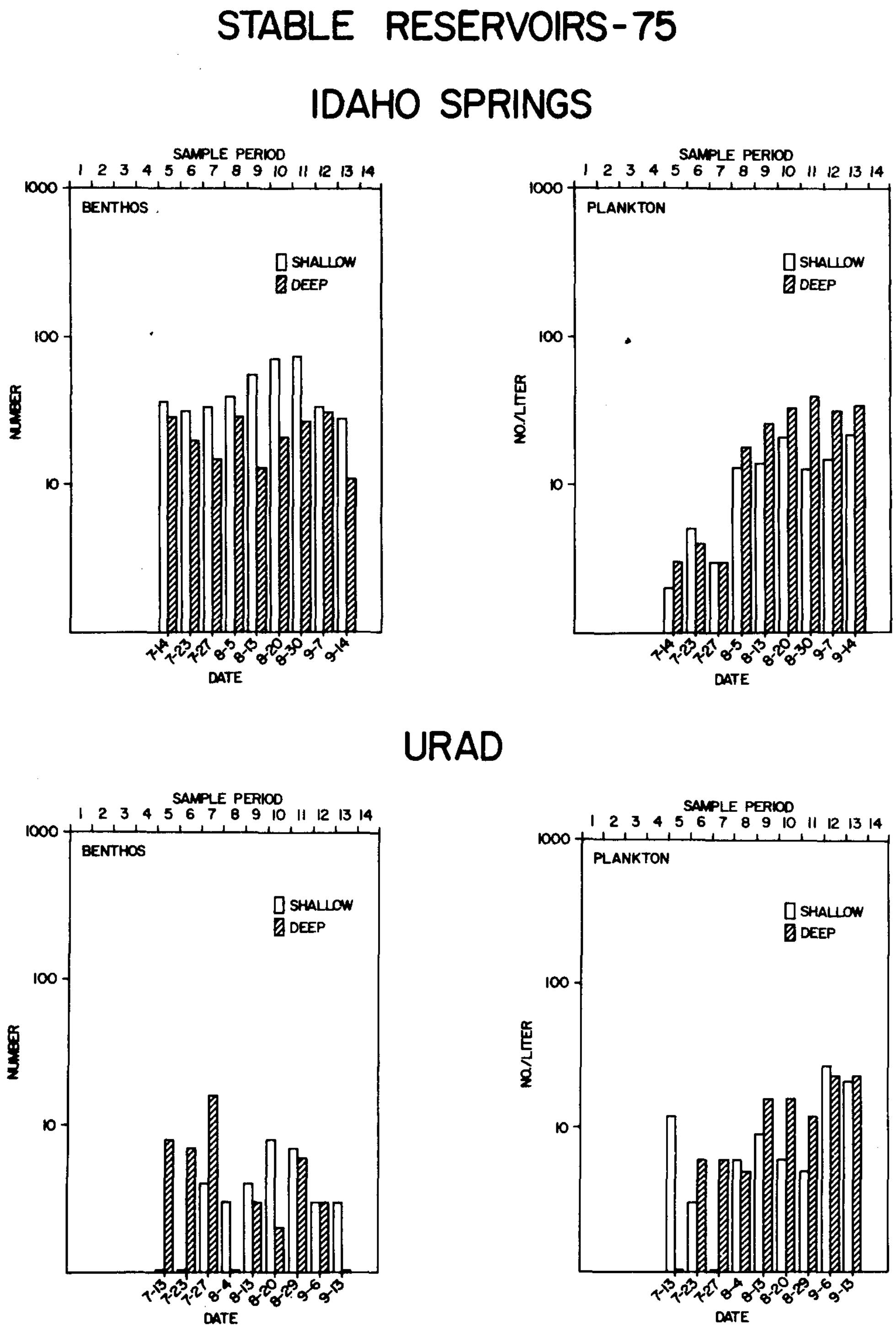


Figure 7. Results of invertebrate sampling of two stable study reservoirs, 1975.

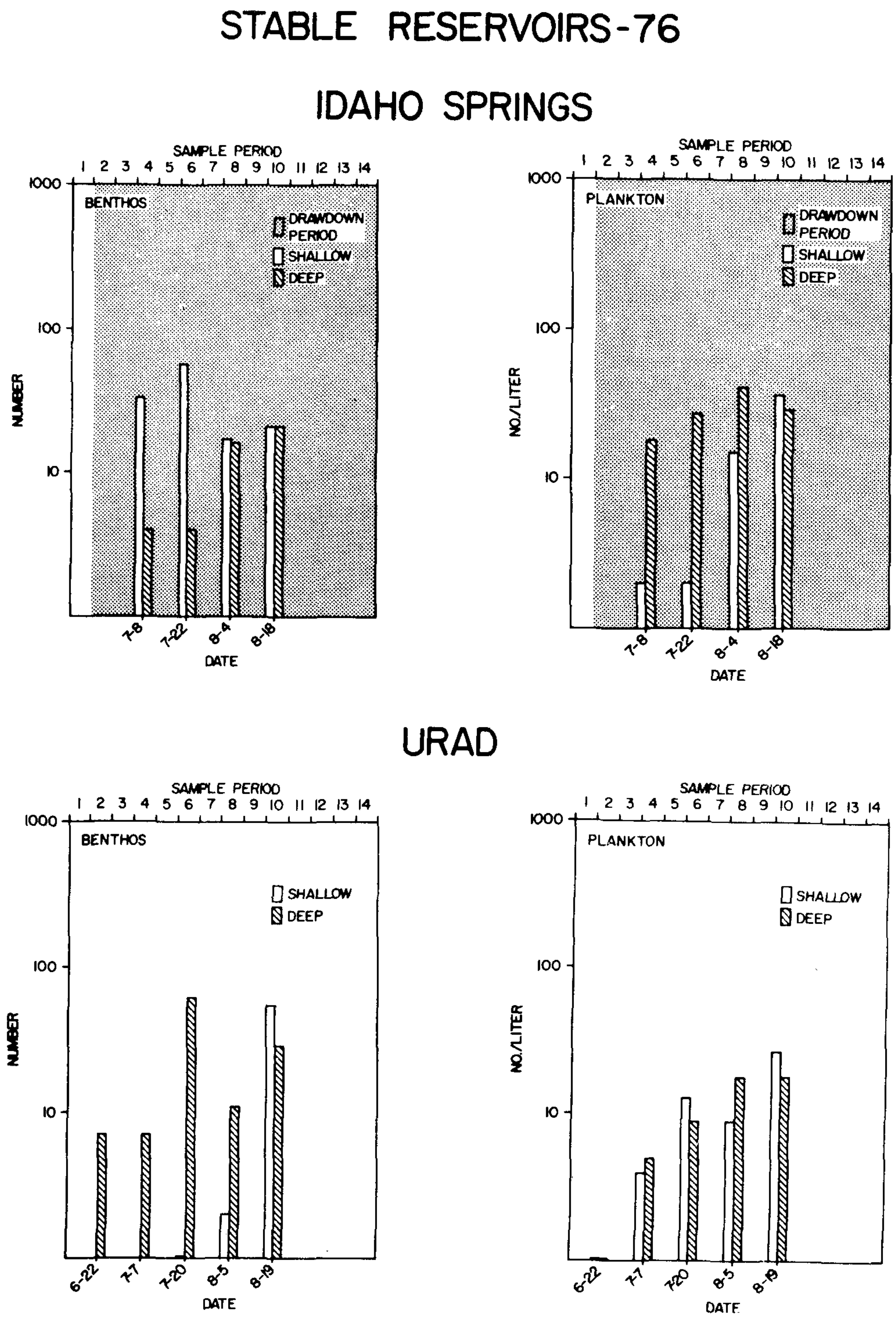


Figure 8. Results of invertebrate sampling of two stable study reservoirs, 1976.

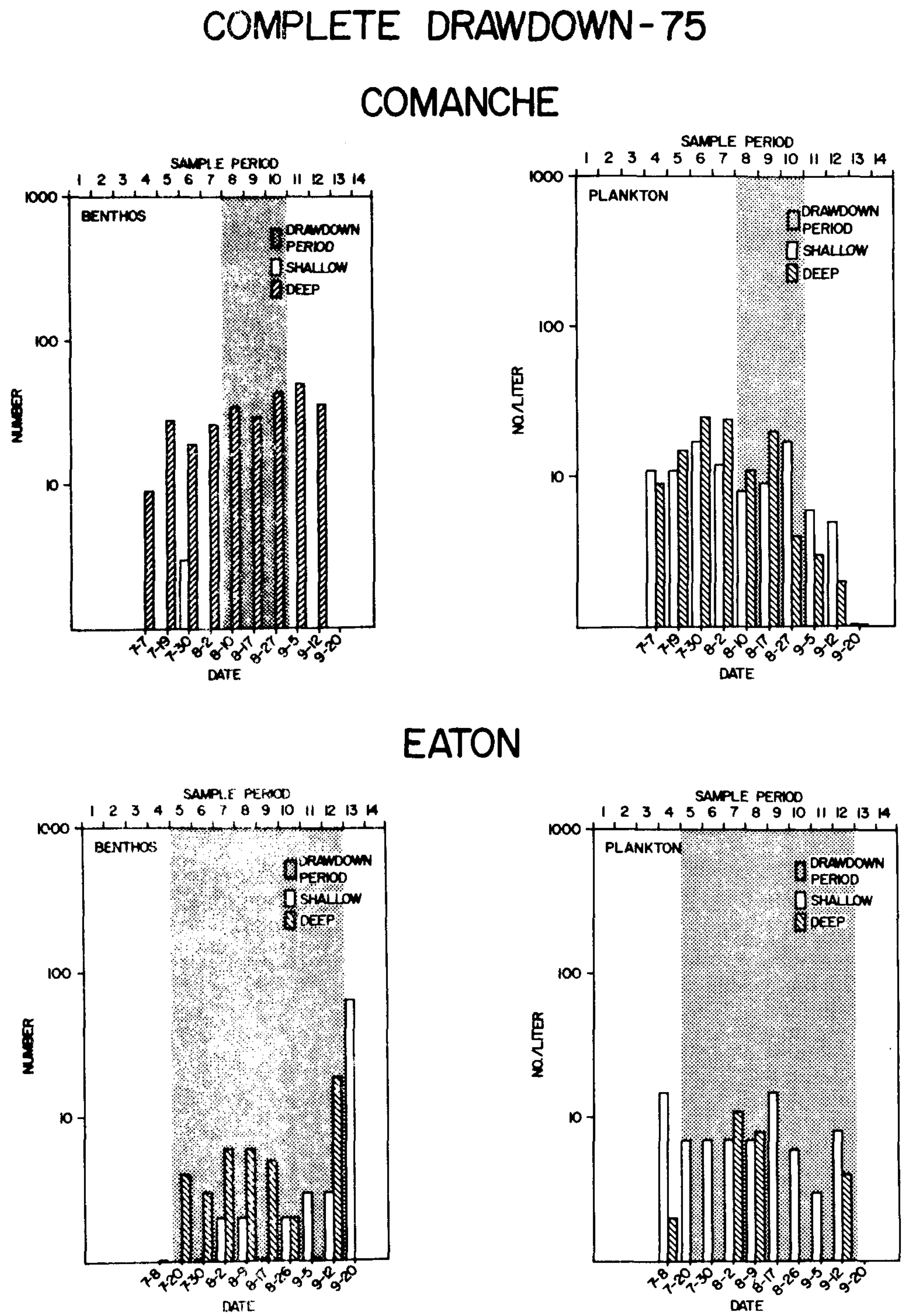


Figure 9. Results of invertebrate sampling of two drawdown study reservoirs, 1975.

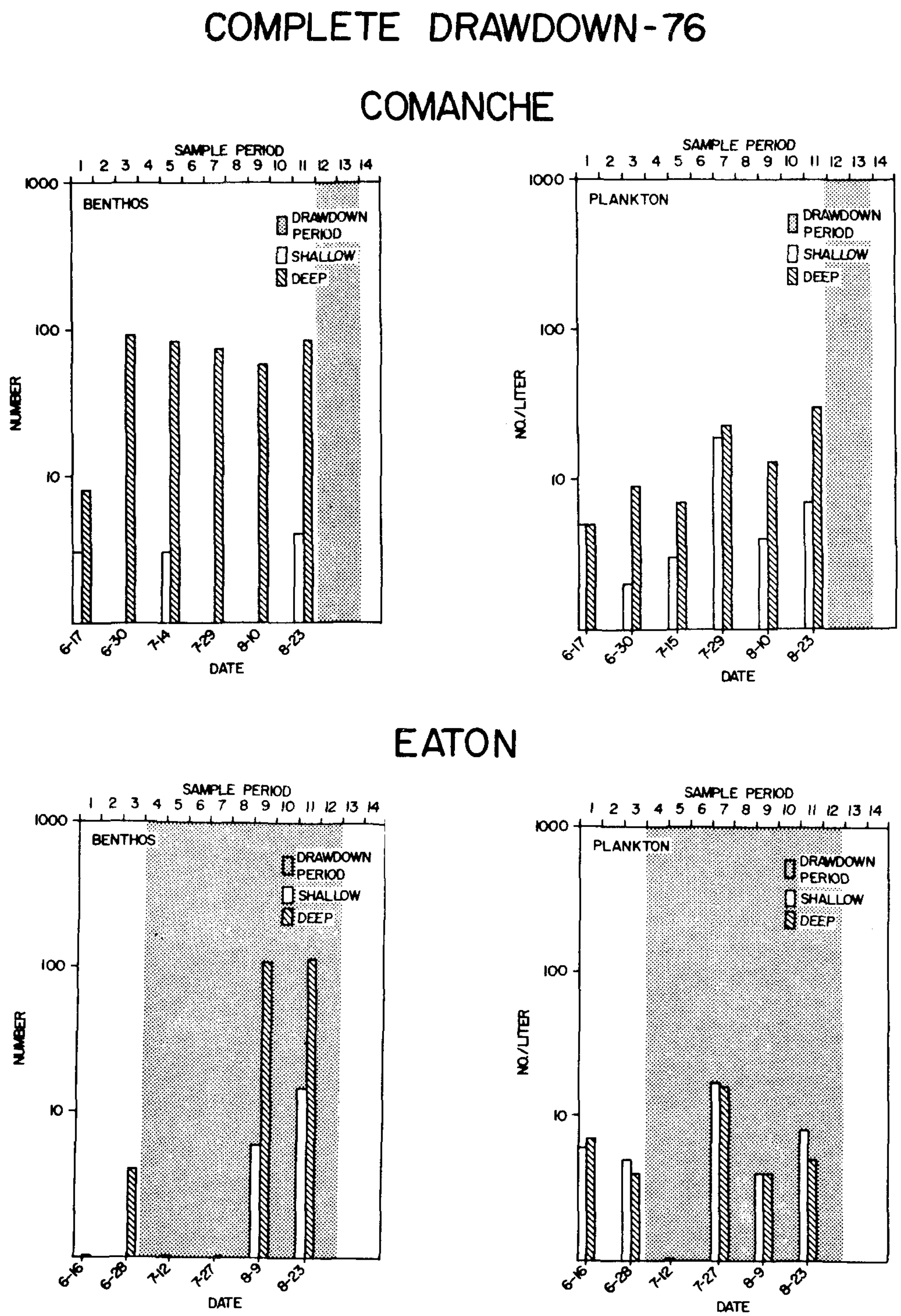
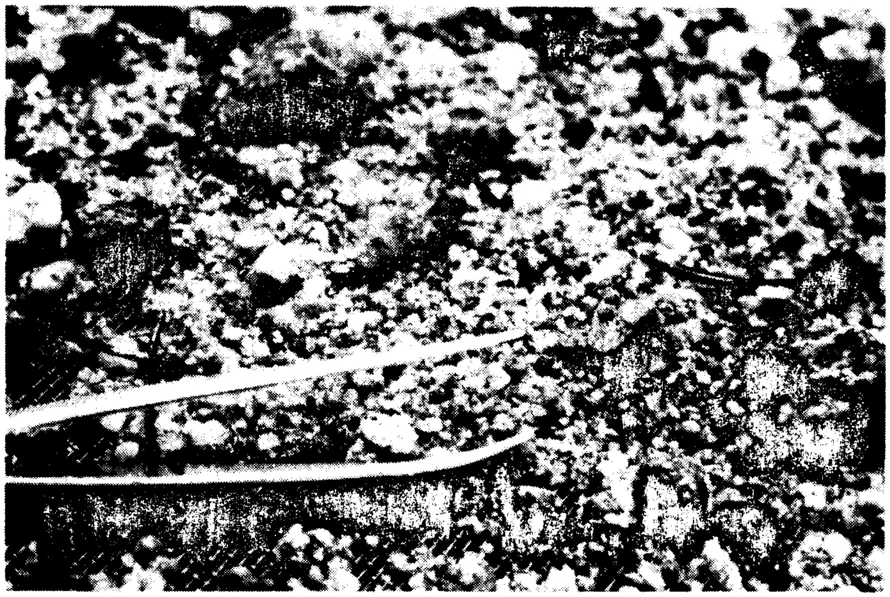


Figure 10. Results of invertebrate sampling of two drawdown study reservoirs, 1976.

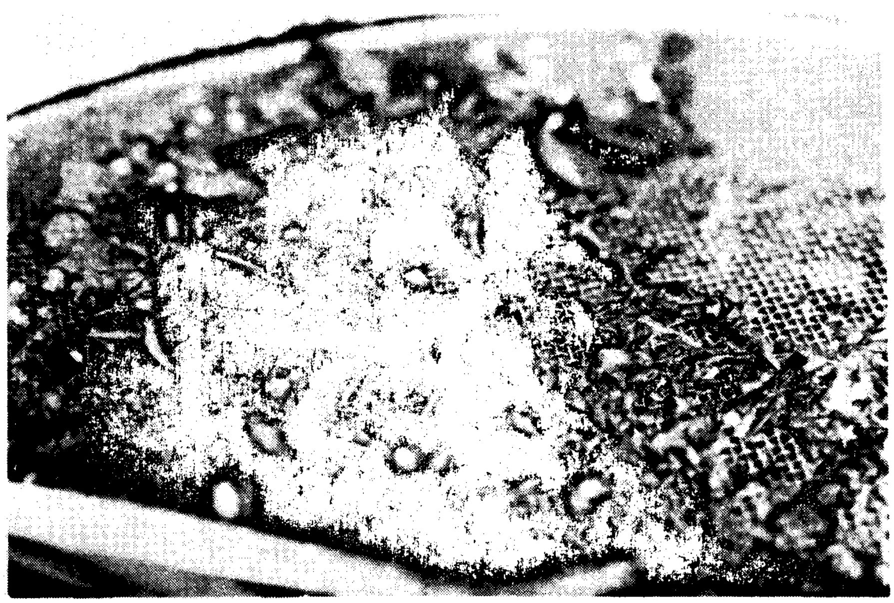
There was a very sparse littoral benthic fauna in Comanche and Eaton, the drawdown reservoirs (Figures 9 and 10). In contrast, this community was relatively dense in the stable reservoirs, Idaho Springs and Urad (Figures 7 and 8). The benthic fauna was concentrated in the remaining water as drawdown neared completion in Eaton Reservoir. Concentration was less evident in Comanche. The 1976 drawdown in Idaho Springs may have destroyed some of the deep-water benthos (Figure 8).

Density of benthic fauna in all reservoirs was also related to the type of substrate. Very sparse populations were found on gravel or very hard substrates. In contrast, bottoms composed of discrete, recognizable pieces of plant material (e. g. pine needles or pieces of bark) imbedded in fine mud usually produced dense populations (Figure 11).

The trend toward sparse littoral communities in drawdown reservoirs and denser communities in stable reservoirs did not extend to the zooplankton. Zooplankton densities increased throughout both summers in Idaho Springs and Urad (Figures 7 and 8). This increase was seen in Comanche during 1975 until drawdown began during sampling period 8 (Figure 9); a similar trend was seen in 1976 (Figure 10). The zooplankton in Eaton appeared to pulse (show marked increases followed by decreases) during both summers and did not show a relationship to drawdown such as was seen in Comanche (Figures 9 and 10).



Medium gravel from Eaton Reservoir, Larimer Co., supported sparse benthic populations.



Discrete plant material from Idaho Springs Reservoir, Clear Creek Co., supported dense benthic populations.

Figure 11. Comparison of some benthic substrates from study reservoirs, Northern Colorado, 1975-76.

Composition of the planktonic and benthic invertebrate communities for the entire study period was calculated (Table 4).

Statistical analysis of the data presented in Figures 7-10 showed that the variability in the samples was so great that it was impossible to conclusively determine the effect of drawdown on either zooplankton or benthos (Tables 5 and 6). Similar analyses were conducted for each of the major taxonomic groups collected and are presented in the appendices.

The means of data for the drawdown reservoirs included samples taken before and during drawdown. Therefore, these numbers may reflect concentration of benthos and loss of zooplankton during drawdown, which were suggested by the graphs. The numbers for 1975, when no drawdown occurred in either of the stable reservoirs, seemed to show that Idaho Springs produced more benthos and plankton than Urad. Large differences between years in some of the reservoir were also apparent, and variation between individual reservoirs in each drawdown type was often greater than that between the stable and drawdown groups.

Since all invertebrate sampling depends on the collection of very small portions of entire communities, extremely high variability is to be expected in the results of short-duration studies in which a limited number of samples are taken. In zooplankton and benthic sampling it is important to gather a large number of samples at

Table 4. Percentage composition of benthic and planktonic invertebrate communities in four study reservoirs, Northern Colorado, 1975-76.

	Reservoirs			
	Stable Reservoirs		Drawdown Reservoirs	
Communities	Idaho Springs	Urad	Comanche	Eaton
Benthic				
Tendipedidae	32.3	71	80	21.8
Tubificidae	1.8	27.1	19.4	71.7
Sphaeriidae	61	0	0	6.3
Other	4.9	1.9	.6	.3
Planktonic				
Cladocera	54.1	21.7	45.7	59.5
Copepoda	45.9	78.3	54.3	40.5

Table 5. Statistical analysis of total zooplankton densities in four study reservoirs, Northern Colorado, 1975-76.

	Reservoirs					
	Stable Reservoirs			Drawdown Reservoirs		
Years and Results	Idaho Springs	Urad	Ave.	Comanche	Eaton	Ave.
			1975			
Mean	22.3	9.5	16.0	13.1	6.0	9.6
No. of samples	27	26	53	29	27	56
Std. dev.	19.4	7.8	16.1	8.9	7.5	8.9
95% conf. int.	14.6-30.0	6.4-12.7	11.6-20.5	9.7-16.5	3.0-8.9	7.2-12.0
			1976			
Mean	21.5	10.8	15.6	10.6	6.6	8.6
No. of samples	8	10	18	12	12	24
Std. dev.	14.9	8.4	12.6	9.0	5.0	7.4
95% conf. int.	9.3-33.7	4.9-16.7	9.3-21.8	5.0-16.2	3.4-9.7	5.4-11.7

Table 6. Statistical analysis of total benthos densities in four study reservoirs, Northern Colorado, 1975-76.

	Reservoirs					
	Stable Reservoirs			Drawdown Reservoirs		
Years and Results	Idaho Springs	Urad	Ave.	Comanche	Eaton	Ave.
			1975			
Mean	33.5	4.5	19.0	13.9	6.6	10.3
No. of samples	18	18	36	20	19	39
Std. dev.	17.8	3.8	19.4	17.4	14.7	16.3
95% conf. int.	24.7-42.3	2.6-6.4	12.4-25.6	5.8-21.9	-.5-13.7	5.0-15.6
			1976			
Mean	21.6	17.4	19.3	33.9	21.3	27.6
No. of samples	8	10	18	12	12	24
Std. dev.	17.1	23.4	20.4	39.6	43.3	41.1
95% conf. int.	7.7-35.6	.95-33.9	9.2-29.4	9.0-58.8	-6.0-48.5	10.3-44.9

various times and places to assure that a representative picture of the community is being obtained (Longhurst 1959; Ruttner 1963). Time and manpower constraints made such thorough sampling impossible in this study.

Longhurst (1959) listed four problems which lessen the accuracy of benthic sampling:

1. benthic fauna are buried in or attached to substrata of varying consistency,

2. individuals are arranged patchily on both a large and a small scale,

3. individuals vary in size, and

4. individuals are often sparsely distributed.

Deevey (1941) described "concentration zones," or depth zones where benthos is especially dense, and warned that these may bias benthic samples. Eggleton (1939) stated that emergence of aquatic insects in the summer can cause problems in benthic studies, and Brinkhurst (1974) found that such seasonal variability followed a different course at each place and depth in a lake. Robertson (1947) emphasized the intimate relationship between the type of bottom and the abundance of various species of benthic organisms.

Plankton distribution is also variable and large numbers of samples are needed to provide representative population values. Wind can cause differences in horizontal plankton distribution (Small

1963; Wetzel 1975), as can other variables such as the nature of inflowing streams, irregularity of shoreline, currents, and action of predators (Welch 1952). Zooplankton are also subject to large variations in individual size and population age composition, and they are very sensitive to changes in their food supply (Edmondson 1965; Hazelwood and Parker 1961; McLaren 1963; Slobodkin 1954). All these factors combine to make a plankton community very difficult to sample. Ruttner (1963) stated that 10-20% variations have no significance in statistics on plankton populations.

From the standpoint of the relation of invertebrates to fish flesh, the invertebrate data might better have been presented in terms of biomass. However, Pennak (1946) stated that mean number of organisms per unit of volume or area may be used to make meaningful comparisons between lakes. Such data are just as useful in determining drawdown effects in reservoirs. In addition, most of the organisms collected from all four reservoirs were of approximately the same size. The only exceptions were the zooplankters in Eaton, which were sometimes larger than those from the other reservoirs.

Although the variability in the invertebrate sampling was high, certain interpretations could be made. These will be presented in the discussion.

Fish Sampling

Coefficients of condition were calculated for fish in each reservoir. Data mean values and 95% confidence intervals for game fish (predominantly brook trout, Salvelinus fontinalis) and rough fish (suckers, Catostomus spp.) were determined (Table 7). These data show that the game fish in Urad, a stable reservoir, and Eaton, a drawdown reservoir, were in better condition than those in the other reservoirs. The rough fish in Idaho Springs, a stable reservoir, also appeared to be in better condition than those in the other reservoirs.

An analysis of variance conducted on the data showed that game fish conditions in all reservoirs remained stable between 1975 and 1976 ($p = .05$, $F = .41$ with 3, 1 degrees of freedom). However, there were statistically-significant year differences in rough fish conditions ($p = .05$, $F = 11.95$ with 2, 1 degrees of freedom). This reflects a slight drop in the condition of the rough fish in both Idaho Springs, a stable reservoir, and Comanche, a drawdown reservoir, during 1976. The lower conditions of rough fish in Idaho Springs could be a result of the drawdown which occurred there during 1976, although that drawdown did not affect the game fish in the reservoir.

The analysis of variance also confirmed the differences in fish conditions between reservoirs that were indicated by Table 7 ($p = .05$, $F = 7.04$ with 3, 1 degrees of freedom). However, these data did not

Table 7. Mean coefficients of condition (and 95% confidence intervals) of fish from four study reservoirs, Northern Colorado, 1975-76.

	Reservoirs and Results			
	Stable Reservoirs		Drawdown Reservoirs	
Fish Types	Idaho Springs	Urad	Comanche	Eaton
Game fish				
K	1.02	1.16	1.03	1.20
C.I.	.95-1.09	1.09-1.23	.99-1.07	1.17-1.23
Rough fish				
K	1.16	--	1.01	1.05
C.I.	1.03-1.29		.99-1.03	1.03-1.07

reveal any variations in condition that could be attributed to drawdown patterns.

A gill net index (number of fish caught/38.5 m of net/day) was used to compare fish densities in the reservoirs (Figure 12). These indices showed more fish in Comanche, a drawdown reservoir, than in the other three reservoirs. Urad, a stable reservoir, had the fewest fish.

Statistical analysis of the gill net data showed some variability that tended to weaken any conclusions about the effect of drawdown (Table 8). This is partly because equipment and manpower constraints permitted use of only one net for each sample. Moyle et al. (1950) recommended that eight nets be set for any one sample in a lake under 50 ha surface area to get a good estimate of fish density. Moyle (1951) also warned that gear selectivity and variations in catch caused by fish movements and population groupings are important variables in gill net catches. Therefore, gill net indices can be considered a measure of the density of fish communities only in a general sense.

There appeared to be some positive correlation between the densities of fish in the reservoirs and the densities of benthos and zooplankton there. However, the correlation with invertebrate densities did not extend to condition coefficients (i.e. the reservoirs

Table 8. Statistical analysis of gill net indices for four study reservoirs, Northern Colorado, 1975-76.

	Reservoirs			
	Stable Reservoirs		Drawdown Reservoirs	
Results	Idaho Springs	Urad	Comanche	Eaton
Mean	31.8	20.6	69	30.8
No. of samples	5	5	3	5
Std. dev.	13.6	8.4	21.7	9.5
95% conf. int.	16.2-47.4	11.0-30.2	29.1-108.9	19.9-41.7

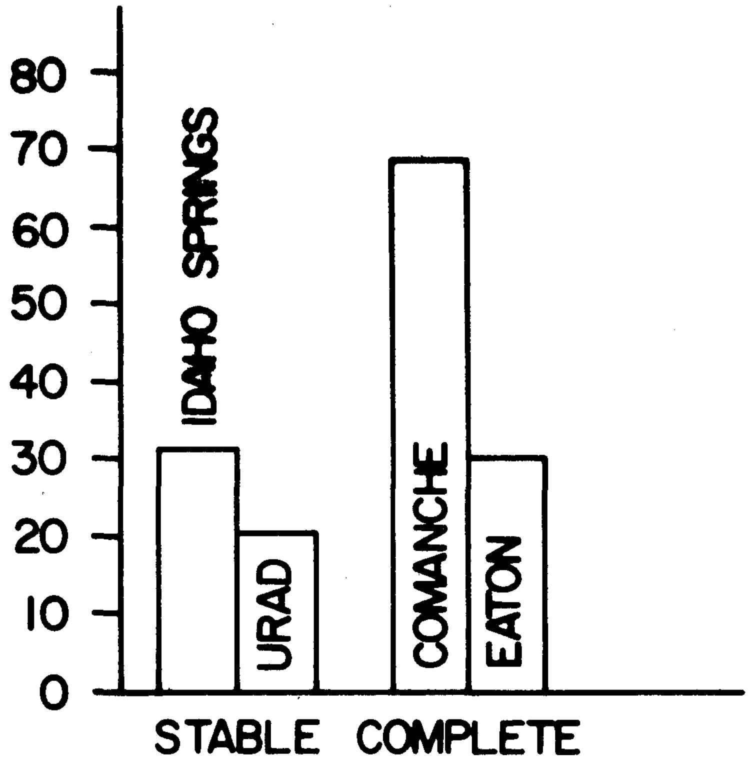


Figure 12. Gill net indices for four study reservoirs, Northern Colorado, 1975-76.

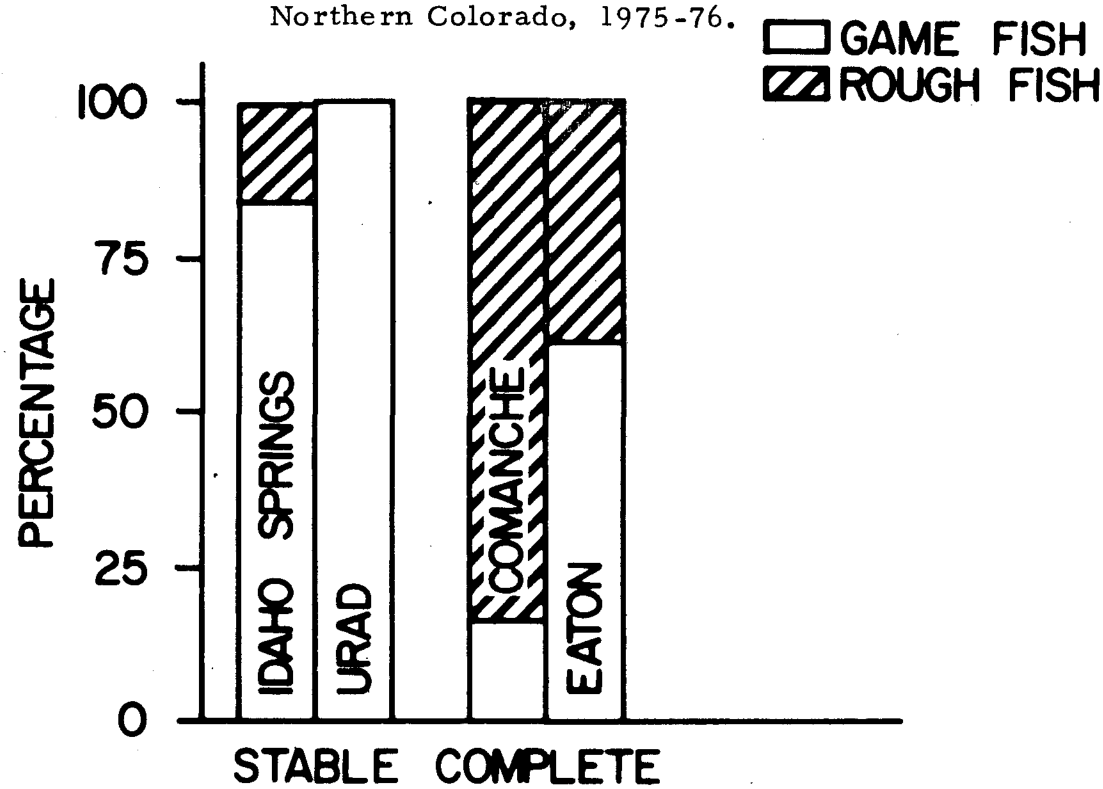


Figure 13. Fish community composition in four study reservoirs, Northern Colorado, 1975-76.

which supported larger amounts of invertebrate fauna did not necessarily have fish with high condition factors).

A summary of the composition of the fish communities in each reservoir showed significant differences between reservoirs (Figure 13). Both the drawdown reservoirs, Comanche and Eaton, had larger percentages of rough fish than the stable reservoirs. Comanche's fish community was predominantly rough fish, and Eaton's was almost half rough fish. The figures for the two stable reservoirs presented a sharp contrast. Idaho Springs contained a small percentage of rough fish, and the fish community in Urad was composed entirely of game fish. Interpretations of these findings will be presented in the discussion.

DISCUSSION

Competition for the use of limited natural resources presents a challenge to elected officials, the voting public, and other decision makers. Multiple-use management of reservoirs for irrigation, recreation, electrical generation, wildlife and other needs requires that a variety of alternatives be analyzed by policy makers. Drawdown is a major consideration in management of a reservoir for a fishery.

Problems involving the effect of drawdown on the recreational facets of a reservoir exist wherever multiple-use management is attempted. These problems range from loss of aquatic plants to muddiness of boat launching areas. Solutions are particularly difficult to find in the Front Range area of Colorado because of severe competition between agricultural and municipal water uses and demands for water by fishermen and other recreationists. Such competition eliminates the possibility of single-purpose reservoirs.

Although there are almost no quantitative data on the effects of drawdown on the fauna in Colorado mountain reservoirs, conclusions and hypotheses have been drawn and have been used as bases for policy decisions. Tanner stated that fluctuating water levels cause reduced biological productivity, higher fish management costs, and more hazards to fish communities as a whole. Nittmann (pers.

comm.) discussed several instances in which lack of water or water circulation in drawdown reservoirs had resulted in severe winter-kill. Wespestad (1975) suggested that drawdown destroyed benthic food organisms and decreased total fish communities in the mountain reservoirs he studied.

Results of the present study did not produce any conclusive evidence of drawdown effects. However, several properties of the reservoirs and their drainage basins might have worked to obscure drawdown effects.

Edaphic factors are very important in determining the productive potential of a lake or reservoir (Rawson 1939; Sparrow 1966). Solubility, erosivity, and chemical composition of the geologic material in the drainage basin are important in controlling the amount and nature of inorganic nutrients in the water and the type of substrate that lines the bottom. Nutrients are essential for the photosynthetic processes which support the food chain, and the composition of the bottom plays an important role in determining the species in and densities of bottom-dwelling communities. A reservoir such as Idaho Springs, which is in a barren granitic basin, might be expected to be less fertile than one in an area of well-developed soil, such as Eaton.

Edaphic effects on bottom-dwelling communities indirectly influence the fish populations since some taxa of invertebrates are more available fo fish than others. Thus a reservoir, such as Eaton, with a large percentage of burrowing Tubificidae which are often unavailable to fish, might support fewer fish than one such as Comanche, with many available Tendipedidae.

Other factors are less significant than the basic edaphic character of the watershed but may still be important in determining the nature of the water and the bottom substrate. The type of terrestrial vegetation influences the amount, type and distribution of organic detritus in the lake basin (Edmondson 1957) and may also determine which nutrients are leached from the soil and which are retained by plant growth (Robertson 1954). The presence of environmental disturbances, such as the burn in the drainage basin of Comanche Reservoir and the floating limbs in Eaton, can also be expected to affect the water. Fredrikson (1971) and Likens et al. (1969) reported that dissolved ion loss from the soil was increased by clearing of forested land and by burning of the wood. The turbid water that is often produced by such disturbances can also reduce the effectiveness of photosynthetic organisms (Murphy 1962).

The morphometry of a lake or reservoir basin also exerts an influence on the productivity of that body (Rawson 1952). A basin with very steep side slopes will have a small littoral zone, and the productivity usually associated with that area will be greatly restricted (Berg 1938). Steep-sided reservoirs also do not accumulate sediment in places where aquatic plants can grow as well as those with gentler sides (Peltier and Welch 1970). The higher primary productivity value of Idaho Springs Reservoir might be a result of the fairly extensive littoral zone there.

In addition, mean depth, which is a function of the surface area and volume of a reservoir is often important in determining trophic efficiency. Equal amounts of volumetrically-expressed photosynthesis will have equal trophic effectiveness only in lakes of similar mean depth (Stewart 1967). This factor might help to explain the productivity differences between the two stable reservoirs; Idaho Springs was shallow, and Urad was deeper.

Morphometry also influences the circulation of heat and dissolved and particulate matter in the reservoir basin and may affect productivity by increasing or decreasing the percentage of the water volume in which conditions for photosynthesis and secondary production prevail (Findenegg 1965; Murphy 1962; Northcote and Larkin 1956). This influence may be complicated by the fact that reservoirs are subject to man-made variations which produce circulation patterns from those in natural lakes (Neel 1963; Rounsefell 1946; Wunderlich 1971). Among these man-made variations are the vertical placement of inlets and outlets and the location of the area of maximum depth.

Climatic factors are the third major group of influences that may tend to obscure drawdown effects. The most important influences of climate are on temperature of lake water and duration of temperatures amenable to the growth of aquatic plants and animals (Efford 1967; Hall 1964; Rawson 1942; Talling 1966; Wilson 1939). Within the tolerance limits of a species, a higher temperature will usually cause faster growth and onset of maturity and, consequently, a higher rate of production. Climate influences lake temperature indirectly by control of the volume and temperature of the inlet streams. Thus, a reservoir such as Urad, which receives large volumes of direct snowmelt well into the summer would be expected to be colder than Eaton, which receives no direct snowmelt after the last of April.

Stratification is controlled largely by climatic influences and is important in determining the distribution of heat, nutrients, and plant and animal life within a body of water. Stratification may limit production by trapping nutrients in the hypolimnion, where they are unavailable to the autotrophs present in the epilimnion until the water mass circulates during spring and fall overturn.

Climate is also responsible for variations in insolation, which may be responsible for variations in photosynthetic production (Goldman 1960; Kerekes 1974; Robertson 1954; Russell-Hunter 1970). Differences in insolation become significant even in small regions if one area is consistently cloudy while another is clear. Differences may also arise when one reservoir, such as Urad, is in a deep basin with an average of only 11 hr of direct sunlight on a mid-summer day, while another, such as Eaton, is in an open area receiving an average of 16 hr of direct sunlight on that day.

Wind is another important climatic factor. Wind and wind-induced currents are instrumental in transporting and distributing heat, nutrients, dissolved gases, and particulate matter horizontally and vertically within a reservoir (Small 1963). Wind also affects the shoreline, and its ability to support life, by causing wave action (Boyd 1971; Wilson 1939). Pounding by waves may severely limit the number of species which can establish themselves on a shoreline. The dearth of benthic fauna in the littoral samples taken from Comanche Reservoir might have been caused, in part, by the consistent high winds in the area. The waves might also have destroyed littoral vegetation near the shore of Comanche and thereby caused the low primary productivity value there.

A final characteristic of reservoirs and their drainage basins which may be important in determining drawdown effects is the presence or absence of refugia. These areas serve as protection for fish and aquatic invertebrates during times of complete drawdown. The perennial stream, upstream lakes, and beaver ponds which were found at Comanche Reservoir may be very important to survival of the fish community in that reservoir. In contrast, the very small inlet stream, and no other bodies of water upstream, may have been a disadvantage to the fish in Eaton Reservoir.

Characteristics of a reservoir and its drainage basin which would tend to make it well-suited for fish are

1. water from a fertile rather than a barren watershed,

2. terrestrial vegetation which contributes debris to the water and allows many nutrients to be leached from the soil into the water,

3. a basin with gently-sloping sides so that a littoral zone with rooted aquatic plants can develop,

4. shallow mean depth, so that a large proportion of the reservoir can support photosynthesis,

5. morphometry which allows complete circulation of the water mass,

6. a relatively high water temperature within the tolerance limits of the desired species, and a long duration of this water temperature,

7. absence of consistent high wind-caused waves which pound the shoreline, and

8. adequate refugia for protection of fish and invertebrates during drawdown periods.

Observation and analysis of standard drawdown practices in small mountain reservoirs in Colorado revealed elements which appeared to be highly relevant to the fisheries of those reservoirs.

The length of the drawdown period was quite brief, lasting from 15 to 45 days. The time of maximum drawdown occurred during late August and early September when daytime temperatures were approximately 12 C and nighttime temperatures approximately 5 C, thus lessening evaporation from the exposed substrate. In addition, refill began almost immediately. The result of this pattern was that only the uppermost layers of the exposed substrate dried out completely, leaving plenty of moist substrate for survival of burrowing forms such as oligochaetes and dipterans, and for support of other organisms which could find shelter under various objects. Paterson and Fernando (1969) and Fillion (1967) found that most burrowing or shelter-seeking organisms could survive such exposure in above-freezing weather for periods of at least 50 days. Fillion (1967) reported that tendipedid larvae have survived exposure for up to 85 days.

The short duration of the complete drawdown period also guaranteed that remaining pools and pre-impoundment streams did not dry up or freeze. Paterson and Fernando (1969, 1970) and Isom (1971) reported that freezing of exposed substrate resulted in very high mortality of the benthic organisms buried therein. Benson and

Hudson (1975) also attributed a reduction of benthic fauna during the spring following a fall and winter drawdown to freezing of the substrate.

Since refill began in the autumn almost immediately after the completion of drawdown, colonization of the new water volume and the re-inundated substrate by invertebrates could proceed before the onset of severe winter temperatures. Paterson and Fernando (1969) reported rapid dispersal of surviving tendipedids after reflooding of exposed reservoir substrate. Zooplankton increase in numbers rapidly as long as the food supplies will support their populations (Edmondson 1965; Edmondson et al. 1962; Hazelwood and Parker 1961). Therefore, the zooplankters remaining after drawdown would also be expected to rapidly repopulate the increasing water volume. The invertebrates would then overwinter (cladocerans as epphipial eggs, copepods as resistant eggs and larval stages, and benthos buried in the substrate) much as if drawdown had never occurred (Comita 1972; Edmondson 1955; Schmitz 1959). One explanation for the sparse littoral benthic fauna in Comanche and Eaton, the drawdown reservoirs, might be that they were only half full during the winter months and the littoral substrate was, therefore, subject to freezing.

Timing of drawdown has a profound effect on the fish communities in small mountain reservoirs in other ways than through the food chain. The reservoirs studied for this project contained game-fish communities composed predominantly of brook trout (Salvelinus fontinalis). These fish spawn in the fall (Calhoun 1966), and Wespestad (1975) observed them spawning in the streams remaining in Comanche and Eaton reservoirs after the completion of drawdown. The embryos of these fall-spawning fish were almost certainly destroyed as soon as the stream was re-inundated. This mortality and its effects were not determined. Jensen (1971) stated that even a 5% increase in mortality of the 0 age group of brook trout decreased the yield of the fishery.

The rough fish in the community in the drawdown reservoirs were suckers (Catostomus spp.) which spawn in the spring (Beckman 1963). Since the reservoirs are full or almost full by spring, sucker embryos probably suffer little or no mortality of the type experienced by the brook trout.

Nelson (1965) discussed the lack of studies concerning the effect of sucker competition on salmonids. However, interactions such as those outlined above almost certainly have a detrimental effect on salmonids.

Timing of drawdown could also affect different fishes in other ways; spring drawdown might not affect brook trout but could be expected to harm spring-spawning species such as rainbow trout (Salmo gairdneri).

Two other drawdown-related processes which might affect the fishery in a small mountain reservoir are flushing and mechanical sorting of the substrate. Many authors have noted rapid flushing of water through a reservoir as depressing productivity by removal of nutrients (Efford 1967; Kerekes 1974; Lund 1955; Nursall 1952; Taylor 1971). Phytoplankton, zooplankton, and fish may also be removed. The primary productivity data did not suggest any major flushing of nutrients during drawdown, but flushing may have been overshadowed by other reservoir characteristics. There was some indication of loss of zooplankton during drawdown of Comanche Reservoir, although the evidence was not conclusive. The effect of removal of fish during drawdown is also unknown.

Mechanical sorting of the substrate during drawdown was cited by Benson and Hudson (1975) as a harmful effect of drawdown. Sorting occurs through wave action as the reservoir is lowered, removing all silt from the exposed areas of the reservoir and concentrating it in the remaining areas of water. This process removes substrate that is suitable for burrowing fauna and may reduce photosynthesis in the remaining water by increasing turbidity. Mechanical sorting was observed in Eaton Reservoir and to a lesser extent in Comanche, but the effect on the benthos was not documented.

This study did not show any conclusive evidence of drawdown effects for one or a combination of the following reasons:

1. variations in edaphic, morphometric and climatic factors obscured drawdown effects;

2. drawdown patterns used in the study reservoirs did not produce quantifiable effects;

3. the sampling intensity was inadequate to confirm drawdown effects;

4. the drawdown effects were in areas of the ecosystem which were not studied, or

5. there were no drawdown effects.

It is difficult to believe that drawdown of small mountain reservoirs has no effects, especially since several studies have shown effects in other types of reservoirs. Drawdown may affect some variable, such as young-of-the-year fish, which was not studied in this project. However, the most logical conclusion is that complexities of four different reservoir ecosystems combined with relatively harmless drawdown patterns to obscure any effects that might have been revealed in this type of study. If drawdown effects are to be determined with any accuracy, the study must be done on one reservoir over a series of years or on two or more reservoirs with nearly identical watersheds, climates and physical and biological characteristics during an intensive one-year project.

A study done on two or more nearly-identical reservoirs would be most likely to yield concrete results on the effects of drawdown.

This type of study would avoid the year-to-year ecological variation which influences a project done on one reservoir over a series of years. The study would require at least one reservoir with a stable water level and one scheduled for a significant degree of drawdown. Ideally, several different drawdown patterns should be represented.

It would be very important to conduct a complete evaluation of all the candidate study reservoirs. The evaluation would include reports on the geologic and biologic characteristics of the watershed, detailed climatic information, and complete physical and biological investigations of the reservoirs themselves. From this evaluation, the reservoirs with nearly-identical ecological characteristics could be chosen for study. This evaluation must be considered an indispensable first step to any further study of drawdown effects, so that during the study, the investigators could feel sure that they were measuring the effect of drawdown rather than the effects of other ecological variables.

After the selection of nearly-identical study reservoirs with variable drawdown patterns, a sampling scheme would have to be designed. This would include an intensive one-year, year-round, study of the plankton, benthos and fish in each reservoir. The fauna should be studied in all life history stages, so that the exact reasons for any differences between the communities in the reservoirs would be known. The sampling should extend to all habitats in the reservoirs, and a sufficient number of samples should be taken in each habitat and at each time during the year so that a "representative" picture of the fauna in each reservoir could be obtained. Since all the other ecological factors in each reservoir would be similar, any differences in the fauna should be due to drawdown effects.

In addition to biological sampling in the reservoirs themselves, both upstream and downstream sampling should be conducted to determine the types and directions of movement of fish and invertebrates. This sampling should be done in each reservoir during drawdown, after drawdown, and during refill with the stable reservoir as a control. This sampling should complement that done in the reservoirs themselves by revealing the influence of flushing and refugia on the reservoir fauna.

The results of this intensive study could be summarized and used to describe the effects of drawdown on the fauna in other reservoirs similar to those studied. These results could also be used to cautiously predict the relative effect of drawdown on reservoirs with other ecological characteristics.

Any reservoir ecosystem is a very complex set of interactions between factors in the watershed, climatic variables, and physical and biological characteristics of the reservoir itself. This makes it very difficult to predict the behavior of one type of reservoir from knowledge about another. A study such as the intensive one outlined above would be an excellent step in broadening the understanding of the effects of drawdown. However, as Pennak (1949) warned, "There is no such thing as a typical lake," and all decisions concerning drawdown in reservoirs should be based on common sense founded in knowledge and experience with reservoir ecosystems as well as on research findings.

CONCLUSIONS

No conclusive evidence of effects of drawdown on primary productivity, invertebrate abundance, or fish abundance and condition was found. The following interpretations of the data were made:

1. Drawdown may limit littoral benthic fauna by allowing freezing of exposed littoral substrate and by removing silt from exposed areas of the reservoir.

2. Drawdown may decrease zooplankton populations by flushing zooplankters from reservoirs during drawdown periods.

3. Drawdown may concentrate benthic invertebrates in the remaining water body during drawdown periods.

4. Fall drawdowns may be detrimental to brook trout populations by causing embryo mortality and allowing increased sucker competition.

5. Drawdown patterns used in these study reservoirs may have been relatively harmless to the fish and invertebrate communities as a whole.

6. Edaphic, morphometric, and climatic variations between the four reservoirs may have prevented detection of drawdown effects.

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APPENDIX III

LEGAL ASPECTS ASSOCIATED WITH MAINTAINING WATER IN HIGH MOUNTAIN RESERVOIRS

Robert L. Hiller

and

Thomas M. Keith

APPENDIX III

Table of Contents

Page

I. Existing Legal Status of Recreational Water Rights in Colorado 275

II. Existing Legal Limitations 280

III. Alternatives to Existing Legal Limitations 299

Footnotes . . . .

Bibliography 328

Exhibit A. 330

I. Existing Legal Status of Recreational Water Rights in Colorado

Most reservoirs in Colorado were constructed to store water which otherwise would not be available at the time of greatest need. Recreational values have been a secondary and usually neglected consideration. In order to evaluate strategies for enhancing the recreational value of high mountain reservoirs, it is necessary to review Colorado water law.

Colorado water law evolved at a time when the only concern was to develop a system which facilitated water use in connection with the economic development of the state. In view of this concern and in consideration of the state's geography, a system of prior appropriation developed. A basic tenet of this system is the truism "First in time, first in right." In other words, the priority of usage relates to the seniority of the water right. Seniority is determined by the decree date, which is simply court recognition of the rank of a water right within the priority system.

A. Colorado Statutory and Case Law

1. Diversion

The basic procedural requirements of obtaining a water right are diversion and application of the water to a beneficial use.[1] Definition of these terms has been the subject of a large amount of litigation. The courts have recognized natural overflows during time of high water,[2] and the direct use of water from a stream by cattle as valid appropriations.[3] The Supreme Court held in Town of Genoa v. Westfall that, "The only indispensible requirements are that the appropriator intends to use the waters for a beneficial purpose and actually applies them to that use."[4]

This liberal interpretation was not followed, however, in Colorado River Water Conservation District v. Rocky Mountain Power Co., wherein the court held that maintaining a flow of water in a natural stream in order to support a fishery was not an appropriation because it did not entail a physical diversion from the stream.[5] The requirement that a physical diversion take place was codified by the Water Right Determination and Administration Act of 1969, "'Diversion' or 'divert' means removing water from its natural course or location, or controlling water in its natural course or location, by means of a ditch, canal, flume, reservoir, bypass, pipeline, conduit, well, pump, or other structure or device."[6] This restrictive language subsequently gave rise to minimum stream flow legislation which will be discussed later in the report.

2. Beneficial Use

The Colorado Constitution does not define beneficial use. The Supreme Court has stated, "The term 'beneficial use', after all, is a question of fact and depends upon the circumstances in each case."[7] As defined by the 1969 Act, "Beneficial use is the use of that amount of water that is reasonable and appropriate under reasonably efficient practices to accomplish without waste the purpose for which the diversion is lawfully made and without limiting the generality of the foregoing, shall include the impoundment of water for recreational purposes, including fishery or wildlife."[8]

3. Water Storage Rights

There are two basic types of water rights --

direct use and storage.[9] Colorado law provides that a person who desires to construct and maintain a reservoir has the right to store therein any of the unappropriated waters of the state.[10] The amount which can be stored is determined by the capacity of the reservoir and capacity is defined as the amount of water that the reservoir will hold at any one time.[11] The State Engineer has the duty to annually determine the amount of water capacity capable of being safely stored in reservoirs within the state, and it is unlawful to store water in excess of that amount.[12]

A reservoir may be filled only once each year. The courts have held that "Each reservoir shall be decreed its respective priority, and this priority entitles the owner to fill the same once during any one year, up to its capacity, and restricts the right, upon one appropriation, to a single filling for one year."[13] The logic behind this restriction is based upon the fact that "a double filling in effect would give two priorities of the same date and of the same capacity to the same reservoir, on the same appropriation. . ." There is nothing in the law, however, which restricts the number of appropriations which can be decreed for the same reservoir.[14]

Colorado law also provides that the owners of a reservoir may release stored water into any natural streams and may divert the same out again at any point desired, provided there is due regard to the prior or subsequent rights of others to other waters in said natural streams. The law also provides that due allowance must be made for evaporation and other losses from natural causes, such losses to be determined by the State Engineer. An additional requirement is that water released into a stream not raise the waters thereof above the ordinary high water mark.[15]

4. Federal Reserved Rights

Expansion of the federal reserved rights doctrine could result in additional water being available for recreation. The doctrine derives from an assertion that when federal lands, such as national forests, were withdrawn from settlement, water sufficient for the purposes of the withdrawal were also reserved. In 1955, the Supreme Court held that the withdrawal of or reservation of federal lands for specified purposes also reserved water rights for use on such lands, even though the legislative or executive action withdrawing such lands made no mention of water or its use.[16] Following this ruling, the reserved water rights would carry a priority dating from the date of the withdrawal of the federal lands.

A further confirmation of federal reserved rights was provided by the Supreme Court in 1963. Partially relying on the 1955 decision and also on earlier cases involving Indian Reservations, the court ruled that certain reservations of public domain land for particular purposes, e.g. wildlife refuges, a national forest, and a national recreation area, carried with them an "implied" reservation of sufficient unappropriated water to meet the requirements of those reservations without regard to state law.[17]

These Supreme Court decisions have created considerable confusion and requests that Congress either affirm, abolish, or clarify the reserved rights doctrine. So far, Congress has not taken action on the matter. There have been a number of further developments in the courts, however. In 1976, the Supreme Court ruled that establishment of Devil's Hole National Monument in California also created reserved water rights sufficient to preserve a small underground pool inhabited by the Devil's Hole pupfish.[18] Recognition of the reserved right sharply limited the state decreed rights of a rancher to withdraw irrigation water from an aquifer which is hydrologically connected to the pool inhabited by the pupfish.

In Colorado, the state has successfully fought to have federal reserved rights adjudicated in state water courts.[19] A May 1976 report of the master referee recognized federal reserved rights on seven national forests, Rocky Mountain National Park, Dinosaur, Colorado and Black Canyon of the Gunnison National Monuments and for over 1,300 springs and water holes. The significance of these reserved rights, however, is greatly reduced by the master referee's ruling that the priority date of the national forests' rights claimed to minimum stream flows and lake levels did not extend back to the establishment of the national forests but only to 1960, the year of enactment of the Forest Service's Multiple Use-Sustained Yield Act. The logic of the master referee is that minimum stream flows and other aesthetic uses were not intended uses of the national forest prior to passage of the Multiple Use Act.

A 1960 priority date, along with the master referee's ruling that all national forest reserved rights are subordinate to the use of water by appropriators for domestic, mining, milling and irrigation uses pursuant to 16 U.S.C. §481, reduces the federal rights to relative insignificance.[20] The master referee report is presently being challenged by the United States and numerous Colorado water users. The controversy will ultimately be decided by the United States Supreme Court.

II. Existing Legal Limitations

A. Colorado Water Law

1. Over-Appropriation

The state Constitution also provides that the right to divert water and apply it to a beneficial use shall never be denied.[21] Partly because of this provision, and partly because of the state's semi-arid climate, many rivers and streams have been over-appropriated. In other words, water rights have been obtained on streams which have no unappropriated water remaining. The Poudre River, for example, has water right priorities in excess of 199. There is nowhere near that amount of water available, however, to serve all these rights. During the period 1951 through 1961, priority 100 was served only seven days.[22] The effect of this over-appropriation is that many streams and reservoirs are dried up or reduced to very low levels during the season of peak water use.

2. Minimum Stream Flows and Lake Levels

One approach to the problems posed by over-appropriation is obtaining decrees for minimum stream flows and lake levels. As was noted earlier, Colorado case law has traditionally been unreceptive to claims for in-stream values and other aesthetic concerns. A major obstacle to court recognition of in-stream values was the general requirement that water be physically diverted from a stream or lake, a requirement illustrated in Colorado River Water Conservation District v. Rocky Mountain Power Co. In response to this ruling and public concern for in-stream values, the Colorado Legislature enacted Senate Bill 97 in 1973. This legislation eliminates the requirement for a diversion by changing the definition of appropriation to "the application of a certain portion of the waters of the state to a beneficial use."[23] Beneficial use is specifically defined to include appropriation by the State of Colorado of such minimum flows between specific points or levels for and on natural streams and lakes as are required to preserve the natural environment to a reasonable degree.[24] The legislation is apparently limited to natural streams and lakes and would not allow minimum flows or levels with regard to man-made reservoirs.

With authorization provided by Senate Bill 97, the Colorado Water Conservation Board has obtained or filed for minimum stream flows and minimum lake levels on numerous streams and lakes in the state. Obtaining a minimum stream flow decree provides no guarantee that the minimum flow will be achieved. If senior water rights are legally exercised and reduce flow below a minimum level decree which has a junior priority date, there is no basis for the state to take legal action. Since the minimum stream flow legislation wasn't enacted until 1973, minimum flow decrees are junior to the great majority of water rights, especially along Colorado's Eastern Slope. The significance of minimum flow decrees is that they are a water right subject to the same protection as other water rights from injury caused by changes in use, diversion and other aspects.

3. Existing Transfer Mechanisms

Colorado water law recognizes that changing circumstances may require that a water right be changed in its place, timing, or manner of use and/or the point of diversion.[25]

A "change of water right" is defined by Colorado statute as:

> a change in the type, place, or time of use, a change in the point or points of diversion, a change from a fixed point or points of diversion to alternate or supplemental points of diversion, a change from alternate or supplemental points of diversion to a fixed point or points of diversion, a change in the means of diversion, a change in the place or places of storage, a change from direct application to storage and subsequent application, a change from storage and subsequent application to direct application, a change from a fixed place or places of storage to alternate places of storage, a change from alternate places of storage to a fixed place of storage, or any combination of such changes.[26] (Emphasis supplied)

Any change in the exercise of a water right, however, must not materially injure the vested rights of either junior or senior water users.[27] There is no absolute standard which is applied to determine injury; case law indicates that the determination depends upon the facts of each particular case. The facts to be considered cannot include any evidence that the proposed change would produce benefits in excess of the injuries to be suffered; the sole consideration is whether other water users would be substantially injured by the change.[28]

If injury to other users is established, the change may not be approved or conditions may be placed upon the change to prevent injury. Conditions which may be placed on the change include:

- a limitation on the use of the water which is subject to the change, taking into consideration the historic use and the flexibility required by annual climatic differences.
- the relinquishment of part of the decree for which the change is sought or the relinquishment of other decrees owned by the applicant which are used by the applicant in conjunction with the decree for which the change has been requested, if necessary, to prevent an enlargement upon the historic use or diminution of return flow to the detriment of other appropriators.
- a time limitation on the diversion of water for which the change is sought in terms of months per year.
- such other conditions as may be necessary to protect the vested rights of others.[29]

As energy development and increased urbanization continue, many water rights will be changed from agricultural to industrial or municipal uses. Even junior minimum flow decrees would have some protection from injury caused by these changes and thus would have some influence on water usage in the state. On streams which are currently not reduced to low levels, obtaining a minimum flow decree would prevent future appropriators from injuring the minimum flow decree. Since most streams along Colorado's Front Range are over-appropriated, the impact of proposed changes in use may be very significant. In those cases, the courts are required to impose those conditions which are necessary to prevent injury to vested water rights. As will be discussed below, those conditions and limitations may limit or eliminate potential sources of water which might otherwise be available to support minimum stream flows or lake levels.

In order for the courts to evaluate applications for changes in water rights, detailed statutory procedures must be followed. This process can take from seven to thirty-six months. An application for change in water right is first filed in one of seven district courts which handle water matters in each of Colorado's seven water divisions. The Poudre River is located in Water Division 1. The Division offices and Water Court are located in Greeley. Once filed, the water application is referred by the water judge to his referee for futher proceedings.[30] Notice of the application is then given by newspaper publication and by circulation of "resumes" of each application to all persons who have submitted their names to the Division Water Clerk for inclusion on the resume mailing list.[31] "Any person" who wishes to oppose the application may file a statement of opposition by the last day of the second month following the month in which the applicaqtion is filed.[32] The water referee then conducts an informal investigation of the application.[33] The water referee may, in certain cases, either make a determination upon the application or re-refer the matter back to the water judge.[34]

If the referee makes a ruling with regard to the application, protests to that ruling may be made within 20 days of the ruling.[35] Where no protest or re-referral occurs, the water judge must promptly issue a decree, frequently by literally rubber-stamping the referee's ruling.[36] However, where a referral or protest has been made, the matter is set for further hearing by the water judge.[37] Where a referral or protest has occurred, the hearing would normally occur between eight to twenty-four months following the filing of the application. The ruling by the water judge may be appealed as in any other civil action.[38] The appellate process would normally occur during 12 to 36 months following the filing of the initial application.

In addition to the direct legal limitations outlined above, it should be noted that significant economic limitations likely exist. Water which might be available for transfer to recreational uses is also probably available for transfer to industrial, municipal or agriculture use. This would indicate that those seeking to purchase and transfer water for recreational uses must compete in the market place for water rights which are likely to be in high demand for other competing uses.

4. Exchanges

The ability to divert water stored in a reservoir at any point from the stream in which it was released has contributed to the extensive use of water exchanges. Colorado law provides that, "When the rights of others are not injured thereby, it is lawful for the owner of a reservoir to deliver stored water into a ditch entitled to water or into the public stream to supply appropriations from said stream, and take in exchange therefor from the public stream higher up an equal amount of water, less a reasonable deduction for loss."[39]

Colorado law also allows water rights to be stored out of their adjudicated priority "under circumstances such that the water so stored can be promptly made available to downstream senior storage appropriators in case they are unable to completely store their entire appropriative right due to insufficient water supply."[40] Yet another provision of Colorado law allows water users to provide "a substituted supply of water to one or more appropriators senior to them" in order to satisfy the senior's appropriation requirements.[41] The lawful practice of substituting or exchanging may itself constitute an appropriative right and may be adjudicated by the Colorado courts.[42] These provisions enable water to be stored in the high mountain reservoirs early in the irrigation season instead of storing the same water in plains reservoirs which hold the senior appropriation. However, such storage water must be "promptly released on demand of a downstream senior whenever needed by such senior for actual use."[43]

Exchanges are made for a number of reasons. One reason is when a ditch company owns a reservoir below any of its ditches. The North Poudre Irrigation Company (NPIC) is a good example. This company owns a reservoir near Timnath, Colorado, which is well downstream from the company's ditches and canals. In order to make use of this water, the company exchanges their water with other companies who have ditches located near the Timnath Reservoir. These other companies, in turn, provide NPIC with water rights they own which are located above the NPIC ditches.

As noted above, exchanges may be adjudicated, and when so recognized by law, the exchanges are protected from injury. Exchanges are often conducted informally, however, and are made on a year-to-year basis. For this reason, water user associations in Colorado have attempted to modify a minimum stream flow legislation. The most recent attempt was made through the introduction of Senate Bill 453 in the 1977 session of the Colorado Legislature. This bill would have significantly reduced the effectiveness of minimum flow decrees by providing that:

> "... Such appropriation of minimum stream flows or lake levels shall not create such a right in this state as may (a) permit it to object to or be protected against any existing or future exchanges of water, whether or not such exchanges are protected by court decree, or as may, (b) permit it to be protected against any change in point of diversion."

The legislation passed but was vetoed by Governor Lamm.

The source of their concerns is the fact that an exchange cannot take place if it injures any other water rights, including those that are junior. Thus, if a minimum streamflow appropriation is made, an exchange which had not been adjudicated before the minimum streamflow appropriation was made, could be prevented on the basis that it would injure the minimum streamflow appropriation.

5. <u>Status of Poudre River</u>

As was mentioned, the Poudre River is heavily overappropriated. Water exchanges are made often and many are made informally and on a year-to-year basis. The Colorado Division of Wildlife has recommended a minimum flow of 30 cubic feet per second (cfs) on the river for October through April and 65 cfs for May through September. Concern by water users that these minimum flows might disrupt exchanges ultimately led the Division of Wildlife to withdraw these minimum flow recommendations.

It should be noted that minimum stream and lake level appropriations can only indirectly benefit recreation opportunities in reservoirs. As the language of the legislation indicates, the statute is not directed toward man-made reservoirs. The Colorado Water Conservation Board cannot file for a conservation pool in a reservoir owned, for example, by a municipality or a ditch company. The Board would have to purchase storage space in the reservoir or enter into some type of cooperative arrangement or exchange agreement. Minimum stream flow decrees could benefit the fish of a reservoir, however, by providing needed flow through and thus preventing stagnation.

6. Constitutional Questions

Passage of minimum flow legislation did not remove constitutional questions associated with recognizing in-stream uses without a diversion as a valid appropriation. As was stated earlier, the Colorado Constitution declares that the right to divert water for a beneficial purpose shall never be denied. Many people believe, and the courts have generally agreed, that use of the word "divert" in the Constitution can only mean a physical or natural impounding or removal of the water from a stream bed. Thus, a question arises as to the constitutionality of changing the meaning of the word "divert" without also changing the Constitution through an amendment. So far, there has been no litigation in Colorado challenging the constitutionality of the minimum stream flow-lake level legislation. A number of attorneys, however, feel that the legislation could withstand such a constitutional test.[44] Legislation in Idaho allowing the State Department of Parks to appropriate water without a diversion for recreation and aesthetic purposes was found to be constitutional by the Idaho Supreme Court in late 1974.[45]

B. Legal Liabilities and Limitations Associated with Maintaining Recreational Use of Reservoirs

Encouraging public use of reservoirs poses the problem of exposing a larger number of people to water hazards and thus potentially increasing the number of injuries. It is, therefore, very important that users be adequately informed of and protected from hazards which may exist. Even if the best precautions are taken, however, it is always possible that someone will ignore the hazards and subject themselves to injury or death. In view of this possibility, it is necessary to review potential liabilities and how they affect management options.

Legal action seeking to obtain compensation for injuries suffered are generally based on an assertion of negligence. The mere fact that an accident occurred does not raise any presumption of negligence.[46] In order to establish a prima facie case of negligence, the plaintiffs (those seeking compensation for injury) must prove that the elements of negligence were present. These include: the existence of a duty on the part of the defendant; a breach of that duty; a causal connection between defendant's breach and plaintiff's injury; and injury of the plaintiff.[47] An important factor is the duty owed to the injured party.

1. Trespassers

The lowest level of duty is owed to a trespasser. A trespasser is a person who enters upon land in the possession of another without a privilege to do so.[48] It is generally said that the only duty imposed upon a landowner with respect to trespassers is to refrain from inflicting willful or wanton injury.[49]

2. Attractive Nuisance

An exception to the general rule of trespass is where an attractive nuisance is said to exist. The attractive nuisance doctrine emerged from a case involving injury to a child who trespassed upon railroad property and was injured upon a turntable.[50] The original doctrine basically stated that a landowner who maintained a condition upon his premises which was dangerous to young children because of their inability to realize the danger, and which might reasonably be expected to attract young children, was under a duty to exercise reasonable care to protect them against the dangers of the attraction.[51]

Obviously, limitations had to be placed upon the attractive nuisance doctrine since the number of hazards which could be considered attractive to children are nearly infinite. One of the earliest and broadest limitations placed upon the doctrine was the exclusion of water bodies. The theory behind this exclusion is that water bodies are so common that their perils are obvious even to the youngest child.[52] This exclusion was modified by the advent of §339 of the Restatement of Torts which set forth five conditions which must be met to establish liability under the attractive nuisance doctrine.[53]

a. The place where the condition is found must be one upon which the possessor knows or should know that young children are likely to trespass;

b. It must be a condition which should be recognized as involving an unreasonable risk of harm to children;

c. The child, because of immaturity, either does not discover the condition or does not in fact appreciate the danger involved;

d. The utility to the possessor of maintaining the condition must be slight as compared with the risk to the children involved; and

e. The possessor fails to exercise reasonable care to eliminate the danger or otherwise to protect the children.

It should be noted that many states do not recognize the attractive nuisance doctrine. Where it is recognized, §339 substantially expanded the liability of a landowner. A number of courts have awarded damages to the parents of children injured where a water body was deemed to be an attractive nuisance.[54]

Colorado has taken a restrictive approach in applying the attractive nuisance doctrine. In Colorado, the nuisance must be unusual and attractive and be the approximate cause of the injury.[55] In the case Phipps v. Mitze, the court took the general stance that water bodies in Colorado are not an attractive nuisance.[56] The court ruled in this case that a landowner was not liable for a boy's death when he drowned in a pond created by a dam across an arroyo. The court reiterated the restriction that ponds, pools, lakes, streams and other waters embody perils that are deemed to be obvious to children of tender years and, as a general proposition, no liability attaches to the proprietor by reason of death resulting therefrom to children who have come upon the land to bathe, skate, or play.[57]

The case Staley v. Security Athletic Association is also informative.[58] In this case the court ruled that the proprietors of a swimming pool had exercised due care and thus were not liable for a boy's death when he drowned in a swimming pool which was closed and protected by a six-foot chain-link fence.

3. Licensee

A landowner owes a higher duty to a licensee. A licensee is a person who is privileged to enter or remain on land only by virtue of the possessor's consent.[59] As a general rule, the owner of property owes a licensee only the duty to not willfully and wantonly injure him.[60] However, there is a distinction between ordinary negligence and willful and wanton negligence. When a person deliberately avoids all precautions to prevent injury despite being fully aware of a danger and its probable consequences, he may be guilty of willful and wanton disregard.[61] An illustrative case is that of Windsor Reservoir and Land Company v. Smith.[62] In this case the reservoir company was held liable for a boy's death when he drowned in an outlet ditch when the bank upon which he was standing collapsed and he fell into the water. The boy was a licensee because his presence had been tolerated by the company watchman and he and his companions had played in the area on several occasions. The court ruled that a "landowner, if actually knowing of hidden danger, may be required to give notice thereof even to a mere licensee."[63] The hidden danger was an unstable bank created by an accumulation of ice along the outlet. The court also stated, however, that the "landowner did not owe to a mere licensee the duty of using care to know of every hidden danger and an unqualified duty to protect against it."[64] Liability in this case was based upon the company permitting the continuance of a trap after having actual knowledge of the danger.

4. Invitee

The highest level of duty is owed to an invitee. A public invitee is a person who is invited to enter or remain on land as a member of the public for a purpose for which the land is held open to the public.[65] An owner of land is subject to liability to his invitees for physical harm caused to them by his failure to carry on his activities with reasonable care for their safety, if, but only if, he should expect that they will not discover or realize the danger, or will fail to protect themselves against it.[66]

Thus, where a danger is apparent and the victim ignores the hazard, there is no liability. This principle is illustrated in the case Dumond V. Mattoon, wherein a man drowned in a reservoir which was open for fishing, boating, water skiing and swimming.[67] The victim drowned, however, in an open intake area near the pumping station which was enclosed by a concrete wall. The construction of the intake area was such as to not invite public use;

thus, the victim was no longer an invitee and the dangers should have been apparent. There was no liability.[68]

The legal term for ignoring apparent dangers is contributory negligence. The term is defined as, "Conduct on the part of the plaintiff, contributing as a legal cause to the harm he has suffered, which falls below the standard to which he is required to conform for his own protection.[69] In most jurisdictions, when contributory negligence has been established, the plaintiff will be denied recovery even though the defendant's negligence may have also played a substantial role in causing the injury.[70]

The case Heagy v. City and County of Denver illustrates the application of contributory negligence as well as other aspects of negligence theory. In this case, a fisherman died when his boat was swamped by high winds on Eleven Mile Reservoir in Park County, Colorado. Plaintiffs alleged that the city had been negligent in not providing adequate rescue facilities. The accident occurred in October, after the normal recreation use season; there was only one patrolman present, and he was working on a special maintenance assignment. The patrolman attempted to rescue the victim but the severe weather conditions prevented him from reaching the victim before he succumbed. In its decision, the court held that the plaintiffs had failed to establish a duty on the part of the defendants to provide rescue facilities, and that, even if it was assumed that there was a duty, the plaintiffs failed to establish a breach of duty. In other words, plaintiffs presented no evidence to show that equipment or rescue procedures other than those used would have been more successful under the adverse weather conditions.

Furthermore, the court held that contributory negligence also would have prevented recovery, "It was undisputed that the deceased deliberately defied the ominous weather conditions for two hours. This most certainly was negligent and would have banned plaintiff's recovery even if the defendants had been negligent in the first instance."[71]

It should be noted that a different standard of care is generally applicable for water hazards in an area open to the public where swimming is not encouraged and in an area where it is. In areas where swimming is not encouraged, normal hazards are generally held to be apparent. This is illustrated by an Ohio case wherein a boy drowned after he fell into a pond maintained by a city in a public park.[72] The court stated, "We are unable to hold as a matter of law that a nuisance is created by the maintenance of a pond in a public playground without the erection of guards or barriers or without the supervision of guards, or without the posting of signs or signals of warning. Neither do we believe that a nuisance is created or maintained when a walk is constructed around the shore of a lake, in close proximity to the water, without any wall or railing."[73]

A similar finding was reached in Robbins v. Omaha wherein a boy drowned in a lake located in a public park.[74] The court stated that a lake in a park, whether artificial or not, did not of itself constitute a nuisance, and that the city was no more negligent in maintaining an artificial pond unfenced and unguarded, then it would be in leaving a river front so exposed.[75]

There are exceptions to the general rule established in the preceding cases. In Williams v. Morristown, the court ruled that a reservoir was an attractive nuisance and awarded damages to the parents of a girl who fell in and drowned.[76] The reservoir was owned by a city and was unfenced and there were no warning signs.

A higher standard of care is imposed in areas where swimming is encouraged. In addition to being required to exercise reasonable care, the landowner or proprietor has the duty when the character and conditions of the area are such that because of deep water or other hazards bathers may get into danger, of having in attendance some suitable person with necessary apparatus to affect rescues and save those who may meet with accidents.[77] The need for this protection is illustrated by the case Ward v. United States wherein the Federal Government was found liable for the drowning of a teenage girl in Lake Hasty near the John Martin Reservoir in Bent County, Colorado.[78] The girl's drowning was caused at least in part by several boys who repeatedly dunked her. The swimming area was leased to the Southeastern Colorado Recreation Association and the lease stipulated that the Federal Government liable and based this liability on the fact that no life guards were present. The court stated that, "Thus when it is reasonably probable that the antics flowing from the unleashed energy and extravagance of youth may result in serious bodily injury, as in swimming areas, a basis exists for finding that the negligent lack of supervision is the proximate cause of such injury."[79]

A similar decision was reached in the case Longmont v. Swearingen.[80] The City of Longmont was found liable for the drowning of a boy in a swimming pool which it operated. The court ruled that the proximate cause of death was the fact that no life guards were present at the time of the tragedy.[81]

5. Reasonable Man Theory

It should also be noted that there has been a trend away from considering the status of an individual, e.g. trespasser, licensee, invitee, as being determinative of the responsibility which is owed to him by a landowner or proprietor. Instead, the theory has emerged that a landowner in the management of his property should act as a reasonable man in view of the probability or foreseeability of injury to others. This theory is stated in a 1971 Colorado case, "A person's status as a trespasser, licensee or invitee may, of course, in the light of the facts giving rise to such status, have some bearing on the question of liability, but it is only a factor -- not conclusive."[82]

6. Governmental Immunity

In view of the fact that many reservoirs are government-owned, it is necessary to review the doctrine of governmental immunity. The doctrine has been successfully invoked in many cases to shield a government entity from liability for an injury caused by an alleged negligence.[83] The doctrine stems from the cliche that "the king can do no wrong" but its basis in modern times has been fears of fiscal uncertainty along with potentially undesirable deterrents upon governmental functions.[84]

In recent years, there has been a pronounced trend toward abrogating the doctrine both through judicial and legislative actions.[85] In Colorado, the Legislature enacted in 1971 the Colorado Governmental Immunity Act. The act applies to all public entities, including the state, counties, cities, schools, etc., and states that the operation of swimming and park and recreation facilities are not shielded by government immunity.[86]

The Federal Government is clearly subject to liability for injuries caused by an act of negligence. In 1946, Congress passed the Federal Torts Claims Act. This act provides that, "The United States shall be liable, respecting the provisions of this title relating to tort claims, in the same manner and to the same extent as a private individual under the circumstances."[87]

7. Closure of Publicly-Owned Reservoirs

A number of publicly-owned reservoirs are closed to recreational use. Such regulations prohibiting boating, fishing, bathing and other uses have generally been upheld in the courts as valid exercises of the public power.[88] Legal questions generally arise only when such closures infringe on another property right, as when a municipality seeks to close a lake to recreational use even though other individuals own a portion of the shoreline, or when a jurisdictional question arises.

A jurisdictional question is illustrated by the case Brown v. Cle Elum wherein a municipal ordinance prohibiting recreational use of a reservoir was declared unconstitutional.[89] The reservoir was upon federal land and located outside of city limits, but the city had contracted for its use as a public water supply. The

Washington State Constitution limits the exercise of jurisdiction beyond municipal limits and the court thus declared the closure unconstitutional.

It must be emphasized that this case is strictly concerned with a Washington constitutional question and is not generally applicable. In Colorado, there is no comparable constitutional limitation. The powers of home rule cities in Colorado are limited only by their charter, except insofar as they may conflict with state statutes concerning the same manner. The charter of the City of Fort Collins, for example, states that the city has the power to adopt rules and regulations concerning the maintenance of properties within the supervision of the department of parks and recreation, whether within or <u>outside</u> of the city.[90]

III. Alternatives to Existing Legal Limitations

A. Water Rights

1. <u>Purchase of Existing Rights and Transfer</u>

As was stated earlier, a reservoir may be filled only once each year. However, there is nothing in the law preventing the acquisition of additional appropriations for a reservoir to allow the storage of water in a reservoir which has already been filled once but has vacant storage space later in the season, which was created by drawdown. In other words, a reservoir can be filled more than once each year if additional appropriations have been obtained. Thus, if a direct flow right or a storage right in another reservoir was obtained, it is possible that these rights could be transferred to another reservoir which was intended for recreational use. Storing these additional recreational appropriations later in the season would not reduce the utility of a reservoir for other purposes since they would be stored after the reservoir had already been filled once. It would, of course, be necessary to receive approval from the reservoir owners before water could be stored for recreational purposes.

a. Direct Flow Rights to Storage

A direct flow right could be obtained and changed to a storage right. The change would require court approval and would be subject to the imposition of conditions intended to prevent injury to other water users.

In order for such a change or transfer of a direct flow right to a storage right to be effective to retain minimum pools or provide water for minimum flows through high mountain reservoirs would require a court-approved transfer which would allow water which was previously available for immediate use to be stored and delayed for subsequent use. In order to be effective for late summer high mountain use, that subsequent use would necessarily occur late in the irrigation season or after the irrigation season. The existing pattern of water rights and water demands may make such a transfer unfeasible. Where water is in critical demand during the peak irrigation season, it may simply be impossible to transfer direct flow rights to storage rights (which will not be used during that irrigation season) without injurying vested water rights. This would be especially true on an over-appropriated stream like the Poudre River.

It has been suggested by the Water Commissioner for the Poudre River that such a transfer would not be allowed by the courts unless it was conditioned upon use of the newly-stored water during the peak irrigation season. This condition would essentially preclude the effectiveness of the transfer for use to eliminate late irrigation season drawdowns, or for use to supply winter minimum pools.

b. Storage Rights to Storage Rights

It is possible that a storage right could be obtained in one reservoir and then transferred to another. Again, the change would require court approval and be subject to the imposition of conditions. In effect, such a change would amount to a court-approved exchange. However, in order to be an effective method to retain water in high mountain reservoirs for recreational use throughout the irrigation season, it would likely be necessary to purchase storage rights in amounts in excess of that sought to be stored for high mountain recreational use. This would be necessary in order to avoid injury to those vested rights which have historically relied upon the purchased storage right for release during the irrigation season. In other words, additional water over and above that amount "needed" would be required in order to compensate downstream users for injury which would have resulted from the transfer. This type of "transfer" might also be accomplished through a plan for augmentation which will be discussed below.

2. Expand and Create New Cooperative Agreements

Recreation and fish and wildlife resources have been important elements of federal water development planning for many years. The Federal Water Project Recreation Act[91] provides, "That it is the policy of the Congress and the intent of this act that (a) in investigating and planning any Federal navigation, flood control, reclamation, hydroelectric, or multiple-purpose water resource project, full consideration shall be given to the opportunities, if any, which the project affords for outdoor recreation and for fish and wildlife enhancement and, wherever any such project can reasonably serve either or both of these purposes consistently with the provisions of this act, it shall be constructed, operated and maintained accordingly..." The act further provides that, "Project construction agencies shall encourage non-Federal public bodies to administer project land and water areas for recreation and fish and wildlife enhancement purposes..."

An additional requirement to consider fish and wildlife is provided by the Fish and Wildlife Coordination Act.[92] This act states that "...whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever,....by any department or agency of the United States, or by any public or private agency under federal permit or license, such department or agency first shall consult with the United States Fish and Wildlife Service, Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular State wherein the impoundment diversion, or other control facility is to be constructed, with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water resource development."

Another tool available for encouraging the recreational use of reservoirs is Public Law Multiple Purpose Watersheds.[93] This law is directed toward projects on small watersheds (up to 250,000 acres) and is primarily administered by the Soil Conservation Service. Under the provisions of this law, federal funding may be denied for projects which do not provide public access and up to 50 percent of the cost of acquiring land for public recreation or fish and wildlife may be provided by the Federal Government.

In response to the legislation just described, nearly all projects constructed by federal agencies or other projects in which there is federal involvement, contain provisions for maintaining minimum pool for recreation and fisheries. The Forest Service, for example, has required that minimum pools be maintained on Joe Wright and Barnes Meadow Reservoirs. Both these reservoirs are municipally-owned and are located on Forest Service land. When the municipalities owning these reservoirs sought to have them expanded, the Forest Service made approval contingent upon the maintenance of minimum pools.[94]

Long Draw Reservoir also has provisions for a minimum pool. This reservoir is owned by Water Supply and Storage Company. Federal financing of an enlargement of the reservoir was contingent upon the maintenance of a 600 acre-foot minimum pool.[95]

Although it may be argued that not all minimum pools are sufficient to make a reservoir attractive for recreation, the legislation described earlier does provide a good opportunity for providing recreational opportunities on reservoirs in which there is federal involvement.

Another approach is to seek voluntary agreements with reservoir owners to maintain minimum pools. The Colorado Division of Wildlife does encourage the owners of private reservoirs, such as ditch companies, to maintain minimum pools but generally has little success. Municipalities, however, have concerns in addition to providing water and perhaps will integrate recreation planning with water development planning as the demand for water-based recreation increases.

3. Augmentation of Available Supplies - Integration into Present Exchange System

One means of modifying current water use patterns on an over-appropriated stream is to attempt to augment available supplies. One alternative is to acquire new foreign or imported waters. Another is to attempt to augment precipitation through weather modification. A third alternative is augmentation of presently available supplies and integration of those supplies into the existing exchange system. This is a realistic approach, especially in a river system like the Poudre which has already developed a highly complex exchange system.

Colorado law allows the formulation of "plans for augmentation" which must be reviewed by the water courts. A plan for augmentation is defined as follows:

> "... a detailed program to increase the supply of water available for beneficial use in a division or portion thereof by the development of new or alternate means or points of diversion, by a pooling of water resources, by water exchange projects, by providing substitute supplies of water, by development of new sources of water, or by any other appropriate means."[96]

A plan for augmentation is a vehicle to increase available water supplies, not unlike informal exchange agreements or proposed changes which seek to maximize the use of available water. Plans for augmentation typically are designed to increase available water supplies by purchasing senior surface water rights in order to compensate for injury which would otherwise result from groundwater pumping. These types of plans have been used along the South Platte in order to allow continued groundwater pumping. Augmentation plans are also frequently used in the mountain areas along Colorado's Front Range in order to augment available water for mountain subdivisions.

The State Engineer and division engineers have been charged by the Colorado legislature to "exercise the broadest latitude possible in the administration of waters under their jurisdiction to encourage and develop augmentation plans and voluntary exchanges of water..."[97] It would appear that Colorado statutes, coupled with case law dealing with augmentation plans involving groundwater pumping, gives the division engineers adequate authority to promote and encourage new and revised exchange and/or augmentation plans which recognize expanded high mountain reservoir recreation uses. Such revised exchange plans could be formulated formally through the filing of an application for plan for augmentation.[98] Plans for augmentation are subject to somewhat specialized procedures.[99] These procedures allow for review of proposed plans by the State Engineer and allow the State Engineer to adopt rules and regulations describing standards that the State Engineer will use in reviewing such plans.[100] Plans must be designed to avoid injury to vested rights and terms and conditions may be attached to those plans in order to avoid injury.[101] Plans which provide replacement water to senior water rights in order to avoid curtailment of other water rights "shall be sufficient to permit the continuation of diversions when curtailment would otherwise be required" to meet a valid senior call for water.[102] Subject to appeal, final approval of all plans rests with the water judge.[103]

Such plans could also be formulated informally and could be proposed as modifications to existing voluntary exchange agreements. Colorado statute requires that the State Engineer and the division engineers distribute the waters of the state pursuant to the established priorities of water rights. All such priorities must take precedence in their appropriate order over other diversions of water of the state.[104] However, as noted above, the State Engineer may allow the storage of water out of priority, may allow the exchange and substitution of water and may allow and encourage plans for augmentation which maximize the beneficial uses of the waters of the state. The impoundment of water for recreational purposes, including fishery or wildlife, is clearly beneficial uses of the state's waters. It can be argued that the State Engineer and division engineers may carry out their charges of exercising the "broadest latitude possible" in the administration of the state's waters through the modification of existing voluntary exchange agreements in order to maximize recreational and other uses of water. Existing agreements would need "modification" in the location and extent of storage out of priority, the timing of reservoir drawdown and location of drawdown impact as suggested by the engineering model employed in this study. It is these authors' opinion that the significant barrier to implementation of such "modified" exchange agreements or administration policies is not a legal barrier. As noted above, adequate legal authority seems to exist. The significant barriers are likely to be political and socio-economic. Complex voluntary exchange agreements developed over many years will be difficult to modify or alter.

4. Expansion of Minimum Stream Flows and Lake/ Reservoir Levels

A significant legal limitation upon the expanded use of high mountain reservoirs for recreational purposes is the restrictive nature of present methods available to preserve minimum stream flows and lake levels in Colorado. One alternative would be to seek the expansion of existing methods. The analysis of a closely related problem is presently the subject of a research effort sponsored by the Fish and Wildlife Service (See, Identification, Description and Evaluation of Strategies for Reserving Flows for Fish and Wildlife, WELUT Project 23, Phase One, Dewsnup and Jensen). This report will not attempt to duplicate that effort but will evaluate several potential alternatives which might be suitable for use in Colorado and the Poudre River system.

a. The Use of Water Quality Control Laws Management Plans as a Tool to Require Minimum Stream Flows or Lake/Reservoir Levels

The Federal Water Pollution Control Act (FWCPA), 33 U.S.C., §1251 et seq., includes as one of its major goals the development of state water quality management plans to insure maintenance of water quality. As part of the water quality management planning requirements, states must develop a continuing planning process.[105] The overall planning process must include the establishment of waste load allocations for various stream segments. In addition, 33 U.S.C., §1288, requires the formulation of water quality management plans to deal specifically with non-point sources of pollution which would prevent compliance with established water quality standards despite the development of waste load allocation. These plans, referred to as §208 plans, are supposed to meet a number of objectives, including the establishment of procedures and methods to control non-point sources of pollution. Area-wide water quality management plans are sent to the Governor and EPA for approval or disapproval.

No discharge permit or construction grant may be approved if it conflicts with an adopted area-wide water quality management plan.[106]

The requirements of adopted water quality management plans apply in addition to the FWCPA water quality standards, effluent limitations and the National Pollutant Discharge Elimination System (NPDES), or permit systems, which is the regulatory mechanism for applying the water quality standards and effluent limitations to point source dischargers.[107] Water quality standards are ambient stream standards which contain both stream classifications, such as cold water fishery, public water supply, etc., and use criteria, such as permissible levels of dissolved oxygen, suspended solids, etc. Established water quality standards are currently based upon certain minimum or low-flow presumptions. The standards apply at all times except during periods of time when lake or reservoir water levels are less than the minimum seven day low flow or level which is expected to occur once in ten years. (Water Quality Standards for Colorado. Adopted January 15, 1974.)

This creates a significant problem in the western states where streams like the Poudre frequently reach "no-flow levels," especially during the irrigation season. This has resulted in requests, such as that recently made by the City of Fort Collins, to reclassify a segment of the Poudre. This reclassification request was, in effect, an attempt to get the State of Colorado to recognize the chief function of the Poudre River for agricultural, not fishery, purposes. The futility of attempting to require the water treatment requirements necessary to support fish populations when the stream is frequently dry at various points in various segments is obvious. As a result, the State Water Quality Control Commission granted a temporary classification exception for the Poudre River as a Class "C" and directed city officials, water users and others to continue to seek a solution to the conflict between national water quality standards and the realities of water allocations in the water scarce West.

It has been suggested that one "solution" to this conflict is through the use of §208 plans which could require the maintenance of certain minimum flows in order to meet and maintain established water quality standards. EPA regulations defined a water quality management plan as a management document which identifies the water quality problems of a particular designated area-wide planning area and sets forth an effective management program to alleviate those problems and to achieve and preserve water quality for all intended uses.[108] A water quality management plan must, among other things, describe existing state and local regulatory programs and define additional regulatory programs designed to achieve water quality standards and goals.[109]

As a part of the formulation of regulatory programs, the area-wide planning agency is directed to take full advantage of existing legislative authorities. However, the regulatory programs "shall assure that... the location, <u>modification</u> and construction <u>of any</u> facilities, <u>activities or substantive changes in the use of the lands</u> within the approved planning area, <u>which might result in</u> any new or deleterious <u>discharge</u> directly or indirectly into navigable waters are regulated..." [110] (Emphasis supplied)

It could be argued that this broad requirement would enable area-wide planning agencies to adopt land use and other requirements to regulate changes in the use of lands, which in the West necessarily includes changes in the use of lands when water rights are modified, changed or transferred with regard to lands, if, for example, the modification of the use of lands from irrigated agriculture to dryland farming or urbanization clearly "might result" in new point or non-point discharge. In some cases, the transfer of the water might result in new point or non-point sources of pollution simply by reducing the amounts of return flow waters available for the dilution of pollutants which ultimately reach the major streams and rivers. Water quality management plans could under the above-cited authority require the introduction or continuance of minimum stream flows in order to protect or maintain water quality.

Such minimum flow requirements, if made as part of an adopted water quality management plan, could result in an indirect benefit to high mountain reservoir recreational use. One source of water for needed flows, especially along Colorado's Front Range, would certainly be water stored in high mountain reservoirs. Current administrative policies favor the early and continued storage of water in high mountain reservoirs because storage high in the river system increases the flexibility of that water in satisfying water rights during peak demand. The same policy would make that water available for satisfaction of minimum stream flows required for water quality purposes and would likely result in delayed drawdowns in the high mountain reservoirs.

Area-wide water quality management plans could have a significant influence upon the maintenance of minimum pools or the timing of reservoir drawdown even if specific minimum flow requirements were not incorporated in the plan. An area-wide agency could adopt a policy encouraging the management and allocation of water in order to fulfill the dual goals of increased high mountain recreational use and water quality control and maintenance. Such a policy might be an important step towards the implementation of modified exchange agreements or administrative policies suggested and supported by the engineering study in this report.

The potential obstacles attempt to employ water quality controls to enhance the recreational use of high mountain reservoirs and should not be ignored. Significant opposition to certain aspects of water quality planning exists within the state and within the Larimer-Weld Area-Wide Planning Region in particular. Agricultural and irrigation interests oppose attempts by EPA to regulate and control the quality of irrigation return flows. As discussed previously, the City of Fort Collins and others oppose attempts to regulate segments of the Poudre for fishery purposes. If the Poudre were to be "permanently" classified "agricultural" in certain segments, the regulatory mechanism (i.e., the attainment of water quality standards based on low-flow requirements) as well as the incentive for requiring the minimum stream flows may be lost.

In addition to the potential requirements under Sections 303 and 208 of the 1972 Amendments to the Federal Water Pollution Control Act, §404 offers a potential tool for enhancing the recreational opportunities in high mountain reservoirs. Section 404 gives the Secretary of the Army, acting through the Chief of Engineers, responsibility for issuing permits for dredge and fill operations. Under regulations issued by the Corps of Engineers, dredge and fill permits would normally be required of all reservoir expansion and new reservoir construction. The regulation applies, after July 1, 1977, to discharges of dredged material or fill material into any navigable waters.[111] Navigable waters include all rivers, lakes, streams or artificial bodies of water and all tributaries of navigable waters up to their headwaters (a point on the stream above which is normally less than five cubic feet per second).[112]

The regulations require that the Corps of Engineers consider the impact of all permit applications. The Corps must consider the effect of the proposed dredge or fill operation upon, among other things, wetlands, fish and wildlife, water quality, and historic, scenic and recreational values.[113] Notice of proposed applications must be sent to the regional director of the Bureau of Sport Fisheries and Wildlife, the field representative of the Department of Interior, and the head of the state agency responsible for fish and wildlife resources.[114] The Corps of Engineers is required to consult with the regional director of the U.S. Fish and Wildlife Service and the head of the state agency responsible for that state's fish and wildlife resources.[115] A permit may be conditioned upon mitigation of any damage which might result to fish and wildlife resources.[116] Applications must also be considered in light of recreational values as may be reflected by state, regional or local land use policies or similar federal controls or policies.[117] The Corps is directed by its regulations that action on permit applications "insofar as possible, be consistent with, and avoid adverse effect on, the values or purposes" for which those land use classifications, controls, or policies were established.[118]

The Corps of Engineers also has authority under §120 of the 1972 Amendments to the FWCPA to consider the inclusion of storage for regulation of stream flow for water quality control purposes in the survey or planning of any reservoir.[119] The Administrator of the Environmental Protection Agency is directed to determine the need for, the value of, and the impact of storage of water for water quality control purposes and must set forth his findings in any report to Congress proposing authorization or construction of any reservoir which includes such storage.[120] The Corps of Engineers, the Bureau of Reclamation or other federal agencies are also directed to determine the need for and value of storage for regulation of stream flow for recreation and other purposes.[121]

b. Additional Role by the State

Involvement by the State of Colorado in reserving or preserving minimum stream flows or reservoir and lake levels could have a significant impact upon enhancing recreational opportunities of high mountain reservoirs. As discussed earlier in this report, existing state involvement is restricted to existing minimum stream flow legislation which authorizes the state, through the Water Conservation Board, to seek minimum stream flows. The problems with such minimum flow claims, especially with regard to over-appropriated streams, have been discussed previously. An expanded role by the state in a number of areas could have at least an indirect impact upon attempts at preserving minimum pools and flow-through waters in high mountain reservoirs. It should be noted at the outset that this potential expanded role by the state outlined below would require new legislation or significant changes in policy which direct the administration and distribution of the state's waters by the State Engineer. Thus, any direct or indirect recreational benefits which might result from an expanded role by the State of Colorado may not be available until some time in the future.

One potential area of expanded involvement by the State of Colorado would involve an active role by the state in the purchase and resale of existing decreed water rights which are not needed by the water right owners during a particular irrigation season. This idea has been referred to as a state "water bank." Under current law and irrigation practices, many water users, especially irrigators, divert more water than they actually need for their crops in order to maintain a history of continuous water diversions. This practice is continued because irrigators fear they will lose a part of their decreed water rights unless diversion records reflect high levels of "use." This practice is perpetuated in part because of the unclear status of the law in Colorado concerning the abandonment of water rights. The use of a state run "water bank" would attempt to avoid the waste of water which presently occurs by setting up procedures to allow the state to act as a broker for the purchase and resale of such "excess" water while assuring owners of water rights that they are not causing the abandonment of any of their historic rights. The idea is a relatively new one and a significant number of questions remain. It is unclear how such a program would affect existing exchange agreements or whether such a program would make significant amounts of "additional" water available for use in heavily over-appropriated water basins. It is at least possible that such a program could make additional water available for purchase by the state itself or by cities and private reservoir owners for successive high mountain reservoir storage during the peak irrigation season.

Another area of potential state involvement related to the water bank concept is an active program of water right acquisition. The state, through particular fishery, wildlife, and recreation agencies, could appropriate funds for the acquisition of existing water rights for purposes of transfer to recreation-related use. In an over-appropriated river system such an acquisition program could be accomplished by active consultation with existing water users, especially those who actively participate in voluntary water exchange agreements. Such a state-sponsored water right acquisition and transfer program could be formalized through a water augmentation plan which would attempt to make additional supplies available for use as minimum pools and flow-through in mountain reservoirs without injurying vested rights or existing voluntary exchange agreements. A serious drawback to such a program would be its substantial cost. Although acquisition of real property may be a desirable natural resource management tool (such as parkland and open space acquisition), its cost, when required to compete in the marketplace, can be prohibitive.

On a broader scale the formulation and implementation of a state water plan could provide or reserve additional water for recreational use in high mountain reservoirs. A study into the legal alternatives which might be undertaken as a part of a Colorado State Water Plan is currently being conducted by the Colorado Department of Natural Resources. As a part of that water plan, it is expected that a number of specific legislative proposals will be outlined. A number of specific legislative proposals would assist, at least indirectly, in the management of mountain reservoirs for recreational purposes. One such proposal would create new procedures in water right changes which would recognize the "public interest" in the distribution of the state's water. This would presumably include the public's interest in making water available for recreation in mountain reservoirs, especially during the summer. A change in existing legislation would allow the state to file on water rights with respect to reservoirs in addition to streams and natural lakes. Various other proposals are presently being considered which would provide a mechanism for the state to employ its "police power," the power to regulate in the interest of the public health, safety, and welfare, to regulate future changes in the use and distribution of the state's waters. These proposals will undoubtedly be highly controversial. The major obstacle to the implementation of a state water plan will be the issue of protection of existing vested property rights. Any regulatory approach adopted by the state must assure that private property rights are not "taken" unless just compensation is paid. In any case, the tools for implementation of a state water plan rest ultimately with the state legislature. The resulotion of what tools, if any, are appropriate for the implementation of public interest values in the state's waters is not likely to be forthcoming from the state legislature in the immediate future.

Another area of potential involvement of the state would require additional legislative authority allowing the State Engineer to adopt rules and regulations which would govern the use and storage of water for recreational purposes in mountain reservoirs. The State Engineer currently has authority to adopt rules and regulations to assist in the integration and conjunctive use of the state's surface and groundwater rights.[122] The state legislature has set forth principles which are intended to guide the State Engineer in the adoption of those rules and regulations.[123] It is possible that a similar approach could be adopted in order to attempt to maximize the storage potential and the recreational potential of mountain reservoirs. Again, specific action by the state legislature would be required.

c. Design of Water Resource Projects by Municipalities and Other Water Users to Accommodate Recreational Uses of Reservoirs

The planning and design stage of water resource projects is the best time to plan for or provide for the provision of water necessary to meet the desired recreational use of the planned facilities. If this is done prior to construction, the problem of acquiring additional water supplies necessary for recreational use after construction of the facilities is avoided. The expansion of existing reservoirs and the construction of new reservoirs presents the best opportunity for the inclusion of water rights necessary to support desired recreational objectives. If a municipality or other water user recognized the need for recreational use of certain expanded or new reservoirs, it can provide for the operation of those reservoirs by cooperative agreement, through the formulation of specific operating criteria for that reservoir or through other contractual arrangements. As noted above, such agreements exist presently in the upper Poudre reservoir system.

Even if municipalities and other water users do not voluntarily recognize the need for providing water for recreational use, certain federal statutes and programs may encourage or require them to provide water for recreation-related purposes. As noted above, conditions may be attached to federal loans which would require the design of reservoirs to include storage capacity in reservoirs to regulate streamflow or to modify reservoir structures to provide for fish and wildlife propagation. In addition, water quality control laws may require the inclusion of reservoir capacity to regulate streamflow for water quality or other purposes.

The opportunity for joint planning efforts, especially on the part of municipalities, is evident in the case of planning for reservoir design, maintenance and use. If municipalities combine their water supply acquisition planning with water quality control requirements and their recreation/open space needs are integrated, efficient and multi-purposed reservoirs are likely to result. It is clear that the water supply, water quality and recreation goals and purposes are not mutually exclusive. Planning to satisfy the goals and purposes of all three are feasible. The legal tools are available and encouragement and incentives are provided by EPA, the Fish and Wildlife Service, the Corps of Engineers, state wildlife and recreation agencies, local water quality management agencies, and local special interest recreation, fishery, and open space organizations.

d. Planning, Design and Operation of Federal Reservoirs

The best opportunities for including storage capacity in federal reservoirs, as in the case of private reservoirs, comes at the planning and design stage. Again, the opportunities for joint planning are present and are required by the Fish and Wildlife Coordination Act and §102 of the 1972 Amendments to the FWPCA. Cooperative planning between the Fish and Wildlife Service, the Bureau of Outdoor Recreation, the Forest Service, the Park Service, the Bureau of Land Management, the Bureau of Reclamation, the Corps of Engineers, the Environmental Protection Agency, the Soil Conservation Service, the state fish and wildlife and recreation agencies, and the local area-wide water quality management agency should be undertaken.

New or expanded reservoirs may include provision for storage capacity and/or minimum flow-through requirements directly into operating criteria which may form part of congressional authorization for a particular water project or reservoir. Storage capacity which may be reserved for streamflow releases for water quality purposes may also serve recreational purposes without a significant change in the proposed design or operation of the reservoir. Cooperative agreements to maintain minimum pools or flow-through water may be entered into between federal agencies pursuant to adopted Memorandum's of Understanding.[124] Cooperative agreements may also be entered into between federal agencies and municipalities or other water users who obtain federal financing or are a licensee or permitee of a new or expanded reservoir located on federal lands. A copy of one such agreement between the City of Greeley and the U.S. Forest Service for Barnes Meadow Reservoir is attached to this report as Exhibit A.

Providing water for recreational uses in existing federal reservoirs which are presently used primarily for single fill irrigatio storage will be difficult. Two alternatives suggested by Dewsnup and Jensen in their WELUT Project 23, Phase One, Report are purchasing water in federal reservoirs for release to augment in-stream flows and modification of existing reservoir operating criteria to provide additional in-stream flows. It is possible that the same two "strategies" could be employed to postpone current reservoir drawdowns until later in the irrigation season. The implementation of such alternatives would require negotiation with the federal agency responsible for operation of the reservoir and the water users who presently receive water from that facility. Modification of existing operating criteria or purchase of rights in federal reservoirs may require congressional action.

B. Liabilities Associated with Reservoir Ownership and Maintenance

Several alternatives are available to overcome existing potential legal liabilities associated with reservoir ownership and management. One alternative is to use a multiple-use concept in planning for reservoir design and use. That planning should include a recognition of the legal liabilities associated with reservoir use.

The use of the model developed by this report will help to isolate those reservoirs which are best suited for recreation from a recreation, engineering, fishery, and legal standpoint.

Employment of alternative management techniques can help to eliminate or limit potential liabilities which might result from reservoir ownership and use. Specific management techniques should be aimed at the following:

1. Elimination of known dangers
2. Posting of notice or other notification of foreseeable dangers
3. Limitation, restriction, or supervision of:

a. Swimming

b. Diving in hazardous areas

c. Boating, if allowed

4. Provision of rescue facilities, especially if boating is allowed or if swimming is allowed or encouraged.

FOOTNOTES

1. §37-92-103(3), C.R.S., 1973.
2. U.S. v. No. Colo. Water Conservancy Dist., 449 F.2d. (10th Cir., 1971); Town of Genoa v. Westfall, 141 Colo. 533, 349 P.2d. 370 (1960).
3. Thomas v. Guirand, 6 Colo. 530 (1883).
4. Town of Genoa v. Westfall, 141 Colo. 533, 349 P.2d. 370 (1960).
5. Colo. River Water Conservation Dist. v. Rocky Mt. Power Co., 158 Colo. 331, 406 P.2d. 798 (1965).
6. §148-21-3(5).
7. Denver v. Sheriff, 105 Colo. 193, 204 P.2d. 836 (1939).
8. §37-92-103(7), C.R.S., 1973.
9. C.R.S. Ann. §148-5-1.
10. §37-87-111, C.R.S., 1973.
11. Windsor Res. & Canal Co. v. Lake Supply Ditch Co., 44 Colo. 214, 224 P. 729 (1908).
12. §37-87-107, C.R.S., 1973.
13. Windsor Res. & Canal Co. v. Lake Supply Ditch Co., 44 Colo. 214, 224 P. 729 (1908).
14. Ibid.
15. §37-87-102, C.R.S., 1973.
16. Federal Power Comm'n. v. Oregon, 349 U.S. 435 (1955).
17. Arizona v. California, 373 U.S. 546 (1963).
18. Cappaert v. U.S.; Nevada v. U.S., 96 S.Ct. 2062 (1976).
19. U.S. v. District Court in and for the County of Eagle, 169 Colo. 555, 458 P.2d. 760 (1969); U.S. v. District Court in and for Water Division No. 5, 401 U.S. 527 (1971); Colorado River Water Conservation District v. U.S.; Akin v. U.S., 47 L.Ed. 2d. 283.
20. See, "Partial Master-Referee Report Regarding the Claims of the United States of America, Combined Cases in Water Divisions 4, 5, and 6 and Former Water Districts 36, 37, 51 and 52".
21. Colo. Const., Article XVI, §6.
22. Rhinehart, "Minimum Stream Flows and Lake Levels in Colorado", p. 39.
23. §37-92-103(3), C.R.S., 1973.
24. §37-92-103(4), C.R.S., 1973.
25. Colo. Rev. Stat. Ann., §37-92-306, C.R.S., 1973.
26. §37-92-103(5), C.R.S., 1973.
27. Green v. Chaffee Ditch Co., 150 Colo. 91, 105-06, 371 P.2d. 775, 783 (1962); Reagle v. Square S Land & Cattle Co., 133 Colo. 392, 394, 296 P.2d. 235, 236 (1956); Farmers' Highline Canal & Res. Co. v. Golden, 129 Colo. 575, 580, 272 P.2d. 629, 632 (1954); Faden v. Hubbell, 93 Colo. 358, 369, 28 P.2d. 247, 251 (1933); Denver v. Colorado Land & Live Stock Co., 86 Colo. 191, 193, 279 P. 46, 47 (1919); Handy Ditch Co. v. Louden Irr. Canal Co., 27 Colo. 515, 518, 62 P. 847, 848 (1900); see Baer Bros. Land & Cattle Co. v. Wilson, 38 Colo. 101, 88 P. 265 (1906).

28. Hallenbeck v. Granby Ditch & Res. Co., 160 Colo. 555, 569, 420 P.2d. 419, 427 (1966); Monte Vista Canal Co. v. Centennial Irr. Ditch Co., 24 Colo. App. 496, 502, 135 P. 981, 985 (1913); Farmers' Highline & Res. Co. v. Wolf, 23 Colo. App. 570, 579, 131 P. 291, 295 (1913).
29. §37-92-305(4)(a)-(e), C.R.S., 1973.
30. §37-92-203(7), C.R.S., 1973.
31. §37-92-302(3), C.R.S., 1973.
32. §37-92-302(1)(e), C.R.S., 1973.
33. §37-92-302(4), C.R.S., 1973.
34. §37-92-303(2), C.R.S., 1973.
35. §37-92-304(2), C.R.S., 1973.
36. §37-92-304(7), C.R.S., 1973.
37. §37-92-304(1), C.R.S., 1973.
38. §37-92-304(9), C.R.S., 1973.
39. §37-83-104, C.R.S., 1973.
40. §37-80-120(1), C.R.S., 1973.
41. §37-80-120(2), C.R.S., 1973.
42. §37-80-120(4), C.R.S., 1973.
43. §37-80-120(1), C.R.S., 1973.
44. See, for example, "Minimum Streamflow Appropriation", Glenn Porzak, 1973.
45. Idaho Dept. of Parks v. Idaho Dept. of Water Admin., 96 Idaho 440, 530 P.2d. 924 (1974).
46. Heagy v. City and County of Denver, 472 P.2d. 757.
47. W. Prosser, Torts (3rd Ed., 1964) at 146.
48. American Law Institute, Restatement of the Law, §329.
49. See, for example, Hooker v. Routt Realty Co., 102 Colo. 8, 76 P.2d. 431 (1938).
50. Sioux City & Pacific R.R. v. Stout, 84 U.S. (17 Wall.) 657 (1874).
51. 2 Arizona Law Review, 296.
52. Annot., 12 A.L.R., Vol. II, 1262 (1949).
53. Restatement, Torts, §339.
54. See, for example, King v. Lennen, 53 Cal. 2nd 340, 348 P.2d. 98 (1959).
55. Denver Tramway Corp. v. Callahan, 112 Colo. 460, 150 P.2d. 798 (1944).
56. Phipps v. Mitze, 116 Colo. 288, 180 P.2d. 233 (1947).
57. 20 R.C.L., p. 96, §85.
58. Staley v. Security Athletic Association, 150 Colo. 19, 380 P.2d. 53 (1963).
59. Restatement, Torts, §330.
60. Husser v. School District No. 11 in El Paso, 159 Colo. 590, 413 P.2d. 906 (1966).
61. Ibid., cited in Radosevich and Nobe, "Legal Liability and Limitations when Private Property in Colorado is Used for Outdoor Recreation", p. 18.
62. Windsor Reservoir & Canal Co. v. Smith, 92 Colo. 464, 21 P.2d. 1116 (1933).
63. Ibid.
64. Ibid.

65. Restatement, Torts, §332.
66. Van Der Smissen, "Legal Liabilities of Cities and Schools for Injuries in Recreation and Parks".
67. Dumond v. Mattoon, 60 Ill. App. (2nd) 83, 207 NE 2nd 320 (1965).
68. Legal Liability of Cities, p. 46.
69. Restatement of Torts, §463.
70. Van Der Smissen, "Legal Liabilities of Cities and Schools for Injuries in Recreation and Parks", p. 97.
71. Heagy v. City and County of Denver, 472 P.2d. 757.
72. Sailor v. Columbus, 23 Ohio L Abs. 417 (1936).
73. Ibid.
74. Robbins v. Omaha, 100 Neb. 439, 160 NW 749 (1916).
75. 8 A.L.R., 2nd, 1258.
76. Williams v. Morristown, 32 Tenn. App. 274, 222 SW 2nd 607 (1949).
77. 8 A.L.R., 2nd, 1315.
78. Ward v. United States, 208 F. Supp. 118 (1962).
79. Ibid.
80. Longmont v. Swearingen, 81 Colo. 246, 254 P. 1000 (1927).
81. Ibid.
82. Mile High Fence v. Radovich, 489 P.2d. 308.
83. See, for example, Schweikart v. Sandy Hook Reservation Auth., 92 NJ Super.Ct., 508, 224 A.2d. 137 (1966).
84. Notes: Separation of Powers and the Discretionary Function Exception: Political Question in Tort Litigation Against the Government, Iowa LR, 56:930-93, April 1971.
85. Van Der Smissen, "Legal Liabilities of Cities and Schools for Injuries in Recreation and Parks", p. 5.
86. §24-10-101 et seq., C.R.S., 1973.
87. 28 U.S.C., §2074.
88. 56 A.L.R., 2nd, 790.
89. Brown v. Cle Elum, 145 Wash. 588, 261 P. 112.
90. City of Fort Collins Charter, Article 10, §4.
91. P.L. 89-72, 16 U.S.C., 460 1-12 et seq.
92. 16 U.S.C., 661 et seq.
93. P.L. 83-566, 16 U.S.C., 1002 et seq.
94. Telephone conversations with representatives of Fort Collins, Greeley and USFS.
95. Telephone conversation with a representative of Water Supply and Storage Company.
96. §37-92-103(9), C.R.S., 1973.
97. §37-92-307(7), C.R.S., 1973.
98. See, §37-92-302(3), C.R.S., 1973.
99. §37-92-307, C.R.S., 1973.
100. §37-92-307(2) and (8), C.R.S., 1973.
101. §37-92-307(3), C.R.S., 1973.
102. §37-92-307(3), C.R.S., 1973.
103. §37-92-307(4), C.R.S., 1973.
104. §37-92-301(3), C.R.S., 1973.
105. 33 U.S.C., §1313(e).
106. P.L. 97-500, §208(d) and (e).

107. <u>See</u>, 33 U.S.C., §1313, 1311, 1316 and 1342.
108. 40 C.F.R., §131.1(c).
109. 40 C.F.R., §131.1(d)(4).
110. 40 C.F.R., §131.11(n)(3)(ii).
111. 33 C.F.R., §209.120(e)(2)(i)(c).
112. 33 C.F.R., §209.120(d)(1) and (2).
113. 33 C.F.R., §209.120(g)(3),(4),(5) and (6).
114. 30 C.F.R., §209.120(i)(1).
115. 30 C.F.R., §209.120(g)(4)(i).
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117. 30 C.F.R., §209.120(g)(6)(i).
118. 30 C.F.R., §209.120(g)(6)(i).
119. P.L. 92-500, §102(b)(1).
120. P.L. 92-500, §102(b)(3).
121. P.L. 92-500, §102(b)(2).
122. §37-92-501(1), C.R.S., 1973.
123. §37-92-501(2), C.R.S., 1973.
124. <u>See</u>, for example, Memorandum of Understanding between the Department of the Army and the Department of Interior with Regard to Dredge and Fill Operations, 30 C.F.R., §209.120 - Appendix B.

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10 (...) ...

Memorandum of Agreement
between
City of Greeley
and
U.S. Forest Service
for
Barnes Meadow Reservoir

1. Maintain a ten-foot deep conservation pool with a water line at elevation 9,057 feet covering approximately (25) surface acres and containing approximately (72) acre feet.

2. Store as much additional water each winter as, in the sole discretion of the City is permissible considering the needs of the City and in accordance with requests of the river commission and the laws of Colorado.

3. Allow public foot access within the City of Greeley easement around the said reservoir.

April 7, 1970
Date

Lola Bowman
Clerk:

CITY OF GREELEY

By [signature]

Title

4-14-1970
Date

U.S. Forest Service

By W. D. Kelso

Title Forest Supervisor

Approved
[signature]
4-7-70