RESEARCH TECHNICAL COMPLETION REPORT

OWRT TITLE II PROJECT C-6276

A DYNAMIC REGIONAL IMPACT ANALYSIS OF FEDERAL EXPENDITURES ON A WATER AND RELATED LAND RESOURCE PROJECT -- THE BOISE PROJECT OF IDAHO

PART V

ENVIRONMENTAL IMPACTS

By

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Submitted to

Office of Water Research and Technology
United States Department of Interior
Washington, D.C. 20240

This project was supported primarily from funds provided to the Idaho Water Resources Research Institute by the United States Department of Interior, Office of Water Research and Technology as authorized under the Water Resources Research Act of 1964, as amended.

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March 1979

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INTRODUCTION

This report is a general synthesis of the many issues regarding post-project environmental evaluation, using as a frame of reference the Boise Project of the Bureau of Reclamation. The report does not comprehensively summarize the existing literature for the area of an environmental nature or provide systematic analysis of ecological processes in the Boise River Valley. Additional issues and information, particularly focusing on hydrologic, economic, and social aspects of this Southwestern Idaho area in relation to the Project, are presented in several companion reports which collectively document the findings of the "Boise Post-Audit Study". A short description of the Boise Project begins on page four of the text and need not be reiterated here. A discussion of the structure of the report follows, however, to help explain the attempted synthesis.

The original literature on post-project evaluations emphasizes the significance of considering the differences between outcomes of an action and the outcomes without the action. This concept directed the original formulation of the "study" and implies a considerable degree of speculation in order to proceed. Alternative scenarios were developed in a general way to maintain consistency anoung studies.

Three quite serious issues plague environmental evaluation studies of this type, and these are further confounded by the particular characteristics of the Boise Post-Audit Study. Discussion of these problems is somewhat integrated in the text, so identifying them now should help clarify each. Here the three issues will be termed the data/information, the intent, and the methodology problems.

The availability of data is an issue in any study as is the manner of converting available data such as tables, maps, photographs and the like to usable information. In the present instance, the problem is magnified by the settlement history which brought changes to the area and produced an unstable situation upon which the Project was thrust. While knowledge of the settlement to 1900 helps constrain possible alternative scenarios, evaluation of environmental information for the period must be tempered by the realization of significant and ongoing changes. In the text an attempt is made to characterize the region prior to the Project and to demonstrate the significance of the changes having taken place or in progress. Environmental information over the seventy plus years of interest is both sketchy and selective. Evaluation of particular situations is further complicated because of the different points of view of the evaluators. Such data/information issues are an important hinderance to evaluation endeavors.

Many evaluations do not consider the intent of a project. By the issue of intent is not meant in relation to the goals of the study, but rather refers to the goal of the resource project. Consider such projects as thermal power facilities or bridges, about which a goal of minimal environmental impact is both understandable and possible. If either could be constructed and operated without local environmental impact, no detraction from the intended purpose of the project would result. In contrast, an irrigation project must change the environment to achieve its intent. Within the bounds of a project topography is altered, land use undergoes change, and drainage is altered--all by choice. It may be appropriate to evaluate the newly built landscape as agreeable or disagreeable from a personal point of view. But, it seems somewhat odd to construct the evaluaton on an element by element comparison with its former self. As an analogy, nothing much is gained in an evaluation of a chair made of leather by commenting on the condition of the steer prior to its demise. Nonetheless, the evaluation literature almost universally suffers from the failure to make this kind of distinction.

The methodological issue follows directly from the points just presented. Most of the methodological approaches to evaluation have been based on the implicit and faulty premise that impacts ought to be minimized. It is rather improbable that a before-after comparison will ever provide an acceptable evaluation methodology for situations like that of interest here. In a dynamic sense, monitoring of environmental variables can direct attention to situations which may require initiation of a negative feedback mechanism. Numerous such instances have occurred in the area of the Boise Project. Excessively high water table, fish kills, sedimentation are examples. Recognition of more subtle problems have justified more systematic studies and monitoring efforts.

When a project's intent is to deliberatly change the nevironment a different approach to the problem of evaluation seems required. One of the stated goals of the "Boise Post-Audit Study" was to develop methodologies for the evaluation

THE POST-AUDIT CONCEPT AND THE BOISE PROJECT

Post-Audit Intentions

For any activity, the direct and indirect results, insofar as they are determined, provide information relevant to the decision whether or not to initiate and complete the project. In recent years reliance only on the expected outcomes of a project as the decision criteria has been called into question. Increasingly publicized is the understanding that changes will occur in most situations without any planned activity. For federal water projects, recent guidelines propose a plan should be measured by comparing the estimated conditions with the plan against the conditions expected without the plan. Only the additional changes anticipated as a result of a proposed plan, beyond what might reasonably be expected to occur in the absence of the plan, should be attributed as beneficial or adverse effects of the proposed activity. "With-the-plan" expectations are customarily prepared in great detail, but "without-the-plan" expectations are more elusive because dynamic situations can usually be interpreted as having several reasonable development possibilities at each decision stage, leading to innumerable detailed expectations.

In this review of the Boise Project of the Bureau of Reclamation, two questions are crucial to the study. First, what actually happened, and second, what might have happened without the involvement of the Bureau of Reclamation? Before discussing these questions, a brief description of the region seems appropriate.

The Study Area

The Boise River watershed (fig.1) in southwestern Idaho, is characterized by a great variety of environmental features. In its eastern part it is mountainous, intricately dissected, with steep slopes, deep cnayons, and occasional high prairies. Elevations average 5,800 feet, with many peaks exceeding 9,000 feet. Snowfall of more than 100 inches is not uncommon. About 63% of the 4,234 square mile watershed is found in this section east of the city of Boise. Having received the waters of all major tributaries, the Boise River emerges from a narrow gorge about six miles southeast of Boise. In the lower, or western section, the watershed is bordered on the north by a continuation of high elevations and to the south and west by an undulating plateau. A flood plain exists along this stretch of the river,

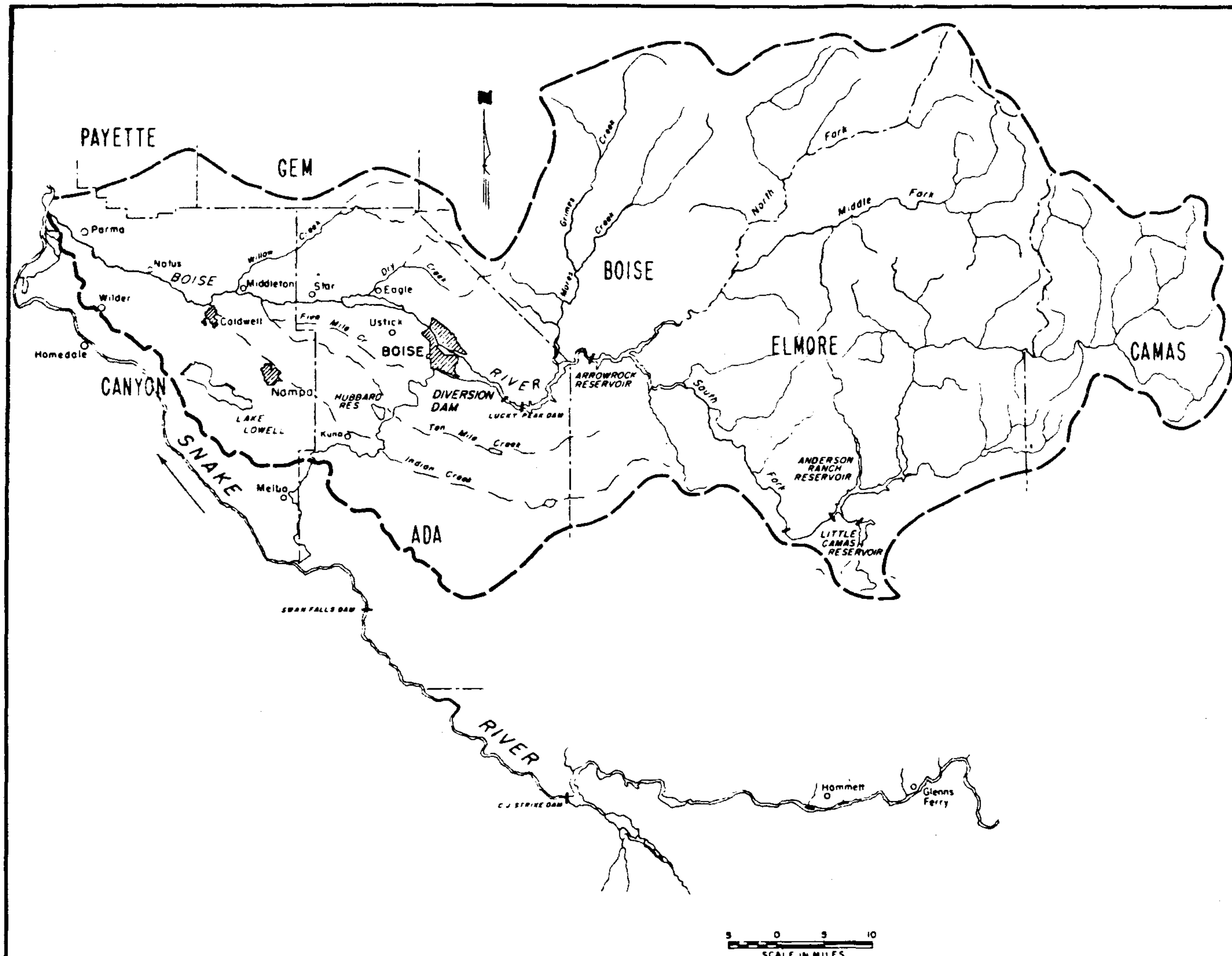


FIGURE 1: THE BOISE RIVER DRAINAGE BASIN

Source: Hydrology Support Study A Case Study of Federal Expenditures on a Water and Related Land Resources Project: Boise Project, Idaho and Oregon" by C.C. Warnick, C.E. Brockway, June, 1974. IWRRI Project C-4202. p. 6.

varying from one-quarter to three miles in width. South of the river, in the vicinity of Boise, two distinct terraces exist although to the southwest they become indistinguishable from the undulations of the receding plateau.

Materials of granatic origin comprise the Idaho Batholith, whose southern edge occupies the steep face and crest of the Boise Ridge along the northern boundary of the lower watershed. The Idaho Batholith has been weathered to a limited extent and provides shallow soil materials except where erosion and deposition have jointly determined otherwise. The steep slopes provide the potential for severe materials-loss to erosional forces.

The other predominate rock unit of the region is the Idaho Group encompassing fluvatile, lacustrine, and interbedded volcanic flows abuting the granatic highlands and forming the dissected footslopes, bottomlands, mesas, and gentler slopes of the area to the west and south of Boise. The Idaho Group materials, in places, are several thousand feet in thickness and provide shallow to deep soil materials and a complex groundwater reservoir, including hot water-bearing zones associated with faulting close to and beneath the Boise foothills.

The climate of the area is typified by a moderately cold winter with Pacific maritime air masses bringing winter precipitation. Summers are generally hot and dry. Annual precipitation averages eight inches near the western boundary to fifty inches in the mountainous eastern section. With precipitation concentrated on the mountainous slopes which has little absorptive capacity, when snow melts the runoff is rapid and generally substantial. In contrast, the loose materials of the Idaho Group receive little precipitation while have great absorptive characteristics. This eastern sector produces little natural runoff, and streams are intermittent, except for the Boise River which flows through the area in a west-by-northwest direction. With this riverine environment being the major exception, habitats are generally constrained by the hot, dry conditions of summer and the cold of a mid-latitude continental location. This climatic situation is generally termed Middle-Latitude Steppe and is characterized by short-grass prairies and local occurences of semi-desert shrubs. To the east, high elevations produce orographic precipitation allowing forest development. Such diverse topographic and climatic conditions produce distinctly different habitats with attendant plant associations and animal communities.

The Boise Project or What Happened

The passage of the Reclamation Act in 1902 established a national policy of promoting the reclamation and settlement of the arid western states. One of the first endeavors undertaken by the newly created Reclamation Service was the consolidation and improvement of irrigation works in the Boise Valley.

Irrigated agriculture had advanced rapidly in the region since 1863, and by 1900 there were reported to be 96,652 acres of land under irrigation. Although this was an impressive figure, the private interests that had developed the early canal systems faced serious problems. The easily irrigated bottom lands had sufficient systems, but getting water onto the benches above the river would require a large scale construction effort, involving either a canal through the rocky canyon above Boise, or construction of a relatively high diversion dam. The history of the pre-federal attempt to construct the New York (or Main) Canal is illustrative of the difficulties of private development.

Investors from New York, seeking to develop a large scale canal that could be used for both irrigation and placer gold mining, financed the start of the Canal in 1882. Efforts to complete the Canal were hampered by business failures, national financial panics, and occasional floods which wiped out significant construction work. Anticipating a firm supply of water from the new canal, homesteaders had gone to higher elevations as early as 1884 to take up land. The failure of the private interests to provide water to these pioneers was especially resented.

Finally in 1900, 19 years after the initial construction, the New York Canal was opened. As originally conceived, the Canal's capacity was to be 4500 second feet of water; in 1900 it carried 200 second feet. Diversion into the Canal was by the rubble diversion dam that had to be rebuilt each season. The grandiose plans of the private developers had collided with the late 1800's technology of building and financing. Thus by the turn of the century, the promises and difficulties of reclamation were obvious to residents of the Boise Valley. The entry of the federal government into the situation was met with considerable public enthusiasm and political support.

Initially, the Reclamation Service was interested in projects that could be quickly and successfully developed. There was an obvious need for action in the Boise Valley, but the complex assortment of private canals and conflicts over water rights detracted from the attractiveness of the project.

Before the Reclamation Service could begin work in the Valley, the existing natural flow water rights had to be judicially established. Water right filings had taken place since the 1860's and the stream was vastly overappropriated. Litigation was initiated to clarify the situation in 1902, and completed four years later. The Stewart Decree of January 18, 1906 established priorities for all who had appropriated Boise River water from June 1, 1864 to April 1, 1904. It also provided the "sliding scale" mechanism for allocating water when the demand exceeded the supply.

While the water rights litigation was taking place, other arrangements for the Project were being made. The formation of irrigation districts was authorized by the State Legislature in 1900, and districts were quickly formed in the Boise Valley. In 1904, the Pioneer and Nampa-Meridian Districts, together with a number of land-owners who supported the Project, organized the Payette-Boise Water User's Association. This provided the legally required, unified agency for dealing with the Reclamation Service.

The Boise Project was formally approved by the Secretary of the Interior on March 25, 1905. Soon after the Stewart Decree was issued, the Reclamation Service signed a contract with the Water User's Association providing a credit of 14 dollars per acre for their earlier investment in canals and improvements. With the needed legal arrangements finally complete, the Reclamation Service was ready to assume its designated role.

The Reclamation Service began controlling water deliveries through existing canals in the summer of 1906, while work began on the first segments of project construction. Work on the Boise River Diversion Dam began in March 1906, with completion planned by April 1 of the next year. Construction was delayed several times by high water, and the Dam was not completed until October of 1908. While work was underway on the first project structures, the Reclamation Service used existing canals and diversion points to deliver water.

The Boise River Diversion Dam is a small earthfill structure located 8 miles south of the city of Boise. The dam created an impoundment that raises the water level to the height of the first bench above the River, where it is diverted into the Main or New York Canal, and the smaller Penitentiary Canal, serving an area north of the River.

Deer Flat Reservoir (later renamed Lake Lowell) provided the first storage facility for the Project. Completed in 1909, Lake Lowell is an off-stream reservoir, receiving water through the New York Canal. Lake Lowell has a capacity of 177,153 acre-feet.

Even with the completion of Lake Lowell, water shortages were experienced, and the need for an upstream storage structure were evident. Arrowrock Reservoir was approved in 1911 and completed in 1916. Located twenty-two miles east of Boise, the dam is a high concrete structure spanning a narrow canyon. After the height of the dam was raised 5 feet in 1937, the storage capacity of Arrowrock increased to 286,000 acre-feet.

With water-short years occurring in 1924, 1926, 1931 and 1934, the demand for additional storage remained vigorous. Anderson Ranch Dam was approved in 1940, but was not completed until 1951. This was the first multiple purpose facility in the Boise Project, built primarily for irrigation, but also incorporating benefits for flood control and power generation. Located on the South Fork of the Boise River, Anderson Ranch has a storage capacity of 493,161 acre-feet, and a power plant with an installed capacity of 27,000 kw.

Lucky Peak Dam, completed in 1955 by the Corps of Engineers, is another multiple purpose facility. Its primary purpose is flood control, although benefits have also been assigned to irrigation and recreation. Lucky Peak has a gross storage capacity of 306,000 acre-feet. The four major reservoirs within the project provide a total of 1,262,314 acre-feet of storage, and are managed cooperatively by the Bureau of Reclamation and the Corps of Engineers for irrigation, flood control, power and recreation.

The present organization of irrigation in the Boise Valley includes three subsystems. The largest area is the Federal Project lands. Serving 166,886 acres within five irrigation districts, these lands are located between the Boise and Snake Rivers and extend west into the Big Bend region of Oregon. The upper system of 116,263 acres is served directly from the Boise River, mainly through the Main and Ridenbaugh Canals. The lower system of 50,623 acres receives water that has been stored in Lake Lowell.

In the northwestern part of the Boise Valley, lands are watered by a transbasin diversion from the Payette River. The Payette Division of the Boise Project is administered by the Black Canyon Irrigation District. This district is also part of the federal project, and irrigates approximately 58,000 acres.

Other lands north of the Boise River are also organized into irrigation districts. These districts have old natural flow rights and have not participated in the federal project, but benefit from it none the less.

The five irrigation districts (New York, Boise-Kuna, Nampa-Meridian, Wilder, and Big Bend) joined together in 1926 to establish the Boise Project Board of Control to administer the Project. Distribution of water to these lands involves both older natural flow and federal storage water rights.

What Might Have Happened

The Boise Project has evolved over seven, sometimes tumultuous, decades. With the large amount of speculation involved in determining what would have happened without the project, several scenarios were discussed in order to determine the latitude of the possible outcomes. Only two alternatives were selected for detailed analysis. The first alternative assumes there would have been no investment, private or federal, in irrigation storage. The other case examines the probable outcome if a storage reservoir of 200,000 acre-feet capacity had been built instead of those constructed. Historical evidence can be cited to support the possibility of either of these developments occurring if the Bureau of Reclamation had not constructed a project.

A third scenario explored, but disregarded, addressed irrigation development from groundwater supplies. Following considerable discussion, it was agreed sprinkler irrigation would not have been practiced on any more land than actually was irrigated from groundwater, with the project. Groundwater development without the project would have followed a similar pattern of growth as the actual case. The technology of pumping for irrigation was not adequate until after 1940, effectively limiting any significant development until after the close of World War II. Further, flood irrigation is believed to play an important role in recharging groundwater aquifers. Without the project the groundwater may have limited development of pump irrigation to levels below those which have actually occurred. Thus, there is little evidence to support either the direction or magnitude of any difference in the amount of groundwater irrigation with or without the Boise Project.

While the development of the area without the Bureau's project can never be known, constraining the scope of the study to only two highly probable alternatives was expected to allow fairly detailed analysis of these. The two scenarios are not as self-constraining as they initially appear. The region had been developing as an area of irrigated agriculture for forty years when the newly created Reclamation Service became involved. With this economic, legal, and physical entrenchment, it is unlikely the actual history of the area could have been redirected very greatly from the irrigation theme then in progress. Given this context, the following two outlines are thought to be reasonable and highly probable "without-project" possibilities. (56)

<u>The Natural Flow Scenario</u>

Without stroage, only the diversion of natural unregulated flows would have been available for irrigation. Because most of the precipitation on the watersheds occurs as snow in the mountains, the heaviest runoff is recorded during the spring as warmer temperatures reach the higher elevations. As summer progresses, flows taper off, leaving less water for irrigation during August when flows are often as little as 15 percent of those occurring in June. Historically the annual flows fluctuated tremendously. For example, the yearly flow for the Boise River in 1924 was only 50 percent of the runoff experienced during the previous year, and 41 percent of the 1922 figure. With a limited and an uncertain supply of water, intensive crops would probably not have been grown. Pasture, hay, and grain crops, which have low late season water requirement and have the ability to withstand some shortage of water, would have dominated the crop acreage without the project. With the growth of irrigation in eastern Oregon and with the irrigation of some land by sprinklers after 1950, some production of more intensive crops might have occurred. The low flows during July and August would have determined the maximum amount of land that could have been irrigated for the entire season. Some partial irrigation could have taken place in the early summer and again in the fall when additional water was available. Partial irrigation would have allowed for early grazing, for cuttings of one or two crops of hay, and for the greening of fall pastures.

Forecasting annual runoff is not perfect and was even less accurate in the past. Therefore, even if it had been possible to do so, farmers would not have had the information to be able to expand or contract their operations each year to correspond to the actual river flows. Estimating irrigated acreage solely from the natural unregulated flows would result in an overestimation of the acreage actually irrigated. Therefore, to provide a more realistic model, unregulated flows of the river were modified using a moving average criteria which normalizes the flows to allow for the imperfections of forecasting. When the actual flow is less than the average, however, crops, even though planted could not have been harvested. Below average flow is a limiting factor at the lower end while the average provides the upper limit. To provide for a start-up period, a gradual increase in the irrigated acreage is assumed to have occurred between 1910 and 1920.

The annual diversions of the Boise River given the natural flow scenario would range from a low of 161,800 acre-feet in 1924 to a high of 481,800 acre-feet in 1956, while over the period 1920 - 1973 the average diversion would have been 381,500 acre-feet. The availability of this amount of water is assumed to have permitted expansion of irrigated acreage from 60,000 to 174,000 acres. The last figure being the lands with water rights at the time of the Stewart Decree. The annual average irrigated acreage would be 152,500 acres after the assumed growth period from 1910 through 1919.

The Storage Scenario

The storage scenario assumes a 200,000 acre-foot reservoir, possibly a Carey Act Project, would have been developed in the early 1900's. Water stored in such a reservoir would supplement irrigation by natural flow, but the location of the project is not specified in the scenario.

With a greater assurance of water throughout the season, a more intensive cropping pattern than in the natural flow scenario would have evolved. Even so, grain, hay, and pasture are assumed to have accounted for 70 percent of the acreage planted, while fruits, vegetables, seed and field crops would have occupied the remaining irrigated area. With the water required for this pattern of crops, 40,900 acres could have been irrigated for the entire growing season. During some years there would have been sufficient water in the River in June to not only irrigate the 174,000 acres having water rights, but also to satisfy some of the demands of other irrigators. In these years, the reservoir would not have been drawn down as far in June as compared to years when natural flows satisfied only the irrigation of the initial

174,000 acres. If the unregulated flows could have irrigated all the lands in June, then the reservoir could have supplied water to 55,500 acres during the remainder of the water season. Thus, the storage scenario assumes full season irrigation to between 40,900 and 55,500 acres each year.

When the acreage irrigated by natural flow of the Boise is combined with the acreage irrigable by the reservoir, an average annual volume of 238,600 acre-feet additional water would have been diverted during the period 1920 - 1973. The storage would have allowed an average annual diversion of over 620,000 acre-feet and brought water to an additional 48,800 acres. The full water service and the increase in acreage would be accompanied by the growing of more intensive, higher-valued crops.

Settlement and Change in the Boise Valley

Occupancy by white men of the Boise River watershed began following discovery of the Valley in 1811 by the Astorian Land Expedition led by Wilson Price Hunt. Not until 1834 did the Hudson's Bay Company expand operations southward to the Boise Basin with a fort at the confluence of the Boise and Snake Rivers. Reports of the John C. Fremont exploration suggest irrigation was occurring to support the resident population of Fort Boise in 1843. In 1853 the post was seriously damaged by flooding. The following year the Company withdrew from Fort Boise and there followed a ten year period during which conflicts with local Indians retarded settlement by whites. Subsequently development has been marked in approximately chronological order by a spectacular mining boom, extensive logging operations, significant live-stock operations, intensive irrigation agriculture, and more recently, governmental and service functions.

Gold was discovered in the Boise Basin in 1862 and silver near Silver City in 1863. Rapid settlement of the region resulted as a part of and in support of the mining activity. In January of 1863 the area had three towns and about three thousand people. By summer of the same year, the population had grown to 19,000. With such a rapid influx of people in a remote area, enterprising folk were quickly at the business of supplying the others with goods, particularly food. Easily irrigated lands were brought into production as rapidly as possible and schemes were being devised to get water to higher elevations. The lower Valley's incorporated villages contained 2675 people in 1870 and 4674 in 1880, and the nonurban population was probably as large.

Large numbers of cattle were brought into the watershed during the late 1860's. Feed was abundant in the lower hills so little use was made of the rougher ranges at higher elevations. In the 1880's large bands of sheep were driven in and crowded the cattle back to the upper watershed. There followed a thirty year struggle between sheep and cattle interests for use of the range. The organization of the national forest Sawtooth Reserve on May 29, 1905 resulted in the beginning of a continuing effort to equitably allocate the available range. National forest ownership of land in the upper watershed has increased since the formation of the Sawtooth Reserve with much of the land now part of the Boise National Forest.

A Fragile Land

Steppe grasslands occupy a tension zone between short grass and tall grass prairies in the direction of increasing moisture availability and semi-desert shrub vegetation with increasing aridity. The climatic indices are characterized by great variability. Precipitation fluctuates greatly around the long term annual mean with wet and dry years strung together, at times producing years of drought or periods of wetness. On a yearly basis a dry season is characteristic, but as one approaches the desert extreme of the dry steppe, rainfall becomes more erratic with a greater tendency to be concentrated in heavy downpours. These lands, intermediate between desert and the closed forest, have been of value to man in supporting pastoral industries and are commonly termed "rangelands". In the Boise Basin, at higher elevations communities dominated by ponderosa pine and Douglas-fir occur, but the lower elevations are typical of the dry steppe. This zone is sensitive to changes in environmental inputs, more-so perhaps than most other vegetation classes.

The cyclic nature of percipitation over long term intervals has become a well known phenomenon in recent years. At the time of settlement of the western lands, however, little was known of the climatic parameters or their trends. This has proved to be unfortunate because in a land so sensitive to outside forces, particularly to precipitation and moisture availability, settlement ought to be based on the expectations of drought. If precipitation were uniform from year to year, or even periodic, management might be easily timed to utilize the available moisture. Being cyclic but not predictable encourages activities which result in land degradation when expectations are based on a wet cycle. Serious land failures can result from over use when occupants attempt to ride out what they hope will be a brief drought.

Range management investigations have shown heavy grazing destroys the ability of vegetation to resist drought because of the removal of the nutrients which must be stored for the next season's growth. Resistance to drought also depends upon the barriers to evaporation from the soil provided by an interposed layer of living plants and plant litter. Water storage capacity of the soil is reduced by compaction, and the loss of plant cover and litter increases runoff and the rate of erosion.

A Space and Time Linkage

The Sawtooth Forest Reserve and subsequent Boise National Forest were established for the primary purpose of promoting watershed protection, and management of these lands has gradually increased attention to fire control, adjustment of livestock use to capacity of the range, and range rehabilitation. Erosion and vegetative studies were conducted by numerous researchers following the 1920's when the serious ness of the watershed degradation became obviously apparent. (19,46, 68,90) A summary of much of this work concludes that plant cover and steepness of slope are the major determinants of erosion in the Boise River drainage. (91,92)

Because of boundary changes and lack of records, considerable difficulty is encountered in determining the historic range use. By combining records for 1922 of the "old" Boise National Forest and the "old" Payette National Forest, range consultant Abb Taylor has been able to create records which are comparable to those of the current boundaries. (78) Using a sheep to cow ratio of 5 to 1 the range use by domestic livestock can be reported in animal unit months or AUM's and compared to similar figures for more recent times.

Table 1: GRAZING RECORD FOR LANDS OF THE BOISE NATIONAL FOREST FOR 1922*

Units**	Cattle Number	Cattle Season(mo.)	Sheep Number	Sheep Season(mo.)
1	5450	6.5	48,224	4.0
2	350	6.5	83,055	4.0
3	4880	5.0	94,696	3.8
4	2150	4.0	30,720	3.5
5	500	5.5	---	---

* Map compiled by Abb Taylor, Range Consultant, Boise National Forest, Boise, Idaho

** Units 1 and 2 comprised the "old" Boise National Forest, units 3, 4, and 5 the "old" Payette National Forest

The most recent figure shows a slight increase reflecting a small transfer of land from the Sawtooth National Forest to the Boise National Forest in the intervening years. Without this addition the trend

Table 2: RANGE USE: BOISE NATIONAL FOREST FOR SELECTED YEARS*

Year	Total AUMS
1922	264,399
1962	66,442
1970	53,317
1976	57,879

Source: Range Reports, Boise National Forest

would still be down. The significant reduction in allowed grazing between the 1920's and now has brought the use more in line with available forage production and reduction in numbers is slowly continuing. Much of the damage was apparently done shortly after the turn of the century. R.W. Roberts has reported the Grouse Creek drainage was said to have been "a wavy sea of grass" in 1904 and by 1910 the area was "grazed completely barren". (73, p.8) During the early 1970's the area was dominated by cheatgrass and similar less desirable forbs and grasses. Robert's thesis contains several comparative photographs showing improved range conditions which reflect the better management of the watershed. One pair of photographs from

A. October 15, 1931

B. September 8, 1970

Figure 2. Sequential photographs taken near the Wood Tick Creek Exclosure, showing marked improvement of the range with the cessation of overgrazing.

Source: Bitter Cherry Vegetation on the Boise National Forest. Thesis by Robert W. Roberts, February, 1971.

the Wood Tick Creek drainage is reproduced here and indicates the marked improvement of the range with the cessation of overgrazing.

The abuses of overgrazing, poor lumbering practices, fire and others are obviously not results of the Bureau of Reclamation's involvement in the Boise Project. The activities are associated in space and time and thereby impact upon one another. For example, recognition of the degradation of grazing lands and the impact on Arrowrock Reservoir from sediment production, led to the enactment of the Arrowrock Purchase Unit in 1935 by the National Forest Reservation Commission. The main purpose of the intended acquisition was to halt misuse of critically depleted lands and apply restorative measures which the private owners could not afford. The gross area of the purchase unit was 726,970 acres but only 36,834 acres were eventually approved for purchase. (93) This partial completion is exemplified by the intermixed ownership pattern on the southwest edge of the Boise National Forest. Federal and state agencies are now attempting to ease the management problem by carefully selected land exchanges with each other and with the intermingled private ownerships. There is little reason to believe the Arrowrock Purchase Unit would have existed if not for the attempt to safeguard the integrity of the reservoir. The current ownership and management implications seem to be a predominate outgrowth of this situation. Problems initiated when the land was in the uncontrolled public domain have impinged on and linked the activities of numerous agencies, and continues to do so.

Related Evidence

It would be incorrect to imply that all or even much of the environmental change that has taken place in the Boise Valley occurred simultaneously with the development of the Boise Project. Direct and indirect evidence supports the belief that many non-reversible processes were initiated quite early. The following quote found in Dobie's article "The Jeepy Jackrabbit" (22) references a rabbit plague in Idaho in 1878, and is of interest:

> "We landed in a country east of the Snake River that must have resembled Egypt the morning after it had been visited by the plague of locusts. This plague was in the shape of thousands of rabbits and black beetles. These beasts and insects had appeared about a month previous in perfect swarms and were

eating the country as bare as a board. They spared nothing that was green, not even sagebrush. The rabbits were a species of Jack, brown in color, gaunt from hunger, and looked as though they had been pulled through a knothole. Like the locusts and grasshoppers, they moved as an army from north to south. The width of the column was about 40 miles, so I was told, and I believe it. The destruction became so alarming that the county offered a bounty of four cents a scalp in order to have them exterminated by the settlers.

"It was no trick at all for a man with a double-barreled shotgun to make four dollars a day, and one enterprising farmer near Boise City built a runway with brush, which ended in a big hole. He then organized a rabbit drive which resulted in his killing 10,000 thereby earning $400 at one clip. Payment of warrents nearly put that county into bankruptcy. The pest finally disappeared, no one knows how or why. One theory was that in their southward journey they brought up in the lava beds and just naturally starved to death during the winter." (Original source was Charles J. Steedman's: Bucking the Sagebrush)

Something in this passage or elsewhere has led Blackburn to attribute to Dobie the claim that these 1878 rabbit drives involved all white-tailed jackrabbits. More likely they were black-tailed jackrabbits (hares) for the following reasons: breeding of black-tails occurs year round while white-tails normally have only one litter each year, thereby favoring rapid increase of the former rather than the latter; cattle were brought to the Boise Valley in the 1860's and the range likely began to deteriorate rather quickly; the black-tail hare is very adaptable, eating a great variety of herbs and shrubs while the white-tail hare favors hilly bunchgrass territory and gives way to the others with the reduction of the bunchgrass from overgrazing; and finally, most reported rabbit drives and rabbit-pest incidents involved the black-tail. (34, 40) All of the above serves the argument that the Boise area rabbit problem of 1878 reflected a range deterioration problem rather than a natural cyclic increase in white-tail hares. The relationship of rodents and rabbits to deterioration of rangeland has received considerable attention and although an overabundance of these "pests" is sometimes considered a cause of range depletion the reverse is more often true. A population boom is instead a consequence of rangeland depletion by livestock grazing. These "animal weeds" may better be considered as animal indicators of degradation brought about by other causes. Once established these species may be capable of keeping a rangeland in a depleted condition. (20, p. 97) Applying these arguments to the Boise Valley landscape of the late 1870's suggests significant environmental changes were in progress on the land at that time.

Water related changes were inextricably bound with the development of the Valley as will be clear from later sections of this report. Beyond such "in-place" developments, early pioneers frequently attempted to improve their environment in other ways. One such person was William H. Ridenbaugh, Boise agent of Wells Fargo, canal operator, city father, and organizer of many Boise companies. Herb Pollard of Idaho Fish and Game made and reported the following observations about this pioneer developer and entrepreneur. (67)

Ridenbaugh's obituary in the August 18, 1922 Idaho Statesman tells us that:

"An ardent sportsman, Mr. Ridenbaugh was actively interested in improving and increasing the small game and fish of this locality. He imported black bass, crappie, and perch..."

"In the early seventies, he assisted in obtaining quail to be released near here which were shipped by Wells Fargo near St. Joseph, Missouri."

"He was also responsible for the importation from California of the first pheasants to be brought to this section."

The bass were largemouth. The original stock was fifty 6-inch fish from St. Joseph, Missouri in 1887. The fish were planted in the ponds at Ridenbaugh's house and mills a short distance upstream along the Boise River from the Fairview Avenue Bridge in Boise. In 1892, Ridenbaugh released 2240 bass, average 1/2 pound, into the Boise River while keeping the fish in "another populous pond of greater acreage" for another stocking.

Details of the perch and crappie importation are less definite, but it is known that fish from Ridenbaugh's ponds were planted throughout the Boise and Payette river drainages. The bass, perch, and crappies that we catch today in Cascade Reservoir, Lake Lowell, and the Snake River are descendants of Ridenbaugh's original efforts.

The bobwhite quail, from Missouri, found the Boise Valley to their liking and increased rapidly. By 1900, the little birds were plentiful along the Boise River with a month-long hunting season in November. The 1907-1908 state game warden's report to the Governor makes reference to bobwhite occuring "naturally" along the river.

The pheasant introduction is somewhat a mystery. The earliest records available to the Department of Fish and Game indicate pheasant plantings were mady by Dr. J.F. Bridwell of Kamiah in 1903 and by the Buhl sportsmen in 1907. The Department got into pheasant-raising in 1908 near Boise and purchased 1000 pheasants from Oregon in 1909 for distribution around the state.

The 1907-1908 biennial report notes pheasants on the increase in the valleys of southern Idaho and the 1909-1910 report states that pheasants had been distributed to "settlers and gun clubs" for two years previously. It is obvious that pheasants occurred in Idaho before these introductions. The 1899 act which created the Office of State Game Warden states "No mongolian pheasants shall be killed, ensnared, trapped, or destroyed for a period of three years following the passage of this act."

Chinese pheasants in North America are historically dated to two plants made in Oregon; one on Savvies Island at the confluence of the Columbia and Willamette Rivers in 1881 and a second at Washington Butte near Lebanon in 1882. These birds were sent to Oregon by Judge Owen Denny,consul to China who had grown up on a homestead in Oregon. The two successful plants were sent by ship from China to Portland.

A third shipment was sent by steamer to San Francisco to be transhipped by Wells Fargo Express to Oregon. This shipment of birds arrived in San Francisco, but disappeared before it arrived in Oregon. The shipment might have become someone's Sunday dinner in San Francisco or maybe they escaped or were released in transit.

However, there remains the possibility that Mr. Ridenbaugh, who expended considerable effort and personal expense "in improving and increasing the small game and fish of this locality" got wind of the shipment and took advantage of his position with the express company to divert them to Idaho. Whatever the case, Ridenbaugh was credited by his contemporaries with bringing the first pheasants to Idaho and the birds came from California.

Another of Ridenbaugh's efforts was the introduction of bullfrogs to the Northwest. Again the stock came from Missouri via Wells Fargo Express and was planted in the ponds in south Boise. The frogs soon moved down the Boise River and colonized the Snake and the Payette. In 1914, I.B. Hazeltine, Oregon Game Warden for Grant and Baker counties, purchased 12 adult frogs and 30 tadpoles from citizens of Payette for introduction in ponds near John Day. From this plant, frogs were transplanted to the Willamette Valley and western Washington. Other transplants from the mid-west and south were made, but Ridenbaugh's frogs were the first and their progeny are spread throughout the Northwest. (67, pp.8,9)

The introductions discussed above were wholly intentional but accidental transplants of animals and plants have also taken place. Most observers consider on balance that successful and desirable introductions are outnumbered by undesirable transplants. Others argue that all introductions of non-native species are undesirable from an ecological perspective. Once an area has been stimulated to change, by overgrazing for example, such positions become difficult to sustain. Thus, cheatgrass is considered a poor substitute for native grasses, but we must ask whether "cheat" is better than no cover whatsoever.

Intentions and Reality

In this section the post-audit paridigm has been presented in the context of the Boise Valley. A description of the region and the actual development thereof is contrasted with two "without-project" alternatives. The stimuli for white occupation of the area, namely trapping, mining, grazing, lumbering, and agriculture, when coupled with the favorable cross-roads position and the relatively late timing of major settlement were conducive to rapid environmental change. Alteration of every component of the landscape was well underway by the turn of the century, if not before. This flux is illustrated by the sampling of both the inadvertent and the planned environmental modifications known to have occurred early in the modern history of the valley. Each component of the environment might be thought of as having been launched on a trajectory of change by the first settlers, to be buffeted in its path by new sets of forces with each increment of development. Interactions among the forces of change and among the environmental components are not well determined. The environment is an intricate and sometimes delicate array of physical, chemical, and biological systems juxtaposed in time and space. Ramifications of external stimuli may require long periods to fully develop and for the system to reach a dynamic steady state. Evaluations of the effects of specific stimuli in a situation of environmental flux, such as the Boise Valley at the turn of the century, surely exceeds the bounds of contemporary science.

ENVIRONMENTAL EVALUATION METHODOLOGIES

Purpose

This section attempts to clarify the problem confronting the Environmental impact "sub-project" of the post-audit study of the Boise Valley. The problem is not unique to this project except in one respect, namely, instead of looking to the future, we are trying to look back. Lack of information on environmental parameters in this historic sense is a serious limitation for our efforts. A second critical problem is not in this technical/data sense, but rather it is one of failing to have a workable methodology.

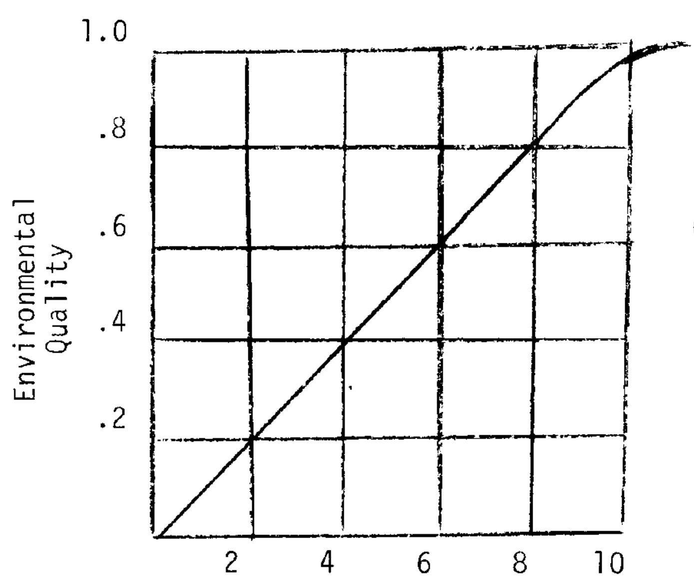
The distinction between methodology and our data problem is easily described by reference to a simpler idea: given a concept of "length," humankind has agreed (more or less) to compare the unknown to a known standard (e.g., a meter), and to record the result as the length of the unknown. This process works in contrast to comparing something to the distance between wrist and elbow. The "technique" of making the comparison with the meter may vary with the circumstances and the required precision, but there is no ambiguity in what one is attempting to do. With such a complex concept as environmental quality it is difficult to develop a workable methodology even though some parameters can be measured with great precision (i.e., temperature). It is not surprising to find many people unhappy with current approaches at environmental impact assessment while applauding the attempt.

Methodologies for environmental assessment range from the purely verbal descriptions to very technical and quantified approaches. Computerized models may be used to attempt to better ascertain the probabilities of various alternative futures. Still, there is no accepted methodology for environmental assessment--there may never be.

An Example

The Boise Project team, with hopes of adaptation, studied a report done by Battelle-Columbus Laboratory, wherein is described an Environmental Evaluation System (21). With the benefit of hindsight, attraction to the report was premature. The Battelle EES has problems but what they set as their goal is most attractive. In short, the EES attempted for the environment what the benefits-to-costs ratio provides for the national economy--an extremely precise figure concerning the overall environmental impact of a project. If such figures could be churned out, for project after project like a B/C ratio, they might take on the importance the B/C ratio has historically had. The Battelle EES attempts this comprehensive quantification by taking the subjective aspects away from the field technician and report writer and giving the same to an "interdisciplinary" research team.

To achieve commensurate units this team has begged, borrowed or thought-up relationships between environmental parameters (see diagram below) and environmental quality (EQ). For example, dissolved oxygen and EQ are related thusly:



(Source: (21), Figure 24, page 45)

Figure 3: Example of an Environmental Quality Relationship

Further, dissolved oxygen gets weighted by a factor of thirty-one, while, for example, "appearance of water" gets weighted by a factor of fourteen. With a relationship (curve) and a "weight" for each parameter, each can be converted to environmental quality units which can be subjected to arithmetic calculations just like dollars.

Problems with the EES

An initial reaction is to criticize the weights and the relationships; for example, is BOD or DO a more important parameter of

EQ?; or, such and such relationship is not right. These are critiques of technique rather than methodology. Refinements and updates can supply more acceptable results if deemed necessary.

Two methodological aspects are quite troubling, however. One is the fact that many of the EES parameters are time and/or place specific. Take dissolved oxygen (DO) as an example. Measurements are often taken at 6 AM and 6 PM at a given location. Even in a normal situation (not a post audit study) it is fair to ask which measurement of DO is compared with which. How do we average or combine measurement of DO from different places? Do we average stream readings separately from lake readings and partition the 31 "weight" points according to the proportional volume of each? This criticism can be leveled at most of the water and air pollution parameters. Contrast this with an index like "basin hydrologin loss" which attempts to measure a project's impact on the water budget through evaporation losses from reservoirs and irrigation. This is a basin-wide index with a one year cycle implied in the definition. Such measurements may lack precision but the concept appears meaningful.

The second conceptual problem is the "closed" aspect of the parameter list. There are 78 parameters and no way of adding new ones. Existing parameters can be deleted insofar as the mathematical structure is concerned and only minor conceptual harm would result. Adding a parameter is impossible without giving it a weight and these have all been done simultaneously by the Battelle team. In any case, the issue of deleting and changing parameters points to the real problem of describing the environment in a meaningful way.

Environmental Data

While the amount of information generated about the environment is overwhelming and continues to accumulate, the degree to which this information is, or will be of value in solving environmental problems is questionable. The data is found in a variety of forms including maps, written documents, sets of measurable variables, photographs, and satellite imagery. The only common characteristic of all this data is that it is historical. As such it may be of use in reconstructing past environmental conditions and present base-line conditions. If the data is temporally and spatially compatible it may be of use in determining changes or trends in environmental conditions through time and space. However, the utilization of this information is fraught with difficulty.

First, the source of storage location of the data may be so obscure as to create enormous problems in second-hand data collection. Second, a lack of evidence as to how the data were collected may raise questions as to their validity. Third, variation in techniques of data collection, if known, may make the data incompatible with other data collected at the same time and place. Fourth, the environmental variables measured in the past may bear little relationship to variables relevant to present problems. These and other difficulties have discouraged the use of historical data and have detracted from concerted efforts to assess the degree to which environmental conditions have changed.

In reviewing studies involving environmental description, we have come to recognize two interrelated types of variables. Primary variables are measured directly in the environment. Secondary variables are derivatives of one or more primary variables. In addition to primary and secondary variables, there are surrogates or substitute variables. As our understanding of functional relationships between environmental relationships develops, so too will the ability to use certain key indicators as monitors for a complex of numerous other variables. Attempts to do this using specific animals or plants might be termed the "miner's canary" approach to environmental assessment. However, if such an approach is to be used in a curative function, we must understand what the conditions of these indicators mean in terms of ecological processes.

A general definition of the environment would be that it is a composite of the elements lithosphere, atmosphere, biosphere, and hydrosphere superimposed with land use activities. Given the present understanding of functional relationships between environmental data, some opt for the "shotgun" approach--using a large number of variables so as to be sure all the "right" ones are included. Describing the environment in this way seems arbitrary. The various elements are interdependent, being related through the variables. This is apparent if we consider such questions as whether groundwater should be considered part of the lithosphere or hydrosphere; whether soil microorganisms are to be considered part of the biosphere or lithosphere. Such issues illustrate the artificiality of trying to compartmentalize the environment, yet there is need to do so.

Indices

Increasing emphasis has been placed on the development of environmental quality indices. Given that the environment is described via compartmentalization, the question of what variables should enter the formulae for producing indices is problematic. Of major concern would be that variables from each element or compartment are included.

Indices must be considered as a third level of environmental data, having meaning because of conceptual or theoretical relationships which we are willing to accept. The benefits of such indices derive from their potential contribution to the development of priorities among environmentally oriented activities. Part of the desire for indices is based on the efficiency provided by them. For policy makers and planners, the myriad values of many variables for numerous times and places necessary to describe the status of the environment is cumbersome. Hence, a single index or series of indices describing the environment provides a powerful tool.

The development of an environmental quality index should involve the following steps. First, those variables which will contribute to the index must be decided upon. Second, one needs to develop a standardization procedure which translates the variables into compatible units. Third, recognizing that the contribution of each variable need not necessarily be equal, a weighting strategy for the variables must be developed. Finally, the standardization and weighted units must be combined. Numerous environmental quality indices have been proposed and some have been operationalized for forecasting purposes. Most refer to the quality of a specific environmental element such as water or air. Nonetheless, such constructs as soil fertility and species diversity have sometimes been offered as quality indices. Although our knowledge of what constitutes soil fertility has changed, this is an index with long-standing recognition. Likewise, diversity in biological communities could be considered quality indices although the quality-meaning of species diversity has not been well articulated.

A major deterrent to the utility of indices is that quality criteria vary greatly between environmental elements and for different uses to which an element may be put. Air quality criteria are most often related to human tolerance levels and human health. Water quality criteria vary between uses such as consumptive, irrigation, industrial process and cooling water, water for contact recreation, or water for game fish. In the case of soil, should fertility or structural-engineering characteristics or both be used as criteria? These examples illustrate that quality indices are closely related to the purposes or functions of the environmental elements as they related to human activity.

Files of data are virtually useless in decision-making. In view of the possible complexity and volume of environmental measurements, the development of indices must be an integral part of environmental monitoring and assessment. The development and usefulness of environmental indices is dependent on knowing what are the most pertinent variables and on the validity of the original data. The technology of producing environmental indices has as its goal generating information useful to decision makers out of raw data. The use of a variety of summarizing statistics as indicators of central tendency and dispersion have been of use, particularly in the case of data representing continuous distributions through time such as temperature and humidity. Most such measures of long standing are more or less value free. In contrast, more recently developed indices which summarize environmental conditions as combinations of two or more variables are more closely tied to the developer's value system.

Data Availability

The assessment of the impact on the elements of the environment is very dependent on data and on understanding functional relationships between and among variables. In a contemporary situation we can assume data is either available or collectable, at a cost. Empirical (correlational) relationships in a temporal framework are frequently more difficult to determine. The environmental scientist proceeds under the assumption that such problems are tractable.

The Boise Project Post-Audit Study differs from many other environmental assessment studies in one important respect. Much of the data which we would like to have is not available because it was never collected. The concerns, the interests, the values systems of the project collaborators were different than those of the contemporary environmental scientists. This lack of data places us in a position of ignorance with regard to numerous parameters generally held to be useful indicators of environmental conditions.

Methodology

Regarding methodology it will perhaps be enlightening to consider the importance of measurement in science. At the moment it is necessary only that we distinguish between two constructs used in science--systems and properties. The relation between these constructs is perhaps obvious, but it is very important.

Properties are essentially the characteristic of the empirical world, they are the observables. When such a characteristic is defined, it always seems to be a property "of something." For this something, the term "system" is used. The things of our experience, such as chairs, automobiles, soil, rivers, atmosphere and irrigation projects are systems. Properties are such aspects as weight, height, seat area, and color with respect say to a chair, and with respect to irrigation projects we have such aspects as water volume, canal length, and areal extent.

This difference between properties and systems is of interest because of the fact that it is always the properties that are measured and not the systems themselves. One does not measure a river, although its rate of flow is measurable. Thus, while a system itself is immeasurable by its very nature, each possesses properties that perhaps can be measured. To go full circle, then, it may be possible to define a particular system as roughly that which possesses some particular properties.

Individual Differences

The distinction outlined above is important to the present discussion because the environment is a system, involving many subsystems, with numerous properties. It is logical to speak of measuring certain properties of the environment and to consider the change that might have taken place since the property was last measured. For example, the number of surface acres of lakes, ponds, reservoirs and the like may have increased or decreased, there may be more or fewer pheasant, there may be less sagebrush and more corn.

Sometimes when a particular property is defined, evaluation is implied of its direction of change. Thus, a certain automobile (system) may get 15 mpg (property) while a different model may get 16 mpg. An impulsive conclusion would be that the latter measurement is indicative of something better than the former. Clearly, this need not be the case, but the tendency to infer such value judgment is all too easily ignored.

Consider the following two quotations for a moment. The first is a statement about the Boise Valley, the second was made with reference to no place in particular.

> "What are the environmental impacts? There are several big ones on the plus side. The first and most obvious is that of providing irrigation water. Irrigation has changed the land areas adjacent to the river from a decidedly hostile desert sagebrush area to the lush area of irrigated farms we know today. I can't really imagine anyone arguing this point." (44)

And now this:

> "To the laborer in the sweat of his labor, the raw stuff on his anvil is an adversary to be conquered. So was wilderness an adversary to the pioneer. But to the laborer in repose, able for the moment to cast a philosophical eye on his world, that same raw stuff is something to be loved and cherished because it gives definition and meaning to his life. This is a plea for the preservation of some tag-ends of wilderness, as museum pieces, for the edification of those who may one day wish to see, feel, or study the origins of their cultural inheritance." (41)

If the two writers of the above words could meet and talk, they would agree that irrigation has changed the Boise Valley; but there might be some argument as to which side of the ledger should get the positive entry.

As a second illustration of the kind of problem being faced, consider that proponents of irrigation projects, whether it be the Boise Valley Project or the Central Washington one, frequently cite the increase in the number of ringneck pheasants as a plus for the environmental ledger. However, there are naturalists who consider this bird a gaudy intruding foreigner and a detriment to the environment to which it has been introduced.

The illustrations just related provide a key to explaining one of the major difficulties in assessing the environmental impacts of any project. While all might agree on certain factual results--a lake is created, a stream segment is inundated--we frequently cannot agree whether such accomplishments are good, bad, or indifferent with respect to the environment. Some sources of individual differences are suggested in Table 3. In the face of individual differences to both extremes, the hope is frequently expressed that an "objective" way will be found to balance losses against gains. A search for a totally objective evaluation will, most assuredly, be frustrating for it assumes implicitly a magical disappearance of people's individual differences in beliefs, values, and attitudes.

Approaches

The objective evaluation of the varied impacts of resource development projects seems impossible because of the different perspectives of people. This leads to the supposition that a rather chaotic situation would result. In fact, this appears to be the case. Consider just two studies.

A U.S. Geological Circular proposes a method for use in assessing impacts whereby 100 types of actions are cross-classified by 88 environmental properties. (42) The magnitude and relative importance are each rated on a scale from 1 to 10 for the 8,800 cells, giving a total of 17,600 entries. There appears to be no control or recording of the evaluator's bias in making the ratings nor any reasonable and meaningful manner of summarizing the thousands of entries. Thus, we have a situation where we go from the perception and/or measurement of numerous properties to a tremendous data matrix with only a vague notion of the usefulness of the final result.

A second study with serious weaknesses involves Battelle's Environmental Evaluation System mentioned earlier. A major methodological weakness of this system of evaluation is that it does not recognize different perspectives with regard to the positive or negative implications of an environmental change. The "team approach" is cited as a desirable aspect of this system, even though, theoretically, meaningless results could be obtained. Real differences in how people perceive environmental change can get "averaged" out with such an approach. This might be likened to having ten Republicans and ten Democrats rate a dozen candidates from each party relative to their own leanings, and then average the result. The composite score

TABLE 3
SOME FACTORS AFFECTING INDIVIDUAL RECOGNITION AND DEGREE OF CONCERN OVER ECOLOGICAL IMPACTS OF WATER PROJECTS*

A. PERSONS LIVING IN AREA OF WATER IMPOUNDMENT AND/OR DIVERSION (AREA OF ORIGIN)

Land owners directly affected by project-concern depends on whether:
- land area is submerged,
- land provided with new vista or shoreline frontage,
- land is subjected to increased seepage or higher water table,
- land receives better flood protection.

Area residents-concerned about:
- Effects on general economy of area:
  - loss in agricultural production from submerged areas,
  - payroll arising from project construction and operation,
  - development of adjacent areas for housing and industry,
  - altered recreation opportunities and travel.
- Effects on tax base.
- Effects on local government costs for public services (police, fire, roads), schools, and social programs.
- Anticipated effects on future development and economy of area.

Sensitivities to ecological issues: may be secondary to above considerations for many individuals.

B. PERSONS LIVING IN AREA SERVED BY WATER PROJECT

Land owners, farmers, and residents of rural areas
- Increased land values and crop income.
- Improved economic conditions for rural communities.
- Higher tax base for local governments.

Urban areas: augmented water supply may:
- Eliminate or lessen periodic water shortages for present populations.
- Improve water quality.
- Allow increased land development, new industry, increased construction and higher population with economic benefits to some residents.
- Permit expansions of industry and population unwanted by some residents.

Undeveloped areas: new water supply permits settlement and urbanization of previously unoccupied or sparsely settled districts.

Sensitivities to ecological issues: for many individuals, these are secondary to above consideration.

C. PERSONS LIVING OUTSIDE OF AREAS OF ORIGIN OR SERVICE

Farmers and rural communities already adequately supplied with water may suffer economically from production of new irrigated areas.

Rural and urban dwellers:
- May be concerned about possible future costs to them for water projects through taxation.
- May deplore disturbance of natural conditions of wild rivers.
- May be concerned about maintenace of beaches along sea coast.
- May desire to boat, fish, and hunt in undisturbed areas.
- May be concerned about effects of project on commercial fishing and continued availability of sea food.
- May welcome new opportunities for fishing and water-based recreation on newly-created lakes.
- May be concerned about continued opportunities for dilution and transport of wastes from their community.

Sensitivities to ecological issues: many individuals consider these of compelling importance.

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* Source: Goldman, C.R. et.al. Eds. Environmental Quality and Water Development, 1973; W.H. Freeman, p. 212.

would tell very little about the slate of candidates, but might suggest something about the evaluators.

While each of the above mentioned studies contains many excellent ideas, as do other such studies (17, 20), neither appears to have developed a satisfactory methodology. In the first case, no constraints are placed on the conversion of raw data to "information" and a parsimonious reduction of the mass of numbers is not possible. In the second instance, the attempt to contain the results to a single evaluation, that is team weights, squeezes out expected variation.

Both of the problems mentioned can be overcome by recourse to more sophisticated scaling technology, if it is desirable to do so. (15, 18, 82)

Environmental studies need not be separated from the evaluation processes of individuals. The cultural constraints existing within society make it possible to summarize the evaluations of numerous individuals according to the dominant patterns existing in their judgmental data. This will provide a cluster or group of people who view their environment in like manner. Such a group may or may not be essentially comprised of what we now term an "interest group."

The outline of this type of methodology could be synthesized from previous attempts at environmental assessment and scaling techniques. Environmental properties would continue to be defined and measured, indices and surrogates investigated, and critical points established by the appropriate specialists. This is simply the process of generating information from raw data. Next this information must be transformed into compatible units and weighted via the evaluation mechanism of distinct clusters of people with different viewpoints. Once unique group weightings are determined the environmental information can be compared and used to fuel public debate. But, such an approach may just as easily be used to classify individuals as resource projects. Recognition of such individual differences and their open discussion would help interest groups to better understand and appreciate the feelings of others. Consider, for instance, Odum's work incorporating an ecological oriented anti-development bias and the following critique:

> "Odum has developed a system for assessing environmental impacts of highways...benefit/cost ratio is one of the parameters; its contribution to overall impact is calculated by multiplying benefit/cost ratio by a relative weight of -10. Thus, even the most favorable benefit/cost ratio contributes a negative impact to environmental quality. Several inadequacies of this type detract from the utility of the system." (21, p.5)

Obviously, Odum must feel further investment in highways, which would promote traffic and nearby land development, would be environmentally counter-productive. The only inadequacy is the reviewer's insensitivity to the individual differences concerning changes in the environment and the designer's right to incorporate such feelings into subjective evaluation procedures.

Getting at Inputs and Outcomes

The concept of an ex-post or follow-up analysis of resource projects derives from critical consideration of the concepts and procedures of pre-project or ex-ante economic evaluation. To suggest a simultaneous ex-post economic and environmental evlauation presupposes at least a rough equivalency of endeavors. Therefore, much can be gained by reviewing the nature of the arguments which justify ex-post economic evaluation and their corresponding fit to environmental concerns.

Evidence of the existence of a congressional or national goal which can be called economic efficiency with respect to publically supported projects has been demonstrated by Haveman (24). Years of involvement have brought about institutionalized procedures for pre-project economic analysis or ex-ante evaluation of benefits and costs. Similarly, but more recently, a goal which might be called environmental conservation has appeared as official doctrine, and here too the emphasis has been on pre-project analyses.

Because of a lack of perfect foreknowledge, a decision to act follows from evaluation of uncertain outcomes attributable to the action and a comparison of these anticipations with uncertain estimated inputs. The uncertainties involved are of different character depending upon whether the element of concern is an input or an outcome. Inherent in an economic analysis are uncertainties peculiar to the concepts of project costs (inputs) and benefits (outcomes). As explained by Haveman, costs and benefits differ conceptually in several ways, and significantly, all of these differences appear to result in a substantial divergence in the degree of uncertainty included in the estimates of each of them. Because of both the estimation techniques used and the characteristics of the concepts themselves, estimates of project benefits must, generally, be viewed as possessing a substantially lesser degree of credibility than estimates of project costs. This conclusion derives from evaluation of the following: (1) the possibility of the continuous reappraisal of estimate accuracy, because construction, operating, repair and maintenance costs are actually experienced and can be compared to the estimates with subsequent improvement in estimation procedures; (2) the degree to which the variables are deferred or immediate, because deferred effects, generally the bulk of the benefits, involve a greater uncertainty than do immediate effects and may depend on the long term development of the region; (3) the nature of the components upon which the real estimates are based, because costs are based on engineering practice and theory applied to quantitatively measurable physical and economic data, while benefits being real, their value may be quite elusive and the time frame makes accuracy extremely important; and (5) the relative insurability of project costs and benefits, because the practice of cost estimation and comparison leads to a procedure with a known degree of accuracy thereby producing a range of costs substantially more insurable than can be obtained from the unconfirmed benefits estimation procedure. This last idea simply means that since the benefits are never actually determined it is impossible to know how accurate the estimation procedure is.

A graphic summary of the above arguments is possible if we assume the possibility of an index of credibility. The expected value of project benefits, in general, will possess a lower index of credibility than will the expected value of costs. Furthermore, the distribution of possible project costs will have a smaller variance than the distribution of possible project benefits. The accompanying figure displays these concepts for a project whose expected benefits to costs ratio equals unity. The graph suggests a mathematical or probability basis for a phenomenon frequently encountered at the intuitive level. Namely, those with widely divergent viewpoints can develop quite reasonable arguments, and present them with equal righteousness, in support of high or low benefits. Conversely, cost estimates are theoretically and practically more constrained, with arguments focusing on assumptions rather than the actual existence of the costs. Simply put, extreme possible project benefits appear more credible than extreme costs because of the difference in the variance, regardless of whether the estimates are high or low.

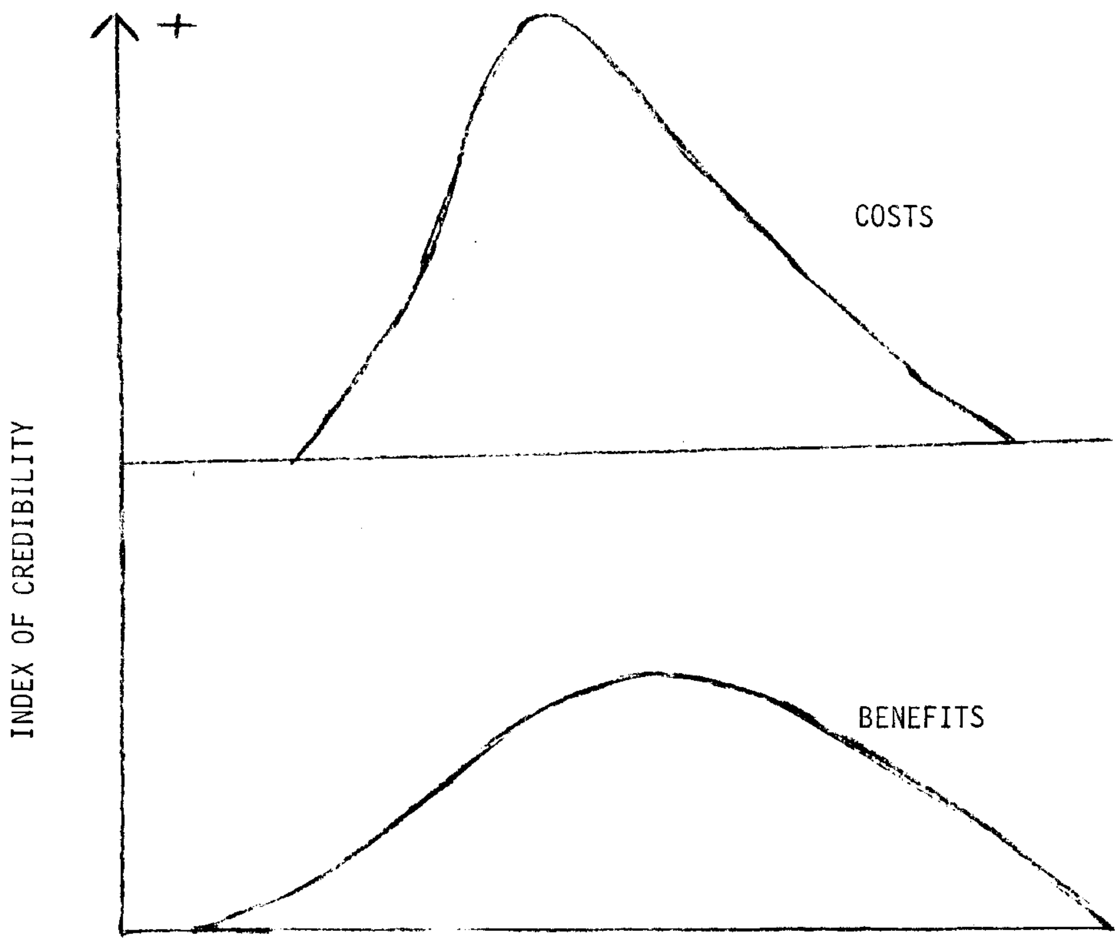

Figure 4: Distribution of Benefits and Costs of a Project Whose Benefit-Cost Ratio Equals Unity

Source: (27, p. 166, Figure 6.)

At the minimum, an ex-post economic analysis should attempt to very accurately determine the inputs (costs) and the outcomes (benefits) which actually occurred. In addition, concern should be given to what would have happened had the project under question not been developed. Numerous alternatives, some more plausible than others, can be suggested for any given locality and situation. Obviously, analysis of inputs and outcomes becomes hypothetical in such cases with the perplexing distributional problems, summarized in Figure 4, playing an increasingly important role as the time period is extended.

To this point, this discussion of post-audit intentions has been couched generally in terms of the "economic efficiency" goal. The economic analyses of projects has been characterized as having developed over a number of years to the point of having become institutionalized with certain inherent differences between the concepts of costs and benefits. The ex-post or follow-up analysis of projects is a logical extension of economic evaluation and contributes toward bettering the performance of public investment policy.

A goal termed "environmental conservation" is likewise of national concern and it is of interest to examine the concepts of post-audit evaluation in this context. Institutionalizing the methodology of environmental change evaluation is now taking place with the outcome still far from clear as indicated in the first part of this section. This does not preclude consideration of the conceptual issue of using environmental aspects for evaluation purposes. The expression of inputs and outcomes of a project as costs and benefits dominates the methodology of economic evaluation. An environmental evaluation is faced with the problem of finding appropriate meaning for the input and outcome concepts. When the question is framed in this manner there is an apparently simple and trivial answer. Namely, the existing environment becomes the input and the resulting environment the outcome. But in application that is neither simple nor trivial. Environmental systems are delicate and intricate arrays of energy flow and chemical recycling systems which through years of evolution have developed, and are sustained by physical, biological, and chemical processes driven by the sun. From the earlier discussion (p. 27) it is clear a system cannot be directly measured. Environmental evaluations have therefore concentrated on measuring the obvious properties of the system, for example, miles of streams, surface acres of lakes, wildlife population (estimates), rate of flow, water temperature, and other items. In a report on impacts of water resource projects, Hagan and Roberts outline the variables that might be of significance in the area of the impoundment, downstream, along the conveyance route, and on lands receiving project water. (26, Chapter 11)

The accompanying tables are from their report and most but not all of the implied measurement of properties would be applicable to the Boise Project if data existed to compare the "with" versus the "without" scenario. As previously mentioned it is not objectively possible to take these sometimes distinct but often interrelated properties and construct an index of the change in the quality of the environmental system which jointly they represent.

Behavioral psychologists have carried the terminology "phased decision model" to represent the situation wherein some decision criteria are considered absolute with others having lesser and varying degrees of importance. (18)

In the environmental change case an absolute criterion may be the impact of a project on an endangered species. Scientists and non-scientists alike have argued for maintenance of the genetic diversity of the earth because man's activities have so greatly increased the once relatively slow demise of species. Other properties of the environmental system may be altered and so long as certain bounds are not exceeded this situation does not raise sufficient concern to stimulate corrective action. Dissolved oxygen of water is such a variable for which critical levels are often selected. Natural variations of such properties dictate such an approach to their use. Their measurement and any implied corrective action provide a negative feedback loop for the environmental system. Current attempts at environmental monitoring seem implicitly to accept the assumption or simply hope that sufficient negative feedback will maintain the system at a homeostatic plateau, that is, keep it from going out of control. For some time environmentalists have been calling attention to indicators of environmental system changes and spurring institutionalization of negative feedback, thereby making an important contribution to environmental system maintenance.

A checklist approach, such as reviewing all the aspects of project impact contained in the tables of this section, provide a means of organizing environmental data. The Battelle EES attempts to provide an index of environmental quality by parsimoniously selecting, translating, and combining the measurements taken on just a few of all possible variables. The checklist provides data which the reviewer must absorb and through some unknown personal calculus, resolve the intricacies of environmental change

TABLE 4
POSSIBLE ECOLOGICAL IMPACTS IN IMPOUNDMENT AREAS*

Disturbs natural state of area

- Desire to preserve natural conditions for present and future generations: "wild" rivers versus controlled rivers.
- Changes scenic values: conversion of rivers to lakes.
- Modifies micro-climate: temperature, humidity, wind.
- Alters land form, vegetation, wildlife, etc. (through construction and subsequent activities) and thus affects ecological diversity.

Increases evaporation loss

- Reduces water supply.
- Degrades water quality.

Changes water temperature

- Altered aquatic life.
- Effects on some water uses, primarily water sports.

Alters erosion and sedimentation

- Erodes reservoir banks, causes land slides.
- Deposits sediments in reservoirs: delta formation, loss of reservoir capacity.

Submerges land areas

- Affects scenic values: submerges scenic treasures; creates new scenic values; causes visual "pollution" from exposed banks during drawdown.
- Loss of historic sites.
- Displaces people (see economic and social effects).
- Alters habitat for fish and wildlife (see below): mitigation enhancement.
- Creates environments for new life forms: plants, insects, fish and other wildlife.
- Possibly influences earthquake frequency.

Modifies fish production

- Substitution of lake for stream fishing: changes in fish species.
- Dam creates barrier for anadromous fish migrating to spawning grounds: fish ladders.
- Still water and deeply submerged spawning beds affect reproduction and return of young fish to sea: fish hatcheries.

Alters wildlife production

- Submerges feeding areas.
- Substitute other areas or more intensively managed areas.
- Provides new nesting and feeding areas for migrating birds.
- Denuded zone exposed during drawdown restricts access to water by timid animals.
- Reservoir brings "people pressure" which may upset delicate environmental balances, adversely affecting rare species.

Modifies recreation potential of area

- Alters opportunities for swimming, skiing, and boating.
- Modifies fishing and hunting.
- Creates or expands sites for camping and other recreational facilities.
- Increases people pressures on life of area with resultant ecological impacts.
- Increased penetration of adjacent and remote wilderness areas by hikers.
- Intensifies traffic, noise, and air pollution.
- Expands needs for pollution control and waste removal.

Increases development of surrounding lands for urban or vacation housing.

- Destroys native plant cover.
- Increases erosion from construction and loss of plant cover.
- Increases people pressure on surrounding areas.
- Intensifies pollution and waste disposal problems.

Alters economic, social, and political life of area with resultant secondary ecological impacts.

Source: Same as table 3; p. 202

TABLE 5
POSSIBLE ECOLOGICAL IMPACT DOWNSTREAM FROM IMPOUNDMENTS AND/OR DIVERSIONS

A. IN RIVER CHANNEL AND FLOOD PLAIN
Disturbs natural state of area

Modifies downstream hydrograph
- Reduces peak flows.
  - Minimizes flood damage along channel and in flood plain.
  - Reduces channel scouring and increases sedimentation (affecting channel capacity, fish spawning grounds).
  - Reduces capacity for flushing, diluting, and transporting wastes.
- Increases minimum flows.
  - May weaken stream banks and levees, causing slumping.
  - May increase severity and duration of seepage and raise water table along channel and river basin.
  - Permits more adequate year-round waste dilution and transport.
  - Benefits navigation and power generation.
  - Increases water supply for expansion of agricultural, domestic, and industrial uses along river with resulting secondary impacts.
- Introduces abnormal and variable flows caused by project operation.
  - High flows to create flood control space in reservoir.
  - Periodic discharges for peak power generation.
  - Mitigating effects and impacts of regulating reservoir.

Alters quality of river waters
- Evaporation can increase salinity of stored waters.
- Maintenance of higher minimum flows can reduce salinity of rivers affected by salty tributaries or return irrigation water.
- Alters content of nitrogen and oxygen in discharges waters.

Alters river water temperature
- Typically, lowers temperature during summer flow period.
- Affects agricultural and industrial uses, types of fish and their production, and water sports.

Modifies sediment transport
- Reduces peak flows lessening channel scouring, increasing sedimentation.
- Traps sediment in reservoir.
  - Lowers downstream sediment load, affecting agricultural and other uses; increases channel scouring at given flows.
  - Muddy discharges can extend over greater portion of year where sediment remains in suspension in reservoir.

Changes aquatic and riparian vegetation
- Increases encroachment on channels.
- Influences ecological diversity.
- Affects scenic values and recreation uses.

Modifies fish production
- Changes water temperature altering fish production: may prevent survival of uniquely adapted species.
- Dam interferes with migrating fish: mitigation by substitution of hatcheries, and additional artificial spawning areas.
- Dam reduces length of channel for stream fishing; increases people pressure on environment along shortened stream channel.

Changes recreational potential of river
- Shortens channel available for river boating; May improve or worsen boating in remaining part.
- Regulated flow: allows boating and navigation over greater part of year; affects other water sports; alter fishing.

Alters economic, social and political life of area with resultant secondary ecological impacts.

B. IN DELTA, BAY OR OCEAN
Disturbs natural state of area

Alters pattern of water flows and possible effects
- Reduces peak flows or reduces total flow due to diversion.
  - Decreases flood hazard to agriculture and cities in delta.
  - Reduces flooded areas available for bird resting and feeding.
  - Alters channel scouring and sedimentation in delta.
  - Affects commercial and recreational navigation in delta.
  - May alter salinity of inflow water.
  - Reduces capacity to flush pollutants and salts from delta and bay.
  - May reduce turbidity or receiving waters affecting light transmission and, in turn, algae production and estuarine life.
  - Affects land and estuarine plants and wildlife.
  - Reduces sediment supply to maintain beaches of ocean, and possibly increases wave erosion on beach-front lands.
  - Alters off-shore sandbars.
- Increases minimum flows.
  - Alters sediment transport and delta formation.
  - May decrease salinity and pollutants in inflow water.
  - Increases capacity to dilute and transport pollutants from delta and bay.
  - Increases capacity to repel salt intrusion.
  - Improves navigation and water sports in delta.
  - Increases water supply for expansion of agricultural, domestic, and industrial uses in surrounding areas, with resulting secondary impacts.
  - Alters fish and wildlife potential of area.

Altered economic, social, and political life of area with resultant secondary ecological impacts

SOURCE: Same as Table 3; page 204.

TABLE 6
ECOLOGICAL IMPACTS IN AREA OF PROJECT WATER USE

A. AGRICULTURAL AND RURAL AREAS

- Provides potential for changing natural state of area
- Allows development of irrigated farming
  - Causes visual changes in landscape.
  - Alters environment for plants: native plants, crop plants and introduced weed species.
  - Alters environment for wildlife.
    - Area flooded during irrigation and leaching offers resting and feeding areas for birds.
    - Replacement of natural vegetation by irrigated crops under intensive farming may restrict or encourage certain species of wildlife.
  - Changes insect population.
    - Allows breeding of insects in canals, ponds, poorly drained areas, and in wet fields.
    - Allows breeding and development of insects on introduced crops and weeds.
  - Alters incidence of plant, animal, and human diseases.
  - Modifies local climate: increases humidity, modifies temperatures, and changes rainfall patterns (where large dry areas are under irrigation).
  - Increased ground water recharge and high water tables create poorly drained and salinized areas.
  - Increases pollution of surface and groundwater from return irrigation water, use of agricultural chemicals, and plant and animal wastes.
- Supports increased population and altered economic, social and political life of area, with resultant secondary ecological effects.

B. IN URBAN AREAS

- Permits drastic changes in natural state of area
- Permits expansion of cities to become vast urban areas
  - Provides water, permitting populations to exceed other physical or social resources of area.
  - Allows large industrial development including high water-use industries.
  - Need for flood control leads to channelization and levee construction along streams with changes in flow patterns, ground water recharge, and riparian vegetation.
  - Concentrates people, vehicles, and industry, leading to air and noise pollution.
  - Creates vast water pollution and waste disposal requirements.
    - Results in pollution of ground water and surface waters, including bays and ocean shorelines.
    - Affects recreation.
    - Affects wildlife and especially growth of fish and shellfish and their suitability as food.
  - Increases power requirements in area, often leading to atmospheric and thermal pollution.
  - Increases people pressure on surrounding areas, particularly for recreation.
  - Increases social problems.
  - Increases availability of water which can be used to improve environment with parks, fountains, artificial ponds and gardened areas, and to develop water-based recreational facilities.
- Permits introduction of urban areas into deserts and other water-deficient locations
  - Disturbs natural environment.
  - Can spread populations over larger areas, reducing problems associated with urban crowding.
- Affects land development, industry, and population, resulting in drastically altered economic, social, and political life, with resultant secondary ecological impacts.

SOURCE: Same as Table 3; p. 211.

TABLE 7
POSSIBLE ECOLOGICAL IMPACTS ALONG CONVEYANCE ROUTES

A. USING RIVER CHANNELS

Disturbs natural state of river

Increased flow results in:
- Changes water temperature.
- Altered erosion and sedimentation.
- Seepage and raised water tables along channel.
- Modified riparian vegetation.
- Modified fish production.
- Modified recreation potential.
- Improved navigation.
- Increased capacity to dilute and transport pollutants.
- Increased attractiveness for homesites.

B. USING CANALS

Interferes with land access along right-of-way.

May transport and introduce plant, insect, and animal pests along route.

Results in loss of fish at intakes and along canal.

Results in loss of wildlife.

Creates safety for children.

Provides opportunities for parks and recreation where developed.

SOURCE: Same as Table 3; p. 210.

evaluation. The EES substitute a known mathematics if the reviewer is willing to accept the limited, sometimes obscure, and previously "team-weighted" parameters. Continued development and expansion of checklists is warranted because of the creation of negative feedback loops which is implied. Environmental quality indices in the image of the EES may serve a role in the articulation of the views of divergent interest groups, as previously mentioned. Neither approach can summarize the impact of a project on the environment in the sense that a benefits-to-cost ratio summarizes an economic evaluation. The reason is that the usual solution to the input and output concepts in the environmental sense, namely the before and after, or the "with" versus the "without" comparisons of environmental properties is the wrong answer. Such a comparison of diverse consequences avoid a real input-output comparison because a single, unambiguous, and measurable property common to all such systems is not used.

A Proposal

A methodology based on departure from the "natural" system without man's intervention would seem appropriate only in restricted situations. In nearly all environments where development is contemplated man is part of and has been an influence upon the environment for some time. Some critics claim humankind's true role is parasitic but clearly this need not be the case. However, since progressing beyond the subsistence level of hunting and gathering, man has not let Mother Earth go unchanged or untended. It seems reasonable to seek an environmental change evaluation methodology based on whether a particular action moved us closer to a mutually interdependent relationship with environmental systems, a symbiosis, rather than accentuating a path toward ecological disaster. While we no longer appear ignorant of ecological relationships, we do not appear capable of devising, or even agreeing to devise such a methodology.

Unless willing to accept a cultural retreat, we must continue to produce food, supply water, provide for transportation, and communication and otherwise selectively control parts of our environment. These ordering activities of man or non-spontaneous processes require continuous inputs of energy to be maintained. Development of a water resource project and its continued functioning might thus be characterized by the energy required to achieve and maintain the system. Application of the basic thermodynamic principles to ecosystems has been summarized by Kormondy (38, p. 33) as follows:

> "In ecosystems, consistent with the first of the thermodynamic principles, energy is neither created nor destroyed, but it is transformed and the sum total entering can be accounted for on a budget-balance sheet. And consonant with the second law of thermodynamics, energy is transformed ultimately into a nonusable form--heat. But a system which continually transfers its chemical energy to heat tends toward a state of thermodynamic equilibrium, a state of maximum entropy, of increased randomness and hence of disorganization. We have observed, however, that ecosystems are ordered, and later we shall see that they are relatively stable, but dynamic steady-state systems. Hence, by physical laws of the universe they must have a continual source of energy to survive. The physicist Erwin Schroedinger stated a resolution of this paradox in a thermodynamic context by indicating that a biological system delays its decay to thermodynamical equilibrium by 'feeding on negative entropy' (i.e., on a more ordered, less random system--in this case the sun) and that it maintains its high level of orderliness by 'sucking orderliness from its environment'."

Differences in system properties, such as species diversity, food web structures, bio-chemical oxygen demand and many others, are useful in understanding specific parts of our environment undergoing change. Combining these partial descriptions, many of which are value laden as currently defined, to characterize a whole system seems an insurmountable problem. A common denominator that expresses the functioning on any and every ecosystem is power or the rate of flow of useful energy. Among others H.T. Odum has written on the application of energetic principles as a basis for understanding the interactions of society and the environment. (59) Many different aspects of energy may be usefully considered. A first approximation of environmental impact may be the energy subsidy required to establish and maintain the order thrust on the landscape by development. Coal and petroleum resources are the main sources of the energy subsidy, and inputs of waste heat contributing to general environmental disorder is the ultimate impact.

An energy-subsidy approach reflects the impact of both systems and surroundings and is therefore a quite general concept. However, numerous variables would be automatically included which are hard to categorize. For example, the Idaho Community Study on Pesticides reported the use of over 2,728,000 pounds of pesticides, herbicides, and defoliants on crops and orchards in Canyon County during 1973. (7) Occasionally, via magnification in food chains, serious environmental consequences of chemicals comes to light. More frequently perhaps the effects, if any, are not easily detectable. A study of pheasant survival, mating success, and behavior under unsprayed and aerial application of insecticides on the Fort Boise Wildlife Management area did not demonstrate any serious effects. (49) Effects of the reduction of animal protein intake because of lack of insects on the sprayed areas was not examined. Such effects as might occur are somewhat removed from Project responsibility, so to investigate each chemical's actual ecological impact and all the possible interactions seems unwarranted. (See Section IV, Part I) To totally ignore the chemical props, likewise, seems less than honest. Considering the energy required for production of these poisons as a subsidy to maintenance of the system order should be feasible and, with some education, meaningful. Energy relationships in an environmental system include production, storage use and loss concepts. Recent years have witnessed considerable effort toward defining, measuring, and understanding these relationships in particular ecosystems. A purposeful review of this literature ought to provide usable evaluation oriented results. H.T. Odum's previously cited work offers a beginning.

EVOLUTIONARY ASPECTS AND PHYSICAL CONFIGURATION

The Setting

Frequently, although not always, names of landscape features reflect some situational aspect when explorers or early settlers moved through or into a region. With this in mind, a careful examination of a topographic map for the area east of Boise reveals a number of interesting "place names." An abundance of a particular type of vegetation is indicated by creeks with names like Cottonwood, Willow, Alder, Birch, Cherry, and Grape. There is also Grape Mountain. Local populations of animals must have been conspicuous for we find Wolf and Goat Mountains, and among others, creeks such as Beaver, Deer, Grouse, Badger, Elk, Mink, and Bear are found. Rattlesnakes have likewise been honored. There is a tributary to Bear River called Cub Creek, which is plain enough, but Little Rattlesnake Creek leaves some doubt as to the visitor's opinion of the creek or its wildlife. Then there are the domestics: Chicken, Cow, Horse, and Sheep appear as creek names, as does Pony, Jackass, and Dog--the last being a mountain, also in the vicinity of the stream. Such introduced species apparently came with the likes of those whose names adorn Dutch, Irish, French and Hungarian Creeks. There are those names which with imagination tell a story. Little doubt exists as to the activities on Lambing Creek, Lost Man Creek, or Dead Horse Creek. Lost Creek, however, causes some confusion. The several Deadman's Creeks spark one's wonderment as do Devil's and Devil's Hole Creeks. The real challenges are such names as Guess Gulch, Nibbler Creek, and Fury Flat. A master story-teller could go on for hours with such openings.

In the 1860's these creeks and gulches had been minutely inspected by prospectors in search of the elusive glitter of gold. During 1902 and the years following the valleys and streams became the locus of the search for sites amenable to the construction of storage reservoirs. (12) Surveyors looking for sites offering significant storage at moderate cost quickly turned to the lower basin, for the steep descents and narrow valleys of the higher elevations seemed not to offer storage possibilities at the scale desired. Surveys of the Deer Flat area showed more immediate promise, as did a canal from the Payette drainage. Support from local interests was instrumental in accomplishing these surveys so that when the federal government withdrew the Boise Valley land for a project in the Spring of 1903, a general outline of the proposal was well advanced. Legal, economic, and administrative matters delayed initial construction until mid-1906.

The happenings during this early period and continuing for many years might best be described as the evolving of an idea rather than the construction of a project. There now exists four major reservoirs--Lake Lowell, Lucky Peak, Arrowrock, and Anderson Ranch--at respectively higher elevations. The basic system was put together over nearly half a century with many directly related and numerous incidentally related activities contributing to the final outcome.

The various supports of this section will provide basic descriptive measures of the components of the Boise Project and some of the environmental implications. The sequence of presentation follows the chronology of their development and where appropriate other developments of significance are indicated.

Diversion Dam

By 1900 water was being turned into the New York Canal via a rubble diversion dam of hay and loose rock. Yearly repair or replacement of this diversion was necessary, but the water level was raised to the height of the first bench and reached the lands of the New York Canal Company. The Barber Dam, just downstream about three miles, was a low dam forming a mill pond until 1906 when a wood-crib and rock dam combined with a concrete powerhouse was developed for lumber production. Sediment quickly filled the pool, but litigation was even more disruptive of its intended function. Nevertheless, Barber Dam was the first "permanent" structure to block the flow of the Boise. (99) This dam suggests local interests were not incapable financially of a project similar to Diversion Dam, but the anticipated federal role was by this time certain. Further, the subsequent history of Barber Dam indicates the inability of local groups to overcome self-interests in favor of a collaborative effort. In any case, the Diversion Dam site received a permanent structure compliments of the Bureau of Reclamation in the fall of 1908. Power production with an initial head of 33 feet was incorporated as was a fish ladder. Barber Dam was also built with a fish ladder. Deposition has filled the pool behind Diversion Dam and the site has become a source of sand on several occasions.

Because of its key role in the Boise Project, Diversion Dam has received good annual maintenance and periodic repair which contrasts sharply with the downstream structure. Some reconstruction was done on Barber Dam in 1937 by the Idaho Power Company after purchase of the structure from the Boise-Payette Lumber Company. More recently the site has been given little care or concern until its deteriorated condition was recognized as a hazard should it fail and the accumulated sediment be washed downstream. (86)

Diversion's Dam impact on the Boise River and Boise Valley results from its function as a diversion with land use implications rather than its status as on on-stream reservoir. It is certain a non-federal diversion would have been built to supply water to the New York Canal in either non-project scenario. The permanency of such a structure, its care, and current conditions are purely speculative. Without the moderating effect on flow realized by the upstream reservoirs, Diversion Dam and other diversions would likely require greater effort and costs. Differences of impact between a federal or a non-federal diversion would be minor unless modifying assumptions, such as management or operational changes leading to structure failure, are incorporated.

Lake Lowell and Deer Flat National Wildlife Refuge

Viewed generally, the terrace-like topography conspicuous near the city of Boise becomes less distinct in the lower valley. Moving south and southwest increasingly diverse topography is encountered. Within this region a shallow undulation, augmented by low embankments, became the initial storage reservoir of the Boise Project. Originally christened Deer Flat Reservoir, the water body has subsequently been renamed in honor of J. Lowell, an early and vigorous promoter of the project. Lake Lowell covers most of the 11,600 acres of Deer Flat National Wildlife Refuge, which is a Bureau of Sport Fisheries and Wildlife operation superimposed on the irrigation facility in the year following the reservoir's completion. A Snake River Unit of the Refuge, comprised of eighty-six islands between Walter's Ferry Bridge, Idaho and Farewell Bend, Oregon was added in 1937 to the original unit.

Prior to inundation, the area involved is believed to have received some water from the Boise River via the Ridenbaugh Canal, About 1891 this canal system stretched across the bench just south of the city of Boise and

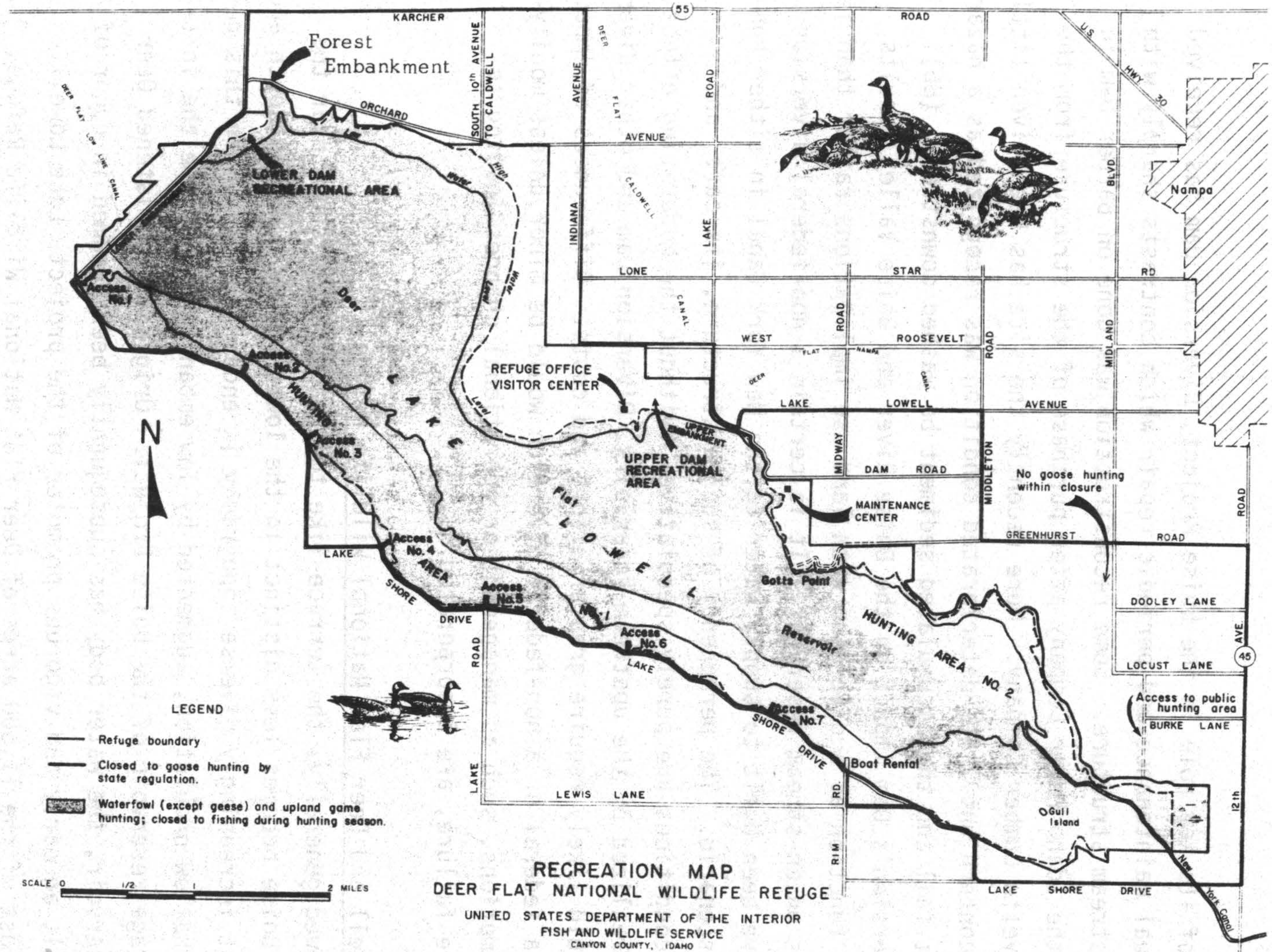

Figure 5. Deer Flat National Wildlife Refuge.

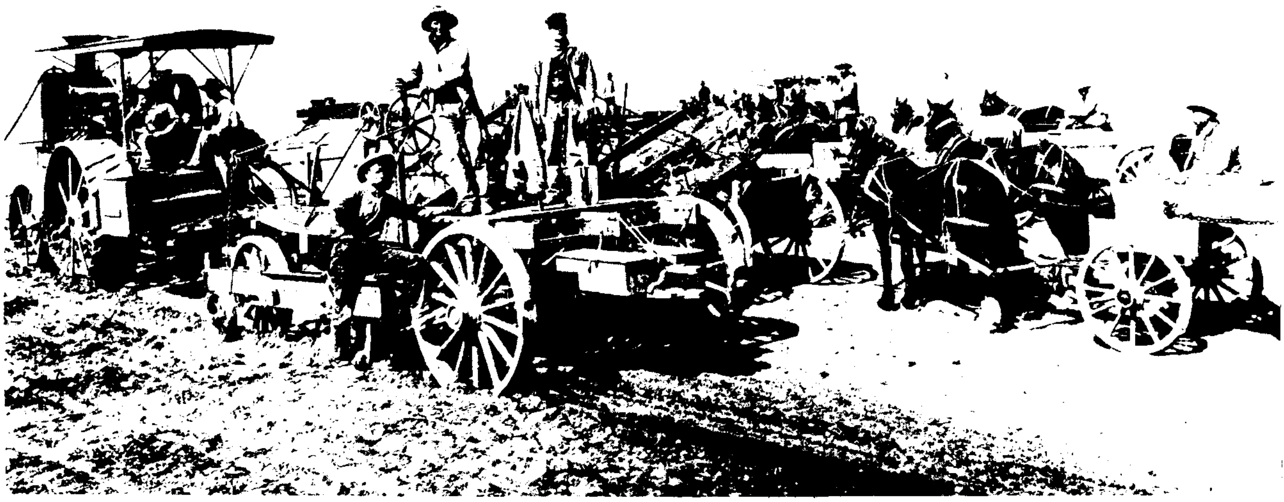

Figure 6. Dam construction in 1906.

Source: Bureau of Reclamation photo

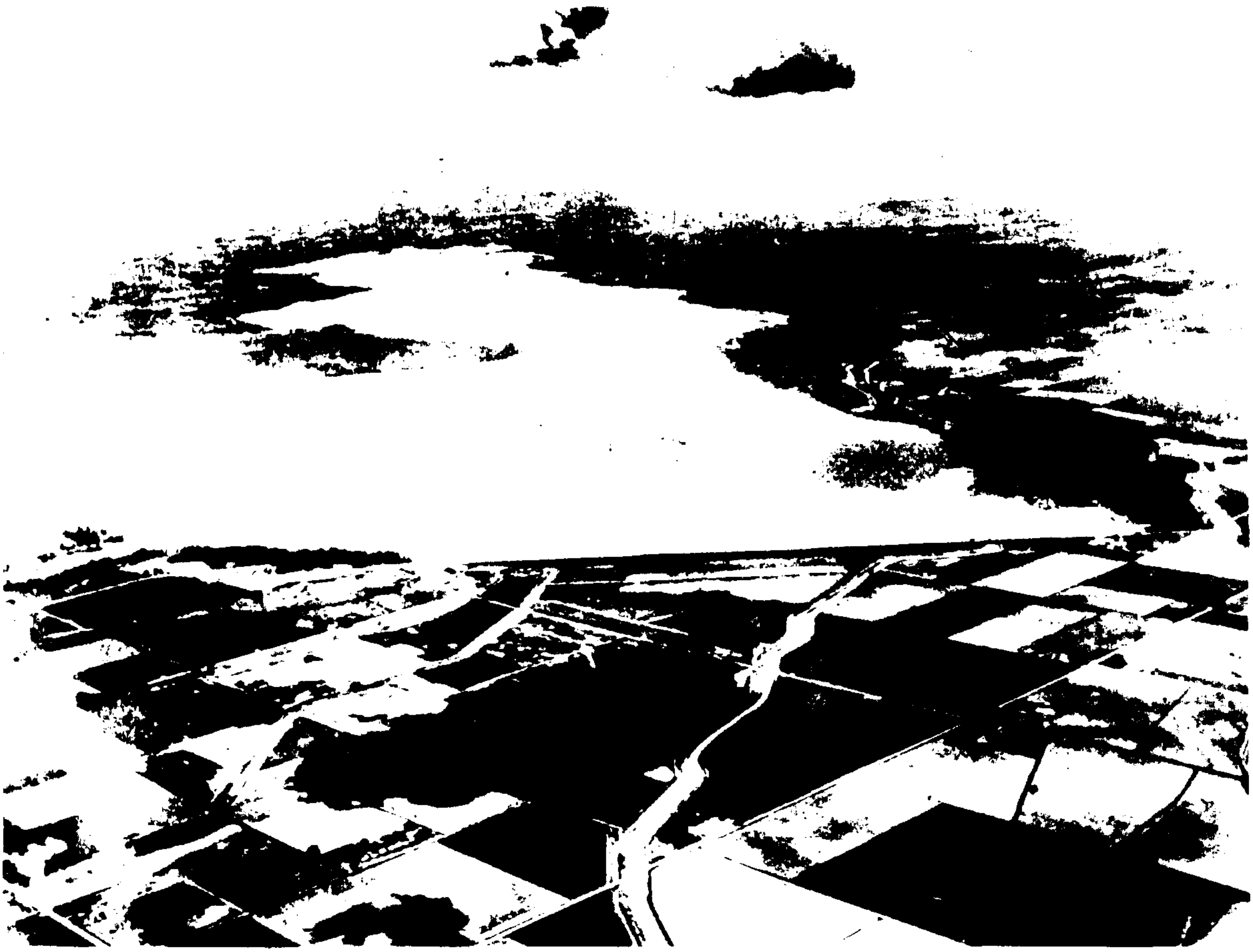

Figure 7. Lake Lowell and Vicinity.

Source: "Deer Flat National Wildlife Refuge." U.S. Department of Interior, Bureau of Fisheries and Wildlife.

included 100 miles of main canals and ten small reservoirs for storage. Although the data is somewhat fragmentary, the general pattern of precipitation in much of the West was slightly above normal during the early and mid 1890's and fell below the long term average during the latter part of the decade. Regardless of the cause, the reservoir site showed evidence of abandoned farms when the preliminary surveys were undertaken. Still sixteen families were reported to have occupied 1,400 acres which had to be purchased. Had water been more plentiful during this early period, it seems likely the Deer Flat area would have been more extensively settled at the time of the survey. However, irrigation in this area would have been very sensitive to periodic water shortages and the years from 1918 to 1935 would probably have been disastrous.

As shown on the accompanying map, Lake Lowell is formed behind three earthen embankments and pinched together near its mid-section by natural contours. On rare occasions when the drawdown is severe these two basins are separated and a connecting channel must be dredged to facilitate the transfer of water. The magnitude of the construction of this reservoir is shown in the accompanying table 8. The approximately 2.3 million cubic yards of material for the three embankments compares with about 5.9 million cubic yards for the Lucky Peak Dam and 9.1 million cubic yards for Anderson Ranch Dam. The lake has a maximum depth of about 35 feet and a maximum surface area of just under 10,000 acres. Its storage capacity of 177,000 acre feet make it one of the largest offstream impoundments in the United States. Water is supplied to the reservoir via the New York Canal, the point of diversion being about twenty-six miles directly east of the lake while the circuitous canal is approximately forty miles in length.

Using standards of today, construction of the embankments would be considered to have involved rather primitive technology. Much of the material for the fills was excavated and transported using horse or mule drawn fresnoes and slips. The material was brought on the average about a third of a mile and from a maximum of about two miles. A small amount came from the reservoir area. Construction and related information about this activity is found in the Project Histories from 1908 through 1912 of the U.S. Bureau of Reclamation--Boise Project. Construction of this project did not result in immediate inundation of the entire area as is shown by Table 9. Nevertheless, the transition from range and farm land to reservoir must be considered as a major land change attributable to the Boise Project involving approximately 10,000 acres.

Seepage

Inspection of Table 9 reveals an important early problem associated with the then Deer Flat Reservoir. Seepage along the dams started almost with the filling of the reservoir. A natural draw emanating from the Upper Embankment area facilitates drainage from the farm land here. Downslope from the Lower Embankment seepage presented a serious problem to farmers, who in anticipation of assured water, had cleared and fenced land in preparation for cultivation. Seepage as the water level rose sparked a debate as to whether the reservoir would ever hold water efficiently or at all. In the initial year of operation (1909) about three-quarters of the water delivered to the impoundment leaked through its porous bottom and retaining embankments. Self-sealing of the reservoir was expected but the increasing water deliveries in the early years resulted in greater coverage and pressure.

The right-most column show the water loss to seepage as a ratio of the maximum area coverage in acres for that storage season. While all other values are increasing this ratio remains almost constant for the first three years. Then this indicator drops rapidly, especially in those years when the coverage does not reach the previous maximums. For the 1918 season the effect of expanding beyond the previous maximum is demonstrated, but with essentially equal water the following year the ratio drops once more. The sediment which helped seal the lake might have eventually resulted in serious loss of capacity but sediment removal by the on-river impoundments upstream from diversion dam seems to have negated this problem or, more precisely, pushed a development beyond the immediate time frame.

Management

The management of this reservoir and adjacent lands demonstrates the complexity, and the difficulty of unravelling, the interactions of environmental change attributable to the Boise Project. It will be useful to consider the sequence of events leading to the present operation of this facility.

Table 8: SPECIFICATIONS OF EMBANKMENTS AT LAKE LOWELL*

Lower Embankment:	Height 40 ft., Length 7,200 ft.	
	Earth body	671,914 cubic yards
	Gravel facing	254,720 cubic yards
	Later gravel	226,400 cubic yards
Upper Embankment:	Height 70 ft., Length 4,000 ft.	
	Earth and gravel	959,516 cubic yards
	Facing - earth	6,000 cubic yards
	- gravel	95,000 cubic yards
	Gravel blanket (1909)	98,000 cubic yards
Forest Embankment:	Height 16 ft., Length 950 ft.	
	Earth and gravel fill	12,000 cubic yards
	Gravel facing	9,000 cubic yards
TOTAL VOLUME OF MATERIAL		2,331,500 cubic yards

* Source: U.S. Bureau of Reclamation, Annual Project Histories, Boise Project, 1908, 1909.

Table 9: AREAL COVERAGE AND WATER LOSS FOR LAKE LOWELL: 1909 - 1919

Year	Acreage Covered Mean	Acreage Covered Maximum	Evaporation Acre Feet	Seepage Acre Feet	Seepage Ratio*
1909	1,355	2,500	4,750	52,850	21.14
1910	3,002	3,900	10,500	84,983	21.79
1911	4,459	6,300	15,600	135,238	21.46
1912	4,625	7,000	16,200	68,889	9.84
1913	5,250	8,200	18,200	71,089	8.67
1914	5,337	8,400	18,700	63,384	7.54
1915	5,123	8,100	17,900	49,500	6.11
1916	4,820	6,900	16,900	26,141	3.79
1917	4,500	7,550	11,000	22,138	2.93
1918	6,171	9,311	13,398	41,418	5.88
1919	6,019	9,535	13,565	31,409	3.29
means (n=11)	4,606	7,063	14,247	58,822	
totals			156,713	647,039	

*Ratio of acre feet of seepage to maximum areal coverage

Source: USBR: Annual Project History, Boise Project, 1919.

There has been some change in the agency of the government responsible for the administration of United States lands at Lake Lowell. Executive Order No. 1032 of February 25, 1909, reserved certain lands within the reservoir site as the Deer Flat Bird Reservation. Executive Order No. 7655, dated July 12, 1937, ordered that all lands owned by the United States in the reservoir area be reserved and set apart for use as a refuge and breeding ground for migratory birds and other wildlife, subject to the use for reclamation purposes. The refuge was to be known as the Deer Flat Migratory Waterfowl Refuge. In July of 1940, the name was changed again. This time to Deer Flat National Wildlife Refuge (Presidential Proclamation No. 2416), which it retains in the current period.

Since 1926 the reservoir has been transferred to the Boise Project Board of Control for operation and maintenance under the provisions of the "1926 contracts" with the irrigation districts. The Board of Control has responsibility for operating, filling, and releasing water, maintaining embankments, and related activities. The latter might include, for example, dredging the channel between the two basins during years of water shortages. Thus, the Bureau of Reclamation does not now have the direct responsibility for the management and operation of Lake Lowell.

The Bureau of Sport Fisheries and Wildlife is responsible for the administration of lands and waters within the reservoir area. This includes the management of the area as a wildlife refuge and administration of the use of the area for recreation purposes, particularly fishing, hunting, and boating. The State of Idaho sets hunting and fishing regulations.

Such a variety of uses cannot always be compatible. Nevertheless, the function of Lake Lowell as updated and clarified by a memorandum of understanding between the Bureau of Sport Fisheries and Wildlife and the Bureau of Reclamation dated November 21, 1968 is that other uses of the area are subject to irrigation use for the Boise Project. Approximately 500 acres of additional land has been acquired by the BSF&W for food plots for wildfowl and would be excluded from the above restriction. Being quite shallow for its areal extent, the water surface responds rapidly to drawdown and therefore other uses are quite sensitive to the irrigation requirements. Wildfowl using the lake as a resting place are viewed by some as a marauding army daily using the lake as a staging area. Plantings of small grains and green browse on the refuge reduces but does not eliminate this problem. Pyrotechnic devices are sometimes furnished to local farmers by the Refuge and State Fish and Game Department also. Correspondence between the Nampa & Meridian Irrigation District secretary (14 April, 1970) and the Project Superintendent of Deer Flat National Wildlife Refuge (28 April, 1970) speak to the above issues and indicate a questioning by irrigators of the expanding utilization of the facility for wildlife and recreation at the expense of irrigation.

There can be little doubt the refuge contributes significantly to local and regional wildlife populations. Estimates of the daily duck count have been reported near three-quarters of a million, mostly mallards. Considerably smaller numbers of other types are also reported along with as many as 10,000 Canada geese. Enhancement of the wintering waterfowl potential takes precedent over the other recreational opportunities provided for by the refuge. This is evident from the many restrictions placed upon boating, fishing and hunting. Nevertheless, fishing pressure is considerable because of the accessibility of the refuge to residents of the local area. Monitoring of such use is difficult although it is known that the sport catch is mostly brown bullhead, black crappie, and yellow perch. It has been reported that a "limited number of local experts also catch large-mouth black bass up to seven pounds." (66)

Discussion

Lake Lowell and Deer Flat National Wildlife Refuge provide an excellent example of "causative versus permissive" actions as discussed in the fourth section of this report. Certain impacts of the construction of Lake Lowell can be said to have been caused by the Boise Project. The conversion of 10,000 acres from land to water is such an impact, as was the seepage and local elevation of the water table. On the other hand, benefits to wildlife and recreation, in this instance, must be considered to result from the permissive nature of the project.

Because the Boise Project built and maintains the reservoir for irrigation purposes other agencies are able to enhance wildlife and related opportunities. In recent years the multipurpose role of Bureau of Reclamation projects has been recognized and included in their development. The nature of the use of Lake Lowell by the BSF&W would likely not have been duplicated by the USBR or the Boise Project Board of Control had the opportunity been open to them. Thus, the existing situations must be viewed as being superimposed on the Project and not caused by the Project.

With respect to the "without-Project" scenarios discussed in section one of this report, the Lake Lowell situation is unique relative to the other construction aspects of the Project. Without the construction of Arrowrock or Anderson Ranch reservoirs, the Boise River, in the respective reaches, would have remained as a freely flowing stream. In the Lake Lowell case we must consider whether the area would have remained as was, to slowly evolve to something else, or whether it's conversion to a lake would be occasioned by some other group.

The natural flow scenario would leave the 10,000 acres of Deer Flat to an uncertain evolution. We can surmise from the record of settlement and the climatic variable that farming in the Deer Flat area was tenuous and sensitive to available precipitation and the potential of the Ridenbaugh Canal. From about 1904 to 1918 water would have been, on the average, more available than in the years immediately preceding 1904 if the general conditions in the Boise headwater region followed the precipitation pattern of much of the rest of the west. Such conditions may have encouraged irrigation expansion in the Deer Flat area via the Ridenbaugh Canal. Across much of the west, with the exception of 1921, 1922, 1925, 1927, and 1932, the seventeen-year period between 1918 and 1935 was subnormal in mountain precipitation and produced a drought the likes of which had not occured since the 1840's. (3)

When viewed in the context of the national economic situation of this period, the local situation would be expected to have deteriorated even more than it did. A WPA Land Classification Project provides a conservative estimate of the combined efforts of economic and climatic hardship. Table 10 provides data on the tax delinquency of privately owned land by type in Ada and Canyon counties. Only land remaining delinquent in January of 1935 is reported so the table does not show the delinquency history of the great bodies of agricultural land which were delinquent during these years but which were paid in full by this time. (102) With the project, then, about 40% of all privately owned land was delinquent in January 1935. The higher rates are associated with the grazing and waste categories.

Under the given circumstances, the natural flow scenario would likely have had quite drastic consequences on the landscape of the Deer Flat vicinity. Temporary or permanent desertification of these lands would have been likely under stress.

In the latter 1800's the area had been grazed, then some was farmed, but the natural vegetation of the area was probably a grouping of several habitat classes dominated by tall sagebrush with highly variable vegetation cover and understory dependent upon site. Evolution of these habitats was well underway by 1900. The natural flow scenario would probably have resulted in the most drastic degradation of the Deer Flat area and much of the surrounding lands. The prospect is somewhat brighter after 1934 but periodic attempts at settlement, grazing, fires, and perhaps other disruptions would have resulted in a highly variable situation. This pattern would possibly continue until the advent of efficient pumping and its application following World War II.

The other alternatives considered in the analysis of the Boise Project is the possibility that a reservoir comparable to Lake Lowell would have been developed by other means. As an off-stream reservoir supplementing the natural flow this hypothesized facility would have some of the characteristics of Lake Lowell. The critical difference would be the complete drawdown of the lake every year. Without the upstream storage to replenish the water, use of the lake for wildlife and recreation would be seriously impaired.

In general the greater assurance of water than in the natural flow situation would have permitted more regular and orderly development of the area with agricultural practices better tuned to the available moisture. More than two-thirds of the total acreage planted in the Valley under this scenario would be in grain, hay and pasture. From the standpoint of habitat enhancement this may have been the most beneficial development.

TABLE 10: ADA AND CANYON COUNTIES, IDAHO:
TAX DELINQUENCY OF PRIVATELY OWNED LAND BY ACREAGE, PERCENTAGE, AND TYPE OF LAND

ADA COUNTY[1]

Delinquency Status[2]	Irrigated crop land Acres	%	Grazing Acres	%	Waste Acres	%	All privately owned land Acres	%
NOT DELINQUENT	73,690	71.5	15,708	60.2	78,189	56.0	167,587	62.4
DELINQUENT TOTAL	29,318	28.5	10,376	39.8	61,353	44.0	101,047	37.6
Delinquent, 1935	30	*	-		50	*	80	*
" 1934	10,432	10.1	1,683	6.5	9,818	7.1	21,933	8.2
" 1933	3,742	3.6	2,022	7.7	6,176	4.4	11,940	4.4
" 1932	8,804	8.6	4,038	15.5	25,778	18.5	38,620	14.4
" 1931	2,693	2.6	480	1.8	5,882	4.2	9,055	3.4
" 1930	1,445	1.4	1,312	5.0	6,286	4.5	9,043	3.4
" 1929	885	0.9	276	1.1	3,909	2.8	5,070	1.9
" 1928	1,170	1.2	565	2.2	3,451	2.5	5,186	1.9
" Before 1928	117	0.1	-		3	*	120	*
ADA TOTAL	103,008	100.0	26,084	100.0	139,542	100.0	268,634	100.0

CANYON COUNTY[3]

Years Delinquent	Irrigated crop land Acres	%	Grazing Acres	%	Waste Acres	%	Other[4] Acres	%	All privately owned land[5] Acres	%
NOT DELINQUENT	91,595	62.9	16,885	48.1	39,707	55.0	15,200	83.9	163,387	60.3
DELINQUENT TOTAL	54,061	37.1	18,250	51.9	32,552	45.0	2,924	16.1	107.787	39.7
Delinquent, 1934	4,229	2.9	621	1.8	1,489	2.2	236	1.3	6,675	2.4
" 1933	13,821	9.5	3,781	10.8	5,162	7.1	724	4.0	23,498	8.6
" 1932	18,173	12.5	4,994	14.2	11,480	15.9	927	5.1	35,574	13.1
" 1931	6,909	4.7	3,195	9.0	4,303	5.9	458	2.5	14,855	5.5
" 1930	6,084	4.2	2,472	7.0	4,311	6.0	339	1.9	13,206	4.9
" 1929	2,028	1.4	1,687	4.8	2,246	3.1	100	0.5	6,061	2.2
" 1928	2,754	1.9	1,500	4.3	3,396	4.7	128	0.7	7,778	2.9
" Before 1928	63	0.04			65	0.1	12	0.1	140	0.1
CANYON TOTAL	145,656	100.0	35,135	100.0	72,259	100.0	18,124	100.0	271,174	100.0

1. Source: WPA , 1937, Ada County, p. 21, Table VI.

2. The tax delinquency status was not obtained on 4,056 acres of land within the corporate limits of municipalities, nor on 13,609 acres of small tracts.

3. Source: WPA, 1937, Canyon County, p. 22, Table VI.

4. This does not give a true picture of the delinquency of land classified as "other" because tax delinquency was not obtained on small, unclassified lots, platted land, and orchard tracts and therefore a higher percentage of this land than the table show is, no doubt, delinquent.

5. Tax delinquency status was not obtained on land within corporate limits of municipalities, 11,833 acres.

* Less than 0.05%

Arrowrock Dam and Reservoir

This structure is a concrete arch dam located on the Boise River about four miles downstream from the confluence of the North and South Forks of the Boise. The original proposal for Arrowrock Dam called for a 150,000 acre foot reservoir. Before commencing construction a larger facility was proposed and after beginning construction, the design height of the dam was increased again. Final plans for the dam were worked out by summer of 1912 after construction had begun. Interestingly, the final design called for a reservoir capacity of about 230,000 acre feet, but upon completion an extra 40,000 acre feet of storage were discovered by project engineers. Construction costs were only about 70% of the projected figure. This "more for less status" must give Arrowrock a position among federal projects more enduring and unique than the frequently touted claim of being the highest dam in the world when it was completed, with a height of 351 feet plus 91 feet to bedrock. Although available storage in Arrowrock was originally 271,000 acre feet, this was enlarged to 286,000 acre feet after the height was increased five feet in 1937. At full pool the reservoir covers approximately 3,100 acres, extends about 11 miles up the Middle Fork and 9 miles on the South Fork.

The Construction Period

The relative inaccessibility of the Arrowrock site made the assembly of construction materials difficult. Initially, materials were hauled in over wagon roads. Lumber used in camp construction and for concrete forms was hauled in by teams from a sawmill on Cottonwood Creek a few miles to the northeast. Other supplies were hauled from Barberton, 18 miles to the west. Eventually such roads as were located along the river had to be removed to higher elevations. Access to the construction site was improved with the completion of the Arrowrock Railway in November of 1911, connecting with the Oregon Short Line at Barberton. This rail service was used by many visitors to witness the progress on the dam.

Work on the dam was preceded by construction of facilities for men and machinery. A camp was established in 1911 on the north bank of the river, just downstream of the dam site. The numerous buildings erected included bunk houses, a machine shop, a bakery, and a hospital.

A small dam on Deer Creek created an 800,000 gallon reservoir for a gravity pressure system providing water for camp use and fire suppression. In addition a 25,000 gallon settling tank for camp waste was constructed. The rationale for the tank was that water from the Boise River, while not used directly for domestic purposes to any great extent, was assumed to indirectly affect domestic sources and waste from camp was expected to be especially troublesome during the low water stages. The tank did not have a drain field, but discharged directly into the river, so its effectiveness may have been less than desirable if judged by current standards.

Work on the Arrowrock Dam was made possible by diversion of the river through a tunnel on the south side of the site. Except for a timbered ceiling, this structure was concrete lined and was 25 feet high, 30 feet wide and 500 feet long. The accompanying photograph (Figure 8) shows the status on the dam near the end of 1912. The diversion tunnel, railroad, construction camp, swinging bridge, and other evidence of activity are apparent. Aggregate used in the construction of Arrowrock Dam totaled more than 600,000 cubic yards, most of which was processed at a borrow area near Diversion Dam. Excavation at the dam site involved another half-million cubic yards of material, about half of which came from the spillway area which passes around the north side of the structure. This spillway was designed to allow harvested timber to be passed downstream to the mill at Barber.

Arrowrock Dam was constructed for the purpose of storing water for irrigation. Although penstocks for possible use in the development of hydroelectric power were included, a power plant was not provided for the reported reason that the discharge would not fit the irrigation demand for water and a suitable reregulation reservoir was not available. Some incidental flood control was obtained from Arrowrock Dam during the filling period but even so, this role was only effective during an average or below-average water-year. Outlets for Arrowrock Dam were not constructed with the capacity to effect control of floods. Its irrigation function required that it be filled and with this accomplished additional inflow simply had to pass through or over the spillway as shown in Figure 9.

Figure 8. Site of Arrowrock Dam Construction. December 1912. The dotted line indicates the top of the finished structure. Note the diversion tunnel to the left of center and the camp in the upper right of the photo.

This photo appears in the Seventh Biennial Report: 1911-1912 of the State of Idaho. Edited and Published by S. J. Rich, Commissioner of Immigration, Labor and Statistics; The Caxton Printers, Ltd., Caldwell, Idaho. Page 93.

Figure 9. Arrowrock Dam and Reservoir During a Period of High Runoff in Spring. (Probably 1940)

Source: Same as previous photo.

Figure 10. Looking Upstream from the North Bank of the Boise River, Arrowrock Dam, September 6, 1940.

Source: The Idaho State Planning Board, J.D. Wood, Consultant, An Economic Survey of the State of Idaho, Part I: The Economy of South Western Idaho with Reference to Irrigation Development; Syms-York Co. Boise, Idaho (1941). Page: between 76 and 77.

Not only was the dam inadequate for that which it was not designed, it also could not provide sufficient water for full-season irrigation. In more years than not the water was completely drained from the reservoir as Figure 10 illustrates. The lack of permanent pool precluded development of a resident fish population and rapid drawdown inhibited shoreline fishing and recreational access. Thus, Arrowrock Dam, while an engineering marvel of its time, seems not to have scored well on most of the main elements of today's conception of a multiple purpose project, namely, power, flood control, recreation, and its designated purpose of irrigation.

Arrowrock Dam, in addition to its real problem, is perceived to have been responsible for the end to salmon and steelhead migrations to the Boise River. Factually, this cannot be denied but the situation is by no means so simplistic. The "without-Project" for anadromous fish are far from encouraging.

Anadromous Fish

Early accounts of anadromous fish in the streams and rivers of south-western Idaho support the belief that the Boise provided excellent habitat. A visitor to the Boise in 1834, apparently made during a period of heavy migration wrote: "This is a beautiful stream, about one hundred yards in width, clear as crystal, and, in some part, probably twenty feet deep. It is literally crowded with salmon, which are springing from the water almost constantly." (83) Placer mining, diversion, land use changes, and harvest would have reduced the anadromous fish population of the Boise. With no regulations fish were taken with primitive spears, gaff hooks, pitchforks, snag hooks, shot with rifles, and obtained in any other manner which got the job done. Traps of willow saplings were commonly used in the smaller streams. While settlers may be assumed to have been interested in food for personal use or sale, some early explorers were hardly conservation minded. A party led by W.A. Ferris visited a tributary of the Salmon River in the 1830's. They observed large numbers of salmon moving upstream and amused themselves, while their horses were feeding, "by adding to the numberless carcasses scattered along the shore..." (4)

A fisheries investigator in the Columbia River Basin in 1894 reported the presence of a six-foot dam on the Boise, in the vicinity of Caldwell. The investigators wrote: "The Boise River like the Bruneau, was formerly a salmon stream but is now partly or entirely closed by a dam near Caldwell and is unsuitable by placer mining on the upper part of the streams." (25) Interviews with Emmett area pioneers by an Idaho Conservation Officer in 1961 also suggest degradation of the Boise had occured by the late 1800's. (48) One early-day resident (Frank Clarkson) of a homestead on Shaffer Creek, about two miles above Horseshoe Bend, remembers big runs of salmon in the years between 1881 and 1905. The early run in April was called salmon trout (steelhead), later there was a heavy run of red meated salmon called chinook, and still later, in July or August the smaller "dog salmon" (coho?) were present in great numbers. Soldiers from Boise rode to the banks of the Payette River to shoot dog salmon on the riffles, using saddle horses to recover and transport their "catch" back to the barracks. From this report it seems reasonable to assume at least in some years the Boise was not receiving large runs of salmon and steelhead. Alternatively, one might assume the soldiers were interested in the ride as well as the salmon.

Early diversion dams on the Boise were frequently less than adequate to withstand the rampages resulting from rapid snow melt and storm fed discharges. In years of low discharge the diversion dams would be effective in preventing the upstream migration. In other years, the stream probably purged the obstructions with ease. For example, in 1896 the annual discharge exceeded 3,300,000 acre feet and peaked at 35,500 cu.ft./sec. on June 14. Such a dishcarge would have inundated about 48,000 acres. (30) The years 1907 through 1914 were years of substantial runoff as shown by discharge records, Table 11.

Table 11: BOISE RIVER DISCHARGE 1907 - 1914 AT DIVERSION DAM.

Year	Maximum Daily Flow Date	Discharge (cfs)	Annual (acre ft.)
1907	April 15	17,000	3,207,016
1908	April 22	10,600	1,845,534
1909	June 6	16,000	2,747,690
1910	March 22	16,600	2,758,160
1911	June 13	15,100	2,494,344
1912	June 9	15,600	2,478,710
1913	May 28	13,300	2,060,494
1914	April 16	11,300	2,133,214

Source: (84) Appendix A-PLATE XIV & XV
Corps 2 Jan 46

A monthly fish and game publication contained a report in 1914 which suggests fatal damage had not occured to the anadromous fish population of the Boise. The reporter wrote: "The unusual run of fish this year it would seem entirely disproves the theory that the fish ladders at the Barber and Government Dams are useless, as has been charged by some--the writer being compelled to admit that he has himself doubted their ability to allow the fish to get over the dams in their passage upstream. This fact, if it may be stated as fact, is a matter for congratulation for sportsmen who compelled the installation of the ladders." (39) The writer's apparent skepticism regarding the efficacy of the ladders, regardless of the migration then in progress, may have been a reflection of experience with other early attempts of this sort. It has been reported the ladder on the Payette Dam at the Boise-Gem County line was reconstructed and repaired several times, but was never successful. (48)

Although more anecdotal than scientific, such information does provide a general assessment of the status of the Boise River as an anadromous fisheries environment at the turn of the century. From the sportsman's viewpoint, at least, the battle for the Boise had not yet been lost. The incorporation of the fish ladder at the Government Dam (Diversion Dam) also suggest the willingness of the Bureau of Reclamation to attempt to maintain the spawn. Later, with the heady atmosphere of developing the record-breaking dam at Arrowrock, consideration of the fishery either evaporated, or very likely the numbers of spawning fish had been so seriously reduced that it appeared useless to attempt to re-establish them. The dam builders and the fish experts were probably as equally surprised by the spawning migrations of 1914. Whatever possibility existed for maintaining the anadromous fish population had ended prior to the 1914 migration because Arrowrock Dam was nearing completion with a design established two years previously.

The Without-Project Scenario

The argument in the preceding section can be summarized briefly. Apparently the anadromous fish population of the Boise was in serious trouble before the turn of the century. The string of years with water substantially above average may have permitted the recovery observed in 1914, although this is surely a simplistic assessment of a complex issue. But, continuing this reasoning, the survival of the Boise's anadromous fish population would not have fared much better under either the "natural-flow" or the "off-stream storage" scenarios.

The factors which were degrading the spawning runs prior to Barber and Diversions Dams would have intensified under either of the without-project alternatives. Further, the climatic variable would have again produced substantial effects, although in the opposite direction. Numerous years of water shortage were to follow. These were not strung together as much as the good water years of 1907-1914, but nonetheless their cumulative effect would have been tremendous given the diversions from the river. Comparing Table 12 to the previous one shows foremost the highly variable total annual discharge of the Boise River and the propensity of high or low water years to occur in sequence. The daily discharge hydrographs for 1930 and 1931 are shown in Figure 11. These are not atypical of low water year hydrographs. The current total capacity of canals along the Boise is about 6,700 cubic feet per second (190 cu.m./sec.). Assuming a without-project potential daily maximum diversion for all canals of 3,500 cfs for the years shown, the entire flow of the river could be diverted except from early April to late June in 1930 and for about the first three weeks of May in 1931. Therefore, spring and summer arriving fish would have not been able to complete the last segment of their journey.

Table 12: BOISE RIVER DISCHARGE AT DIVERSION DAM*
For Selected Years

Year	Date	Maximum Daily Flow Discharge (cfs)	Annual Flow (acre ft.)
1924	May 18	5,186	892,242
1926	May 6	7,094	1,113,374
1929	May 25	9,374	1,336,000
1930	May 30	7,559	1,342,541
1931	May 8	5,434	946,844
1933	June 4	12,508	1,580,350
1934	May 30	6,110	1,106,880
1935	May 25	9,501	1,585,108
1937	May 6	7,705	1,167,414
1939	May 1	8,413	1,379,002
1940	May 13	9,866	1,612,348
1941	May 27	8,861	1,400,910

* Source: Same as Table 11.

Distribution System

The canals and drains of the lower Boise Valley are the arteries and veins of the project, bringing and removing the life-sustaining water of the soil layer. Yet, for all but a small percentage of the people of the Valley these waterways, or more precisely the services they perform, are as taken for granted as is our own circulatory system.

There exists a human tendency to classify known things or situations as "normal" and to assess the new by comparisons with that which is familiar. Recognizing this, the environmental movement has produced eloquent calls for maintaining some completely natural areas so by comparison we will know the degree of change occuring in our occupied landscapes. Some people pay but little attention to the systematic functioning of their environment and slow change goes unnoticed. Any but exporers and pioneers cannot have first hand knowledge of unaltered conditions. For the current resident or visitor of the lands of the Boise Project, problems of interpretation are perhaps most confounding in the irrigated sector of the lower Boise Valley. The broad scale and near all-encompassing changes found

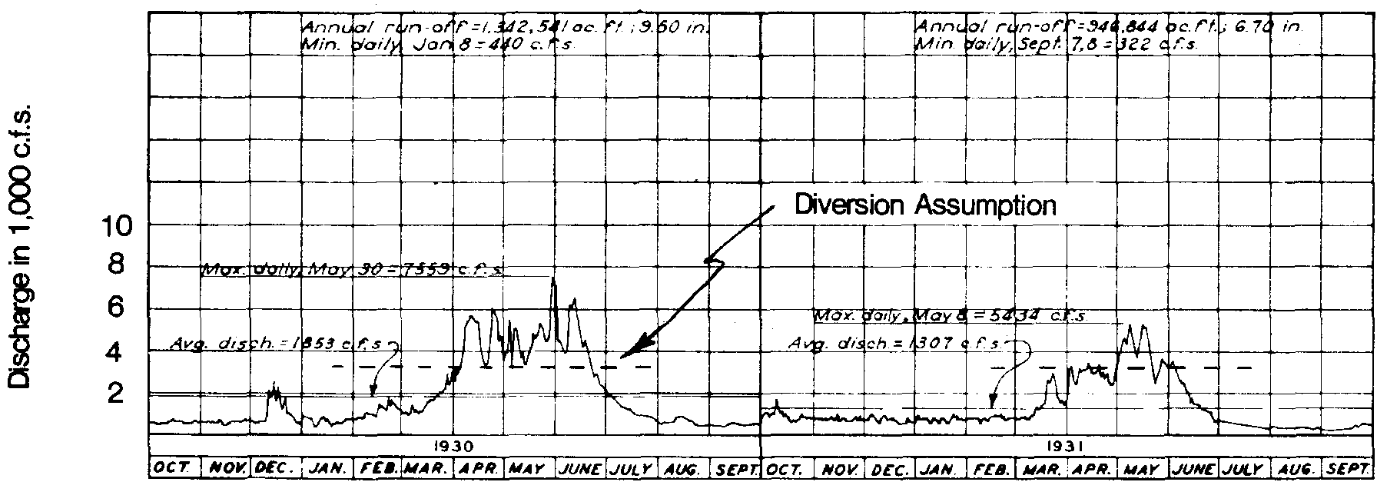

Figure 11. Low-water Year Hydrographs for Boise River as Measured at Diversion Dam.

Source: U.S. Engineer Office. January 2, 1946; Appendix A-Plate XV.

in the lower Valley and the familiarity of the resulting agricultural scene may endanger a deceptively simplistic image of a complex landscape existing only through the continuous support provided by a loosely integrated alliance of public and private parties. In contrast, an on-stream impoundment such as Arrowrock, because of its confinement and distinctiveness with respect to the local setting, directs attention to the environmental change the dam has brought.

The agricultural landscape, dependent on the integrated canal and drain system, is so seemingly permanent it appears as to have always been a prosperous agricultural region. In fact, for a majority of the Valley's residents it always has been. Thus, for the majority, the reference point is an extensive network of canals, carrying water diverted directly from the Boise River, from the canals, from return flow, or combinations of these sources. The system is quite complex. Waters are diverted from the River at numerous points and used or transferred to other canals. (Tables 13 and 14.) Runoff and groundwater enter the drains or the River to be rediverted and reused. Artesian and pumped drainage wells simultaneously serve to provide water for irrigation and lowering of the water table to prevent its rise into the soil zone. The accompanying tabled figures provide some of the pertinent information regarding the extensiveness of these features.

Some of the drains are wholly constructed channels, while others make use of natural topographic channels. Many of the latter have been straightened, deepened, or moved to satisfy the local irrigation-related need. The natural drainage pattern has been used where appropriate and altered where necessary. A subtle but important difference between canals and a natural stream bed is the need for canals to follow a high contour. This means the water flows over a freshly cut surface and at a generally higher elevation than the surrounding land. The natural defenses of a stream against seepage are non-existent, such as flowing at the locally steepest gradient of the topography, self-sealing of the channel over perhaps hundreds of years, and the hydrostatic pressure of being in contact with ground water. The many miles of unlined canals and drains which allow seepage provide a water supply for the development of a linear habitat not otherwise common in the lower Valley. Fractures in the underlying rocks may allow significant loss of water through the bottom of canals.

Table 13: MAJOR CANALS DIVERTING WATER FROM THE BOISE RIVER IN 1975*

CANAL	TOTAL VOLUME DIVERTED (acre feet)	ACRES IRRIGATED (1975)	ACRE FEET OF WATER DIVERTED PER ACRE (1975)
1. Penitentiary	2,882	321	8.98
2. New York	878,784	164,617	5.34
3. Ridenbaugh	163,532	26,877	6.08
4. Bubb (South Boise Mutual)	3,342	1,057	3.16
5. Boise City	12,038	1,838	6.59
6. Settlers	47,994	12,282	3.91
7. Thurman Mill	8,844	1,799	4.92
8. Farmers Union	75,012	8,300	7.22
9. New Dry Creek	20,726	3,059	5.40
10. Phyllis	129,324	24,362	4.91
11. Ballentyne	5,964	763	7.82
12. Middleton	51,726	9,580	5.40
13. Little Pioneer	9,930	1,286	7.72
14. Canyon County	22,876	4,007	5.71
15. Caldwell High Line[a]	17,088	13,960	4.32
16. Riverside	79,042	10,645	4.95
17. Farmers Cooperative (Sebree)	88,482	14,500	5.71
18. Canyon (Campbell)	9,874	802	12.31
19. Eureka #2	32,044	2,625	12.20
20. Upper Center Point	6,772	641	10.56
21. Lower Center Point	11,428	880	12.99
22. Baxter	4,364	200	21.82
23. Andrews	7,442	1,068	6.97
24. Haas	4,586	867	5.29
25. Parma	5,684	602	9.44
26. Island High Line	13,696	945	14.49
27. McConnel Island	12,582	1,600	7.86
TOTAL (All Diversions)	1,756,648	326,297	

[a]Only 3,960 acres are irrigated by water diverted from the Boise River.

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*Source: (51) Table 4, page 6.

TABLE 14: MAJOR IRRIGATION DELIVERY CANALS THAT DO NOT CARRY WATER DIVERTED DIRECTLY FROM THE BOISE RIVER

CANAL	Water Source
Mason Creek Feeder	New York Canal
Mora	New York Canal
Waldvogel	Mora Canal
Deer Flat Low Line	Lake Lowell
Deer Flat High Line	Lake Lowell
Golden Gate	Deer Flat Low Line Canal
"C" Line Canal East	Black Canyon Canal
"D" Line	Black Canyon Canal
Notus	Wilson and Elijah Drains
Fargo Low Line	Deer Flat Low Line Canal
Deer Flat North	Lake Lowell
Deer Flat Caldwell	Lake Lowell
Deer Flat Nampa	Lake Lowell
Canyon Hill	Middleton Canal
Newman Lateral	Middleton Canal
Foothill Ditch	Middleton Canal

Table 14 is not intended to be a comprehensive listing of canals that derive their waters from sources other than the Boise River, but lists the major delivery canals other than those in Table 13.

Source: (5) Table 5, page 7.

These sources together with irrigation water percolating through the soil zone provide additions to the groundwater.

The interactions between the surface and groundwater, as influenced by the complex geology, has received attention because of the drainage problems and the potential for contamination of wells relying on groundwater. The following description has been summarized from a U.S. Geological Report (54). At depth, the Boise Valley is underlain by an impermeable floor of consolidated rocks with a trough-like surface, within which lie stream-and lake-deposited sediments and volcanic rocks. Resting on these materials is a younger group of lake sediments. Upon the surface of the Idaho Formation, streams spread rather permeable deposits of terrace gravel interrupted at times by Snake River basalt occuring at varying depths. On this surface, deposition and erosion continued resulting in terrace and highly permeable recent alluvium and localized basalt flows of recent origin interbedded with the gravel. The more permeable surface deposits occupy a partly closed basin eroded in the older surfaces.

On the surface and at shallow depth water outflow occurs only to the westward. Given pre-irrigation conditions, the water table was from 100 to 200 feet deep under the terraces and lowland slopes but much shallower under the flood plain. Varied irrigation losses add to the water that must be discharged westward through the ground. Somewhat less permeable materials to the west require a rise of the water table to the east to develop the hydraulic gradient necessary to push the water westward out of the trough. The water table has risen to at or near the surface in many years.

In addition to the general rise of the water table, the natural cycle of the water level fluctuation has been changed. Under natural conditions, highest water levels would have occured following the periods of greatest natural recharge, and lowest water levels would have followed the dry season, respectively late spring and late fall. The river and flood waters, the latter highly variable from year to year, would have been the main source of recharge and groundwater levels would have developed a gradient away from these sources.

Recharge now continues through the irrigation season with a wider distribution and including much higher elevations. High groundwater levels occur near the end of the irrigation season in the fall and drop afterward, reaching lowest levels prior to irrigation in the spring. The Lake Lowell area is an exception to this general cycle because it is filled early and tends to leak more with greater volume. Drawdown over the summer lessens the loss rate and the local water table drops. In general, however, the gravels have served as a tremendous reservoir which has been filled over the years and reacts each year to the topping-off via the irrigation-extended recharge period.

Prior to irrigation, base flow of the Boise River had scant resources upon which to draw in the lower Valley, being mostly infiltration and return of flood water. However, as the groundwater reservoir increased and its surface level rose to intersect the river channel, base flow began to be artificially supplemented by irrigation flow, indicated in Table 15.

At least one other situation results in a surface water occurrence emanating from the underground flow. Water migrating westward in the gravel can be confined under the interbedded basalt and develop sufficient head for leakage to occur upward through fractures or loose jointing. When fine silty or clay soils rest upon the basalt, local seepage areas develop. Wells drilled through the basalt and excavation of drainage ways can salvage such trouble spots. Altogether, an extensive network of drainage ditches, streams, and drainage wells have been necessary to correct and prevent recurrence of excessive groundwater levels. Recent studies suggest the discharge of groundwater from the shallow aquifers, averages about 300,000 acre feet during the irrigation season, while that remaining in this source exceeds this figure by several times. (80)

TABLE 15: MAJOR IRRIGATION RETURN STREAMS DISCHARGING DIRECTLY TO THE BOISE RIVER

RETURN STREAM	FLOW (cfs)*	RECEIVING STREAM
Drainage District #3	0.1 - 12	Boise River
Thurman Drain	4 - 39	Boise River
Eagle Drain	7 - 94	Boise River
Dry Creek	5 - 44	Boise River
East End Drain	12	Boise River
Ten Mile Creek	5 -154	Boise River
North Middleton Drain (Mill Slough)	8 -156	Boise River
South Middleton Drain	8 -218	Boise River
Willow Creek	1 - 48	Boise River
Mason Creek	12 -200	Boise River
Hartley Drain	11 - 78	Boise River
Indian Creek	16 -311	Boise River
Conway Gulch	18 - 72	Boise River
Dixie Slough	12 -388	Boise River

*Range as recorded by the Bureau of Reclamation over the period of 1971 through 1975.

Source: (5), Table 6, page 8.

The Boise Project lands have been and remain almost wholly irrigated via gravity flow. As a consequence better irrigation and labor-reducing land leveling has received considerable emphasis as indicated by the more than 160,000 acres so treated in Ada and Canyon Counties. (See Table 16, and Figure 12). If deep cuts or fills are required for the leveling an annual crop is planted and the job "touched-up" after a season of irrigation. Leveling is disruptive of the soil layer and on shallow soils ripping and heavy applications of manure may be advisable. In the short run this restructuring of the surface-layer has the potential for excessive dust production, sediment generation, and local water chemistry changes. Incidences of specialized habitats are reduced in favor of more uniform and more intensely cropped fields. In the long run, more efficient irrigation and less sediment production are possible from these specially prepared surfaces. There is, therefore, a tradeoff between short and long term impacts with the balance depending on the conservation management applied following leveling. Although investigations of these activities may have been completed, no such studies of this phenomenon have been found for the Boise Project.

Evolution

While canal building apparently began with the first occupation of Fort Boise, not until 1863 following the discovery of gold, did organized irrigation development begin. By 1900, just under 600 miles of main and lateral canals were in use providing water to 96,000 acres. The early efforts developed or partially developed three of the major canals used in the Project today, the New York or Main Canal, the Phyllis, and the Ridenbaugh. Developmental histories of most of the canals has been reported previously. (12) The onset of the federal involvement resulted in immediate improvement and expansion of the existing distribution system. Drainage problems soon developed, particularly downgrade from Lake Lowell. By 1914 the Reclamation Service drafted plans to construct over fifty miles of ditches to help alleviate the developing drainage problems. Before irrigation began many of the natural surface drainage channels were intermittent flowing only briefly in the spring or following precipitation events. The few creeks originating at higher elevations east or north of the lower Boise Valley may have carried water most of the time. These streams, and even the Boise River, may have had periods of extremely low or no flow during extended periods of drought such as existed in the 1840's.

In recent years, about 5,000 cubic feet or water per second are diverted to the irrigation canals during peak use periods. (96)

TABLE 16: SUMMARY OF SOIL CONSERVATION SERVICE INFORMATION ON IRRIGATED AGRICULTURE IN ADA AND CANYON COUNTIES*

ITEM	ADA COUNTY	CANYON COUNTY
Irrigation Canal (miles)	294	1,753
Irrigation Field Ditch (miles)	764	2,432
Irrigation Pipeline (miles)	41	405
Irrigation Ditch and Canal Lining (miles)	212	607
Drainage Main or Lateral (miles)	703	587
Subsurface Drain (miles)	8	105
Agricultural Waste Management System	12	1
Irrigation Tail Water Recovery System	10	94
Irrigation Wells	337	81
Structures for Water Control	6,556	21,459
Debris Basin	6	60
Grade Stabilization Structures	7	1,690
Diversion Dam	10	1
Acres of Land Under:		
Conservation Cropping System	51,695	169,397
Crop Residue Management	42,010	159,448
Surface Irrigation System	20,315	102,830
Sprinkler Irrigation	22,840	72,844
Irrigation Water Management	51,505	105,031
Irrigation Land Leveling	43,424	117,590
Irrigation Land Smoothing	17	35,960
Minimum Tillage	42,014	46,390

Source: (51) Table 3, page 5.

Over 1 3/4 million acre feet of water was diverted in 1975, a volume in excess of the annual flow of the Boise at Diversion Dam for many of the years of record. A substantial part of this water is returned to the river with this gain continuing well beyond the end of the irrigation season. Estimates of the average daily return flow to the river exceed 1,000 cfs, although primarily this effects only the lower reaches. (87)

Irrigated agriculture has thus been responsible for substantial changes in the surface and subsurface water conditions of the lower Boise Valley. Many miles of canals and drains have been constructed, all of which contain water during the irrigation season, and streams once intermittent are now perennial as are many of the drainage ways.

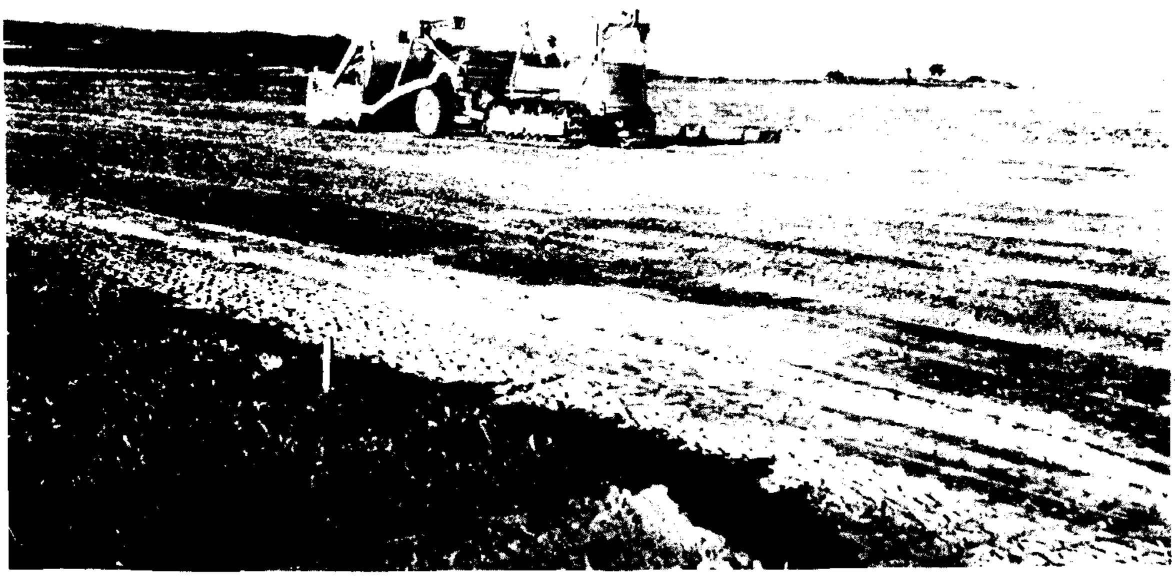

Figure 12. Land-leveling in Canyon County.

Source: "Land Leveling for Irrigation." U.S. Department of Agriculture. Soil Conservation Service, 7-L-14000-13.

In addition to the canal and drain developments, a number of smaller reservoirs have been constructed for irrigation and stock watering. These are dwarfed by Lake Lowell insofar as their project impact is concerned, but they do provide for a surface water source and thus influence local habitats. Indian Creek Reservoir is currently managed for fish and wildlife habitat and recreational purposes.

While the basic design of the distribution system has been well developed for nearly seventy years, refinements have continued. Once the main canals had been completed methods to speed water delivery, reduce water loss, and reduce maintenance costs were continually being implemented. A development of considerable significance in this respect was the creation in 1926 of the Boise Project Board of Control. This agency of the irrigation districts acts as an intermediary between the Bureau of Reclamation and the water users. It is the operating agency for roughly one-half of the irrigated acreage in Ada and Canyon Counties. The Board of Control has sufficient size and continuity to design and control refinements in the distribution system. Aspects where the Board of Control has had the influence include the reduction in the number of flumes, increases in the miles of concrete-lined canals, greater use of pipe for laterals, and the installation of pumps to facilitate exchanges of water.

Early on in the project numerous flumes (wooden troughs) were constructed to carry water over depressions in the natural topography. These were notorious trouble spots, wasting water and requiring frequent repair. As Table 17 shows, nearly all of these have been replaced with pipe either by the Board of Control or the irrigation districts. Lining of canals with concrete prevents leakage, and facilitates water flow by reducing turbulence and friction. Over 800 miles of lining has been placed with over 95% of this work being completed since 1940. Lower volume canals can be replaced by buried pipeline thereby eliminating water loss and maintenance, and frequently reducing distance by passing under a field rather than around its border. The economics of larger fields and clean-farming have contributed to installation of pipeline as has the desire to be more efficient and flexible in the water delivery system. The Board of Control, whose chief mission is the delivery of water, encourages con-

Table 17: FLUMES IN PLACE BY YEAR ON THE BOISE BOARD OF CONTROL IRRIGATION DISTRICTS

DISTRICT	1950	1960	1970	1976
Wilder	33	20	10	5
Kuna	29	14	10	6
Deer Flat	28	13	2	1
New York	19	5	0	0
TOTALS	109	52	22	12

Source: Annual Reports of the Boise Project Board of Control for 1950, 1960, 1970 and 1976.

version to pipeline via a policy of providing installation if the farmers whose lands are crossed by the pipe. The farmer gains additional land to plant and the agency gains a better delivery system plus the workload to maintain a skilled crew. Wildlife is the loser. Lost in the process are many miles of canal-side habitat. The increasing rate of pipe installation is shown in Figure 13, which displays the exponential growth of installed pipe between 1950 and 1976.

While the above mentioned improvements continue the Board of Control and other agencies are looking toward additional means of meeting their commitment to effective water use. Low head electric power driven via canal based generators offers one possibility. Power for pumping for irrigation could be served since the yearly cycle of the source would correspond with the need. A potential site exists where the Waldvogel Canal splits from the Mora Canal, which drops about 30 feet before continuing its westward flow.

Even as the canal and drain system evolved, numerous chronic operational problems required attention. Seepage and breaks have previously been mentioned. Related difficulties include sedimentation, aquatic vegetation growth, and tunneling by gophers. The sediment problem is discussed elsewhere in this report. The significance of the growth of aquatic and other weeds and the tunneling into the canal sides by gophers is perhaps exemplified by the cost to the project for their control. For example, in 1960, the Board of Control spent nearly $11,000 on spraying weeds on right-of-ways, over $23,000 was spent for removal of moss from the canals, about $9,500 for rodent control, and $4,556 bounty on 18,224 gophers was paid to non-project employees.

The moss removal was attempted with over 29,000 gallons of Socal Solvent #2 and xylene (Annual Report, 1960) In 1970, 60,000 gallons of xylene and 11,000 pounds of copper sulphate were used in the canals and a bounty totaling $14,315 was paid on over 57,000 gophers. (Annual Report, 1970) Similar data for other years are available and indicate the problems are continual but with variations. In 1976, for example, copper sulphate was used to the same degree as in 1970, but the xylene was cut by two-thirds, and non-project personnel received $5,384.50 for 21,538 gophers. The quarter-dollar per animal appears to be the only operational cost to the project not subject to inflation.

Non-routine problems with canals and drains are not uncommon and when they occur, the environmental impact is usually immediate and may be dramatic. Canal breaks, drownings, and fish kills are examples. Such an instance occurred in the spring of 1964. Large amounts of organic matter, mainly sphaerotilus, was flushed from the river bottom and into the Eureka Canal diversion near Caldwell. Decomposition depleted the dissolved oxygen and a large number of dead and dying suckers were carried into irrigation laterals and onto cropland. (31)

Scenarios and the Distribution System

Using water from the Boise River under the natural flow or the off-stream storage scenario (Part 1), the average annual total irrigated acreage would have been respectively 152,500 acres or 201,300 acres. Even in the latter case, however, only about one quarter of the acreage would have received a full supply of water. In the natural flow situation annual diversions would be only a little more than one fifth of the current annual diversions from the Boise and with the limited storage scenario slightly in excess of one third.

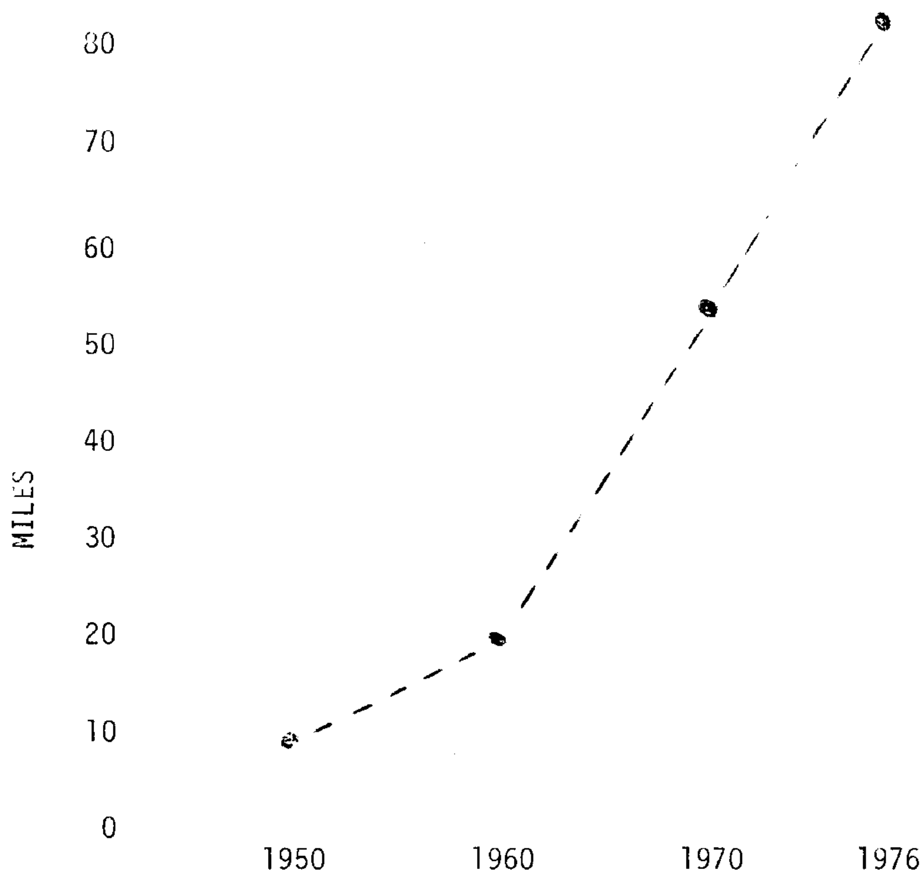

FIGURE 13: Pipeline in Place by Year on Land Administered by Boise Project Board of Control*

*SOURCE: Annual Report of the Board of Control for 1950, 1960, 1970, and 1976.

Very simply most of the water would be lost to the irrigators during its untimely rush through the Valley during the period of spring snow melt or during periods when the need does not exist.

Without the on-stream storage reservoirs of the Boise Project there would still be much the same basic diversion and canal systems, for the beginnings of this extensive distribution system were well advanced by 1906. The good water years between this date and 1915 would have encouraged further developments and the adjudication process would have entrenched the patterns. The Stewart Decree (1906) determined the priorities for all appropriations on Boise River from June 1, 1864 to April 1, 1904 and a case begun in 1909 and settled in 1929 (the Bryan Decree) covered the period from July 2, 1894 to April 7, 1914. It appears demand on the River would have exceeded the total flow during the growing season except for short periods. Water shortages, crop failure, and economic hardship would have been more common than was actually the case. The emphasis on forage rather than grain, fruit, and seed crops would have produced a situation different than contemporary observations might suggest.

The without scenarios imply two major differences of environmental significance other than the scale of operations. The land would generally be receiving less water and thus the propensity for intense management and use would be less. This would have produced a habitat-type more stable throughout the yearly cycle than row crops and clean farming. The second impact would have been on the channel of the Boise River. The storage reservoirs have decreased the peak flows and by guaranteeing water have facilitated canal expansion and maintenance to where 6,700 cubic feet per second can be diverted from the river. By reducing flows in the River the Boise Project has prevented to some degree natural channel scouring and has allowed brush and tree growth to proceed. The efficiency of the channel has been reduced, further encouraging heavy bed load deposition and lateral movement of flow during periods of high runoff.

Additional Storage

The Annual Report for 1931 of the Boise Project Board of Control contains the following statement:

> "...each year a committee is appointed to continue the work of interesting the Bureau in providing additional storage for the project..." (page 5)

Subsequently the 1931 report outlines this committee's then current plan which involved bringing water diverted from the upper Salmon River and conveyed to Red Fish Lake south of Stanley via a 1 1/2 miles tunnel, then via a 7 1/2 miles tunnel to Elk Lake on the South Fork of the Payette. A six mile tunnel to Ballantyne Creek would then dump the water into the North Fork of the Boise. The route would pass 3,000 feet under the highest peaks and 500 feet above some valley floors. Such schemes indicate the vigorous and sincere support by Boise Valley farmers for additional storage. Severe water shortages occured in 1924, 1926, 1931, and in later years also. The Salmon River inter-basin transfer was never accomplished but the project evolved, nonetheless. The height of Arrowrock was increased by five feet, Anderson Ranch Dam was constructed by the Bureau, and the Corps of Engineers built Lucky Peak Dam.

Anderson Ranch

Anderson Ranch Reservoir has a depth of 326 feet, a length of 13 1/2 miles and a surface area of 4,750 acres when full. Its storage capacity of 493,000 acre feet is not quite double that of Arrowrock Reservoir. Despite the remote location, Anderson Ranch Dam displaced a number of property owners from their farms, required displacement of the village of Pine and its cemetery and required the relocation of roads and bridges.

The reservoir behind Anderson Ranch Dam is more than 13 miles long, varying in width from one-fifth of a mile to one mile. The terrain changes from a narrow canyon with steep sides near the dam to a comparatively wide flat area at the head of the reservoir. There were thick growths of willows along the numerous creeks, thick stands of pine and fir on the north slopes, patches of cherry and alder bushes on the south slopes, an abundance of cottonwood trees and willows along the more quiet stretches of the river, with sagebrush and cultivated lands taking up the rest of the area.

About 4,900 acres were ultimately classified by government forces; of this 2,387 acres or about half of the reservoir area was covered with trees or brush which was subsequently cleared. The remaining area consisted of farmland, sagebrush or bare hillsides. The clearing boundary was established at 10 feet above normal high water on the steep slopes and about 6 feet lower on less steep terrain.

The clearing of the reservoir was performed between 1943 and 1946 when weather and fire hazard was favorable. All growth over 5 feet in height and 1 inch in diameter and all other combustible materials was removed. Work was first done by hand crews and horses. The brush and timber, after being felled and cut into lengths that could be easily handled, was stacked in piles and burned.

During the summer of 1945 attempts were made by subcontractors to operate sawmills in connection with their clearing operation, and thus utilize the timber of commercial value from the reservoir area. This idea at first seemed commendable for it was utilizing a natural resource which otherwise would have been destroyed, but it soon became apparent that the production of lumber was receiving unwarranted attention, and the clearing operations were being delayed by the limited quantity of marketable timber and the low capacity of the sawmills.

Considerable debris and a few standing trees had to be left in the area to be covered by water in 1947. Two 16-foot inboard motor boats were used to gather debris on the lake, which was then towed to convenient spots around the reservoir, left on shore to be burned later. During peak clearing periods as many as 90 men were employed in the process.

A large pile of sawdust located in the Fall Creek area had been deposited by a sawmill which had operated in that vicinity over a period of years. It was deemed necessary to cover this sawdust to prevent it from contaminating the reservoir. The slopes of the pile were flattened and about 2 1/2 acres were covered with clay to a depth of about two feet.

Anderson Ranch Dam is situated in a steep, narrow, rugged canyon over 1,000 feet deep, but in horizontal basalt flows, granite, and various igneous dike rocks. Canyon walls are steep and irregular, with broad swales, reflecting zones of poor rock, dissecting the east side of the canyon. Large outcrops of granite and steep slopes of the canyon are deceptively suggestive of the likelihood that hard, sound rock could be found near the surface. Extensive exploratory drill holes did encounter good rock, but later drill holes were supplemented by test pits and exploration drifts for direct examination of rock quality "in place." The results of these extensive tests revealed that the underlying rock was extremely variable in type and quality, much of it being friable and deeply weathered. This situation was further aggravated by a thick overburden of large river boulders, gravel, old well-compacted talus, deposits of sand, silt, soil, and slope wash and disintegrated granite fragments.

The danger of slides was not fully evident until the construction work had opened large, deep cuts which showed numerous clayey seams and zones of badly shattered rock. During spring months when these cracks were lubricated by percolating water, conditions were ideal for slide occurrences. Mass movement, sometimes as large as 500,000 cubic yards, resulted in a much larger environmental impact upon the landscape than was originally imagined.

Over the course of the construction period (1940-1950) numerous slides occurred, primarily on the east wall of the canyon and on the hillside directly above the spillway gate structures. An estimated two million cubic yards of materials was excavated from slide areas, although a great deal of this material was later reused for construction purposes. Nevertheless, many hundreds of thousands of cubic yards of earth was excavated from the canyon walls.

Prior to the actual building of the earth embankment many thousands of cubic yards of overburden had to be removed down to solid bedrock. The entire dam site was cleared of all overburden, stripped clean of all vegetation and washed down. Cleaning required that all unconsolidated material would be sluiced from the granite bedrock. This process undoubtedly washed significant quantities of sediment into the river. The entire process of dam construction entailed the disruption of streamflow increasing turbidity and degrading water quality. Although construction related sediment production ceased within a relatively short period of time after the dam was completed, the impact was prolonged for approximately 10 years. The demands and shortages of World War II imposed extended periods of slowdowns in the schedule and delayed competition well beyond the time to have been expected of a project of this magnitude.

Lucky Peak

Lucky Peak Dam is located ten miles upstream from the city of Boise and roughly 12 miles downriver from Arrowrock Dam. Lucky Peak was constructed between 1951 and 1954 as an Army Corps of Engineers project and thus is authorized primarily as a flood control structure. Irrigation and recreation activities are significant ancillary benefits. Sandwiched between Bureau of Reclamation facilities requires a coordinated plan of multiple-purpose operation for the three-reservoir system and related diversion and storage facilities. As originally conceived Lucky Peak Reservoir would have been the first of the on-stream reservoirs to be emptied during the irrigation season. However, because of its better accessibility and the desire to facilitate recreational activities the operational agreement provides for Lucky Peak to remain full while capacity from Arrowrock Reservoir is being used. Lucky Peak plays a role in the provision of irrigation storage in conjunction with the two upstream dams. Consequently, those dams have taken on a greater role in flood control.

At floodpool, Lucky Peak reservoir has a surface area of 3,060 acres and extends twelve and one-half miles to the face of Arrowrock Dam, and five and one half miles along Mores Creek. About 45 miles of shoreline is created.

In contrast to the rugged, narrow and steep-sided canyons which contain the upstream reservoir, Lucky Peak is situated in a shallower canyon between high and somewhat rolling benchlands. Thin soils support sparse vegetation typical of the arid to semi-arid foothills surrounding the Snake River Plains. Generally, the soils in the Lucky Peak area consist of sandy or silt loams, usually occurring over granitic bed rock, with slopes ranging from 20% to 60%. Their granitic nature exhibits the characteristics of rockiness, neutral to slightly acidic and moderate permeability qualities. Erosion of these soils has been accelerated by overgrazing.

Lucky Peak Dam is a rolled earth and gravel fill dam with dumped stone sides. An estimated 5,900,000 cubic yards of material was obtained from nearby pits, to bring the dam up to a height of 340 feet.

An uncontrolled spillway was constructed in a natural saddle to the south of the dam abutment. To accomplish this task approximately 247,500 cubic yards of earth was excavated from the saddle to make the spillway functional. An area about 600 feet long was then lined with 12,500 cubic yards of concrete. The spillway has never been used although the reservoir level has approached its crest several times.

Controlled discharges from the reservoir are accomplished by a single steel-lined pressure tunnel, 23 feet in diameter, which is capable of releasing 30,000 cubic feet per second at full pool level and only 17,000 cfs at minimum pool level. The tunnel is 1,365 feet in length and is regulated by six 5'2" x 10' slide gates at the downstream end. A flip bucket is used to dissipate energy before the water is discharged into an excavated 188 foot wide and 125 foot long desilting basin. This basin consists of a solid rock base.

Because Lucky Peak is of more recent development and because awareness of indirect impacts of water projects had increased, documentation of the pre-project conditions is found in the official record. From these and other sources the landscape of the Boise drainage can be partially sketched.

SELECTED SYSTEM CONSEQUENCES

The Causative-Permissive Dilemma

Numerous properties of the environment have changed with development of Boise Valley irrigation. With respect to any specific change, a particular action or force for change may be characterized as causative, permissive, or unknown. Illustration of this classification is easily shown by comparing different situations. Consider, for example, the organic waste building up as the food processing industries developed in the Boise Valley. Full-season irrigation provided by the Boise Project permitted production in sufficient quantity of crop types to stimulate local processing industries. State and federal laws, or lack thereof, allowed, and the economy encouraged wasteful and polluting disposal of by-products. The Project caused a situation without which the pollution could not have taken place, but the disposal of the by-products could have been handled in some other manner, by others, without any alterations in Project development. As another example, consider Lake Lowell which can be said to have caused 10,000 acres of terrestrial habitat to be replaced by a variable size impoundment which permits the Bureau of Sports Fisheries and Wildlife to operate the area for waterfowl benefits. Geese and ducks forage in nearby fields and the State Department of Fish and Game has provided pyrotechnic devices to chase marauding birds. Who should be blamed for the noise? Indirectly, the Bureau of Reclamation may claim responsibility, but the honor may just as rightfully be deserved by Ducks Unlimited or Idaho Fish and Game.

The previous section of this report presented the major components of the Boise Valley Project and outlined the direct consequences of these developments in contrast to the Without-Project scenarios discussed in Section I. Early in the study consideration was given to using environmental systems models to determine with/without differences in system properties. The hydrologic model of the Boise River prepared by Chen and Wells and associates was reviewed in this respect. (16) Operation of the model requires input of several hundred values representing the status of the system at a point in time. A run of the model for say 1910, would require assumptions too numerous to list to arrive at estimates of the input values. The source of these assumptions, estimates, and the model is the contemporary environment. Ranges for certain values may be set from observations on other streams, but again similarity assumptions are implied. Comparison of system properties would be difficult to interpret even if meaningful results for the early time period could be assumed. Who or what could be considered causative agents? The insight to be gained from this line of analysis did not seem to justify the heroic assumptions, and so modeling efforts were not pursued.

For quite similar reasons there seems little reason to present data depicting the current status of many system properties, such as physical, chemical, and biological measurements. Status reports of this type are increasingly available for the Boise River and surrounding area. (23,89) Without data for an earlier period and with difficulties determining the causative factors, contemporary status reports fall short of contributing materially to a post-audit analysis.

An unending litany of impacts undoubtedly exists after some seven decades of operation of the Boise Valley Project. One assumes a degree of ordering of the items on this list, but how should the more salient aspects be determined? One key is provided by the more or less equivalent expressions of which environmentalists are fond, such as in nature "... you can't do just one thing" or "... everything is related to everything else". Geographers, attuned to influences of space, add to the concept with the thought "relationships are stronger between near things than between those more distant". Like any "old saw" (excuse the pun) these could use sharpening, but they nonetheless point the way when considering the inputs and outcomes of development projects.

The Boise Project has involved first and foremost control of the River, and second, diversion and delivery of water to the land. To heed the previously mentioned proverbs, attention is now directed to the more immediate consequences of imparting order to the River.

A Systems-Surroundings Interaction

Prior to inundation by the dams constructed on the Boise River, there existed land and water-based habitats intimately tied to the freely flowing stream. The replacement habitats are of interest as outcomes. For example, the most conspicuous replacement habitats, namely variable-depth reservoirs, have been experimentally studied with a view toward enhancing recreational fishing in these waters. (64,65) Such efforts are hampered by the operation of the three-reservoir system for irrigation, flood control, and power.

Downstream, aquatic habitat has been significantly effected, particularly as a result of the design of Lucky Peak Dam and the operational aspects of the jointly managed system of reservoirs. (94,95) Specifically, planning reports for the joint operation of the reservoir system indicated the intention of supplying minimum discharges from Lucky Peak of 80 second feet. Periods of no flow because of inspection and maintenance work on the single outlet tunnel, and flows substantially less than that predicted because of commitments to irrigation demands have received considerable attention. (86,95) Enhancement of the fishery aspects of Boise River including the impoundments is of continuing concern to the Idaho Fish and Game Department. Insofar as the problems could have been anticipated and avoided, the considerable "energies" since expended by all parties should be categorized as a gross energy loss. The extra effort and cost of alternative initial design and development would be subtracted to derive net energy loss. Fish kills, other water quality problems, and the like, if consequences of design and operation decisions, should be included in the litany of impacts.

Keep in mind, however, the diversion presumed under alternative scenario and the availability of water.

Control of the river implies the destruction and creation of habitats within the bounds of the impoundment. Evaluation of the new relative to the old situation is somewhat a matter of personal introspection, and hardly resolvable. However, the second energy law dictates a more searching look for consequences of habitat change. Briefly, any system plus its surroundings tends spontaneously toward increasing disorder. This potential for interaction between any system and its surroundings is of considerable significance for the Boise Project. A case in point has been the condition and management of adjacent lands.

Knowledge of the original conditions of the Boise River watershed is sketchy, but reports indicate a rapid response of the vegetation during the settlement of the region following the 1860's. With the additional stress of a prolonged drought during the 1930's, problems were increasingly recognized and studied. Some of the resulting literature has been cited earlier. (p.11) In a 1949 report, the Forest Service summarized the condition of the watershed and provided a detailed plan of remedial measures. At that time the principal cover types were reported in the order of their areal extent as conifer, sagebrush, browse, grassland, broadleaf trees, and annual weeds and grasses, as indicated in Table 18. By 1940 almost all of the area exhibited evidence of use or fire. On the more heavily grazed areas the perennial grasses and forbs had been greatly reduced or wholly replaced by annual plants with simple taproot systems. Over-grazing had occurred over most of the timbered areas with depletion of the cover most severe within the burned areas. The sagebrush habitat, in a presettlement condition, supported an understory of fibrous-rooted perennials, chiefly grasses, and a mixture of forbs. Recently the Idaho Fish and Game Department began a habitat mapping program which required preparation of descriptions of major habitat types. Their list contains tall, low, and silver sagebrush types and includes associated plants, general location criteria, and a statement concerning the value to wildlife of each class. (32) These maps will be useful in future work but such distinctions are not made in the early Forest Service reports. Therein the general condition of the sagebrush lands is described as either (1) having an increased density of sagebrush with a reduced understory of perennial plants, or (2) having a normal density of sagebrush with an understory of annuals, or (3) a more or less complete destruction of sagebrush and its replacement by annual weeds. The latter condition was reported as most common on burned and heavily overgrazed areas. Depletion of the grassland and browse habitats followed a similar pattern but with less extensive damage in the latter types. Subsequent reduction of grazing pressure has allowed natural succession to return many of the deteriorated sites to a more vigorous condition. (73,78) The category reported in Table 19 as "Annual Weeds" was primarily "cheatgrass" that has replaced former grassland or sagebrush vegetation.

Degradation of the vegetation of the Boise River watershed apparently proceeded apace with settlement and the irrigation development. A partial connection, if one exists, is the increased productivity of the land which permitted the wintering of greater numbers of animals than might formerly have been possible. These additional animals would have contributed to the overgrazing each spring and summer. However, many animals were brought into the region from elsewhere so the local herds were not the sole contributors to the problem.

It is with this perspective of widespread range deterioration that the inundation of the bottom lands must be viewed. Apparently no record was

TABLE 18: ACRES OF COVER TYPES WITHIN LUCKY PEAK POOL

Cover Type	Acres	Percent
Brush dominate	885	31
Grass dominate	1,010	36
Alfalfa and grain farming	292	10
Exposed lava	315	11
Water	348	12

Source: Adapted from (94), Table 3, p.7

TABLE 19: PLANT COVER TYPES, BOISE RIVER WATERSHED, 1939*

Cover Types	Acres	Percent
Conifer		
Protection	542,100	20.5
Commercial	361,300	13.7
Cut-over	54,300	2.0
Burn	39,700	1.5
SUBTOTAL	997,400	37.7
Sagebrush	773,600	29.3
Browse	180,800	6.8
Grassland	156,800	5.9
Annual Weeds	99,800	3.8
Perennial Forbs	18,700	0.7
Broadleaf Trees	4,400	0.2
Urban, Water, Barren, etc.	82,500	2.9
Cultivated	335,500	12.7
TOTAL	2,645,700	100.0

*Source: (92), Table 30, p.103

made of the composition of the vegetation within the Arrowrock pool lands prior to the dam's completion in 1916. Studies in anticipation of Lucky Peak considered the main plant species along the stretch of the river to Arrowrock Dam and on Mores Creek upstream from the mouth. (94,95) Exclusive of agriculture lands, the composition included willow, rubber rabbitbrush, sagebrush, bitterbrush, mochorange, chokecherry, sunflower, beardless wheatgrass, Sandberg bluegrass, downy chess, Russian thistle, yarrow, and kitchenweed. Figures 14 and 15 portray this landscape. Along Mores Creek the principal species were willow, sagebrush, rabbitbrush, mockorange, and downy chess. Of lesser importance were bitterbrush, birch, rose, chokecherry, bittercherry, ponderosa pine, hawthorn, beardless wheatgrass, and Jim Hill mustard. The Mores Creek area is illustrated in Figure 16. The acreages and percentage of cover types within the Lucky Peak Pool are indicated in Table 19.

The vegetation found in the 1940's and later inundated by the reservoir behind Lucky Peak Dam and that which existed within the Arrowrock flow line would have been quite similar. Differences would be the lesser degree of use and the more limited occurrence of introduced species, reflecting the shortened period (by thirty-five years) during which change could have taken place.

Drainage toward the canyon bottom and the immediate influence of the streams and flood plains produces an inherently more productive and diverse habitat than is possible on the more arid surroundings. Water behind the dams efficiently reflects the sun's energy which previously fueled a complex conversion process. The radiant energy is no longer transformed and stored as chemical energy in the plants. Animals of species totally dependent on the riparian habitat are lost while those partially dependent on it must seek another food source or adjust population levels to the lesser availability. Such loss of habitat as a result of inundation, added to the grazing pressure on the surrounding lands already in a deteriorating situation.

An early observation of record for the general region was that of I.C. Russell in 1902. (75) In his report of watershed conditions on lands adjacent to the Snake River Plains, which are similar in character to those on the lower portions of the Boise River drainage, he described the appearance of fresh cuts with nearly vertical walls of loose earth, gullies on hillsides formerly completely covered with soil, gulches across roads necessitating wide detours, and the drainage of "luxuriant meadows" and the replacement of wild grasses by sagebrush. He attributed this recent change

Figure 14. Boise River within Lucky Peak Reservoir Site, September 1949.

Source: U.S. Department of Interior, Fish and Wildlife Service, Office of Regional Director. Region 1, 1950, "Lucky Peak Dam Project Boise River, Idaho.

Figure 15. View of Boise River, showing Mores Creek entering at left center. Deer winter-range lands of Idaho Fish and Game Department in background, September 1949.

Source: U.S. Department of Interior, Fish and Wildlife Service, Office of Regional Director. Region 1, 1950, "Lucky Peak Dam Project Boise River, Idaho.

Figure 16. Mores Creek within Lucky Peak Reservoir Site, September 1949.

Source: U.S. Department of Interior, Fish and Wildlife Service, Office of Regional Director. Region 1, 1950, "Lucky Peak Dam Project Boise River, Idaho.

to the introduction of large numbers of sheep into the area about 1880. Increasing numbers of cattle were also contributing to erosion problems.

The United States Forest Service in 1926 observed that conditions of excessive washing of soil on the lower portions of Boise River watershed were spreading to higher elevations, where they found gullies of various size, abnormal enlargement of stream channels and extensive deposits of fresh debris at the mouths of tributary streams.

By 1927, 12 years after the completion of Arrowrock Dam, sufficient silt had accumulated within the reservoir to cause serious concern as to its future storage capabilities. This silt was accumulating in spite of extensive sluicing operations during low flows. Watershed condition apparently continued to worsen. F.G. Renner in 1936 reported badly depleted topsoil, active sheet erosion on many slopes and deeply channelled canyon bottoms choked with gravel. (68)

The 1949 Forest Services report indicated conditions were continuing to worsen. Extensive damage and silt production was occurring because denuded lands could not absorb the energy of summer thunderstorms of high intensity nor spring runoff from rapid snowmelt. (92)

In the context of systems-surroundings interaction, an insufficient energy subsidy was being provided to impart order to both the river and its watershed. Table 20 provides one estimate, in dollars, of the input required to overcome this oversight and reverse the spontaneous degrading of the watershed. The indicated measures and the costs relate to the entire watershed, both the western or lower Valley and the upper elevations. Further, it is not intended to fix responsibility for system instability on any group or agency. A correct interpretation is simply that with settlement and development the ecosystem went out of control; remedial measures were investigated, some initiated; and while the system may be stabilizing, it has not yet stabilized.

The last comments warrants some explanation. Evidence indicates enlightened range management practices have begun to heal the wounds of the watershed. (73) Downstream a somewhat different problem has been developing. Specifically, both the upper watershed and the agricultural lands of the lower valley continue to contribute sediment to the main channel. Channel capacity changes were summarized in an Idaho Water Resources report in 1972. (30) Channel location changes from 1868 to 1943 are illustrated in a Corps of Engineers report of 1946. (84) Most view this problem as contributing to

TABLE 20: REMEDIAL MEASURES AND COSTS FOR THE BOISE RIVER WATERSHED, 1947*

Measures	Unit	No. of Units	Initial Costs $	Annual Costs $
Watershed Restoration				
Range reseeding	acre	68,130	408,780	
Slope shrub planting	acre	4,900	98,000	
Gully planting	mile	717	35,850	
Channel planting	mile	202	37,170	
Gully plugs or check dams	number	2,216	83,130	1,510
Gully diversions	feet	21,588	17,630	320
Channel diversions	feet	1,400	1,540	30
Bank protection	feet	2,230	29,150	530
Road improvements (general)			428,181	
Drainage	number	6,200	46,624	
Ditches	mile	11	35,695	
Ditch checks	number	120	600	
Reseeding	acre	340	7,800	
Bank stabilization	mile	220	49,500	
Fire control	number	2	426,280	92,950
Range fences	mile	144	132,570	7,060
Water developments	number	8	1,470	60
Water rights and water			5,500	1,000
Work roads	mile	118	43,140	410
Technical assistance			527,360	30,000
Land acquisition	acre	83,176	474,930	9,980
	Subtotal		$2,889,900	$143,850
Structural				
Flood detention dams	number	11	382,350	7,010
Sediment detention dams	number	5	376,050	6,900
New flood channels	feet	26,550	226,720	4,160
Channel rectification	feet	60,500	230,980	4,240
Desilting works	number	23	292,300	2,800
Road improvements			185,400	
	Subtotal		$1,693,800	$ 25,110
	Program integration		40,000	4,000
	GRAND TOTAL		$4,623,700	$172,960

* Source: 92, Table 54, P.195 and Table 55, p.200

Costs estimates are not discounted and reflect 1947 Boise Valley prices

1. Includes costs of maintenance during installation period (4.5 x annual rate)

the flood hazard. Another perspective is that a new habitat-type is being created, perhaps an Idaho equivalent of the southern river-swamp. (100) The area behind Barber Dam illustrates a possible outcome similar to that which might be expected of this system adjustment. Again, energy is the key explanatory variable. The controlled river no longer musters the power to sufficiently scour debris from the channel. A continual energy subsidy would be required to re-impose and maintain the old order, namely open a channel of greater capacity. A new set of relationships may be in the making which, with minimal energy subsidy, may be stabilized as a dynamic steady-state system. Seeking and achieving such a man-environment system would be a symbiotical achievement.

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