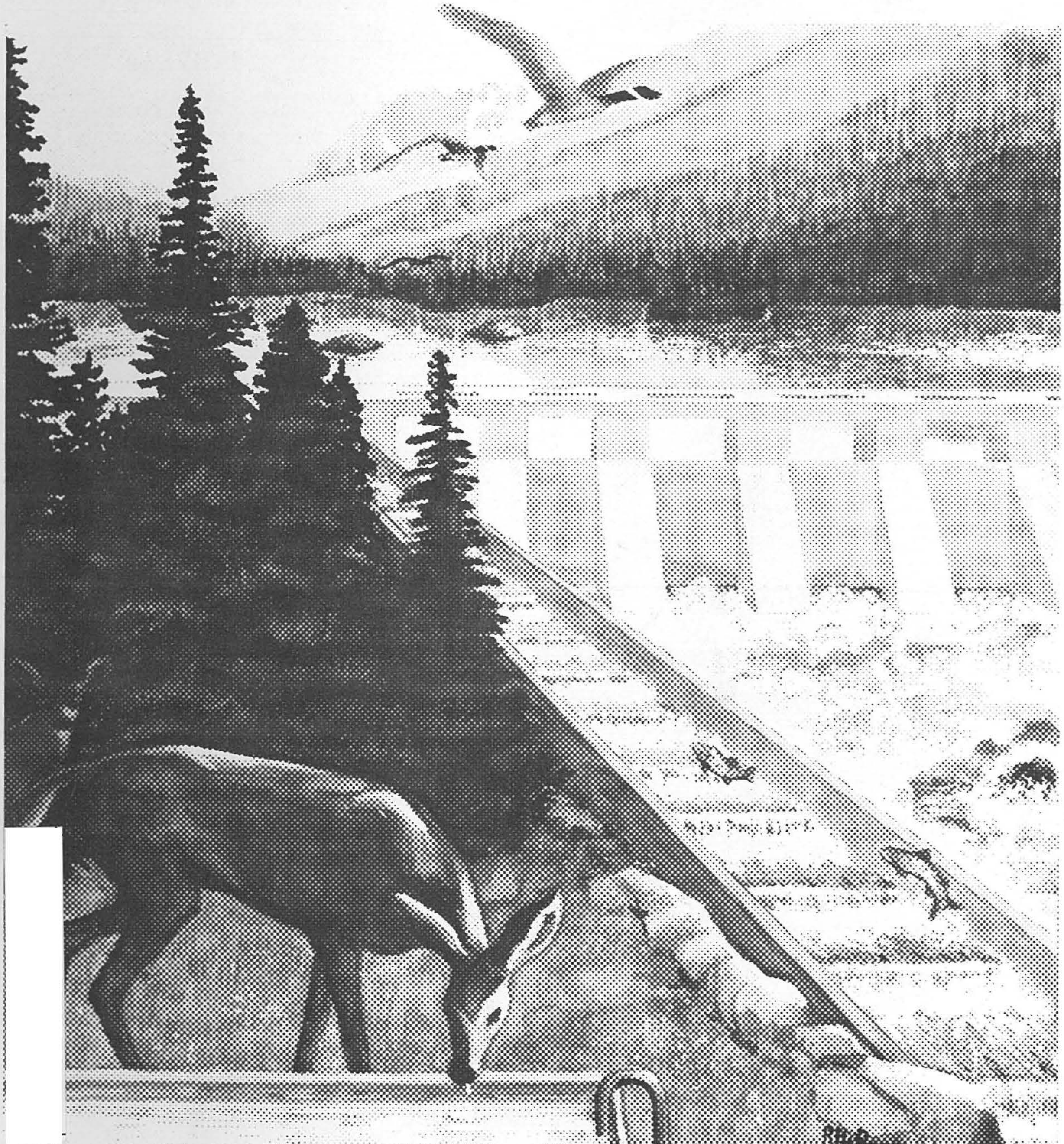
Biological Services Program

FWS/OBS-78/56

October 1978

Western Reservoir and Stream Habitat Improvements Handbook



Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues which have an impact fish and wildlife resources and their supporting ecosystems. The mission of the Program is as follows:

1. To strengthen the Fish and Wildlife Service in its role as a primary source of information on natural fish and wildlife resources, particularly with respect to environmental impact assessment.

2. To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major land and water use changes.

3. To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process, to prevent or minimize the impact of development on fish and wildlife. Biological Services research activities and technical assistance services are based on an analysis of the issues, the decisionmakers involved and their information needs, and an evaluation of the state-of-the-art to identify information gaps and determine priorities. This is a strategy to assure that the products produced and disseminated will be timely and useful.

Biological Services projects have been initiated in the following areas:

Coal extraction and conversion

Power plants

Geothermal, mineral, and oil shale development

Water resource analysis, including stream alterations and western water allocation

Coastal ecosystems and Outer Continental Shelf development.

Systems and inventory, including National Wetlands Inventory, habitat classification and analysis, and information transfer

The Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams which provide the Program's central, scientific and technical expertise, and which arrange for contracting of Biological Services studies with States, universities, consulting firms, and others; Regional staff who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities who conduct inhouse research studies.

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Western Reservoir and Stream Habitat Improvements Handbook

Guide to the Performance of Fish and Wildlife Habitat and Population Improvement Measures Accompanying Water Resource Development

by

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U. S. DEPARTMENT OF THE INTERIOR

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Preface

This handbook guide to the performance of habitat and population improvement measures has received a thorough critique by 53 individual reviewers representing the Federal and State wildlife management and water resource development agencies in the West (see list in Appendix B). This final edition is based on comments received on the draft handbook and revisions proposed by the reviewers at technical review sessions in three Fish and Wildlife Service (FWS) Regions — Portland (Region 1), Albuquerque (Region 2) and Denver (Region 6). These sessions provided FWS personnel and allied fish and game and construction agency staff with an opportunity to weigh the research findings summarized in this handbook in the light of their own experience. In particular, these sessions achieved four objectives:

- To review findings on past performance of habitat and population improvement measures recommended by the Fish and Wildlife Service and implemented by the construction agencies
- To review estimates of the future potential of relatively new or untried improvement measures described in recent literature or currently under study
- To identify technical, administrative or cost limitations to the successful implementation and performance of each type of improvement measure in addition to those reported in the draft handbook
- To identify additional basic references covering design specifications and additional exhibits to better illustrate the physical features and management practices highlighted in this final edition.

To obtain the optimum use of this handbook guide, it is essential to know its designed purpose. The guide was not designed as an all—inclusive, state—of—the—art handbook on habitat and population improvement measures, nor as an engineering reference manual. It is instead a handbook of guidance for selecting more effective measures to recommend and negotiate among administrators, biologists and engineers of fish and game and construction agencies.

The guide is based primarily on measures shown to be effective in the past at a representative selection of 90 dam and reservoir projects in 19 western States (see list in Appendix A). The major effort in preparing the guide was devoted to investigation into the historical success of approximately 286 individual improvement measures within 60 categories (see Contents of the guide for the categorization of measures). Secondarily, the guide presents measures believed to be potentially effective by investigators involved in current research or authors of recent literature.

The binding and format of this handbook were chosen so that each of the 60 numbered sections can be removed and replaced without affecting the preceding and following sections. This feature is intended to encourage periodic revisions and expansion. Users are invited to submit drafts of revised or added sections for consideration. Such new or revised sections that are used to update the handbook will be credited to the source within the new text. Contributions may be sent to:

Information Transfer Specialist
Western Energy and Land Use Team
U. S. Fish and Wildlife Service
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2625 Redwing Road
Fort Collins, CO 80526

Special contributions to the design, development, and production of the handbook are acknowledged as follows:

U. S. FISH AND WILDLIFE SERVICE

Project leadership and guidance by Project Officer Lee Ischinger and Research Manager Harvey Doerksen (Western Energy and Land Use Team, Ft. Collins); Regional Activity Leaders Robert Cleary (Region 1, Portland), Joseph Kathrein (Region 2, Albuquerque), and Kent Andrews (Region 6, Denver).

U. S. BUREAU OF RECLAMATION

Collaboration in study design and funding for handbook design and production by the Division of Planning and Technical Services, Engineering and Research Center.

INTERAGENCY TECHNICAL REVIEW TEAMS

Detailed critique and revision of the draft handbook in three 3–day technical review sessions held in Portland, Albuquerque and Denver by 53 individual reviewers (see list in Appendix B), representing the Fish and Wildlife Service, Bureau of Reclamation, Corps of Engi-

neers, Federal Energy Regulatory Commission (formerly Federal Power Commission), Soil Conservation Service, Bureau of Indian Affairs, and the fish and game agencies of Arizona, Colorado, Idaho, Kansas, New Mexico, Oklahoma, Oregon, Washington, and Wyoming (representatives of other States submitted written comments).

ENVIRO CONTROL, INCORPORATED

Overall project management as well as detailed study design and technical editing by Wayne Nelson (Project Director); collaboration in study design in addition to supervision and performance of project investigations and technical writing by Gerald Horak (Principal Investigator); project investigations and technical writing by James Olson; project investigations by Arthur Hale, Martin Lewis, Karl Kobes, Bradford Shea, Zell Parkhurst, and Joanne Colt.

PATRICE BRAVERMAN GRAPHICS

Handbook format and detailed design by Patrice Braverman; handbook illustrations by Rita Brasz.

Introduction

In this introductory discussion, three topics are addressed to provide an orientation for the reader:

- Overall purpose of the completed research underlying the guide to the performance of habitat and population improvement measures
- General methodology employed in conducting the prerequisite research before preparing the guide to performance
- Formats and classification scheme used in writing and organizing the separate sections of the guide for each category of improvement measure.

Purpose of the Research

The broad purpose of the research was to document successful and potentially successful habitat and population improvement measures accompanying water resource development projects. The projects of primary interest were dams and reservoirs in the western U.S., including diversion dams and canals. The measures considered generally involved structural and operational features as well as direct habitat modification and population control.

The research findings are expected to aid the effectiveness of contributions by the Fish and Wildlife Service (FWS) and State fish and game agencies to project planning and design. To achieve this goal, the guide has been furnished as a basic planning tool to the FWS, State fish and game agencies, and project construction or licensing agencies. For each class of habitat and population improvement measures which are available and considered feasible for incorporation into project design, the handbook presents selected engineering features, hydrological and biological effects, and relative costs.

The specific study objectives sought to fulfill the purpose of the research were:

- To identify measures that were recommended by the FWS, particularly those implemented by construction agencies as features for improving fish and wildlife habitats and populations associated with water development projects (Task 1)
- To critically evaluate the implemented habitat and population improvement measures to determine which ones were effective in producing the desired or anticipated improvement for fish and wildlife (Task 2)
- To identify additional measures not necessarily recommended by the FWS or actually implemented, but believed or proven

successful toward improving fish and wildlife habitats and populations (Task 4)

- To prepare a handbook or guide articulating the measures demonstrated to be most successful and those considered potentially successful, also identifying the best ways they can be implemented successfully (Task 6).

Two additional tasks involved preparing a preliminary handbook for interim guidance and conducting technical review sessions to test and refine the preliminary handbook—Tasks 3 and 5 respectively.

The Task 1 report, published previously under separate cover, identified the habitat and population improvement measures recommended by the FWS for Federal water development projects currently in operation or under construction in the western States shown in Exhibit 1. Projects analyzed were those directly controlled by

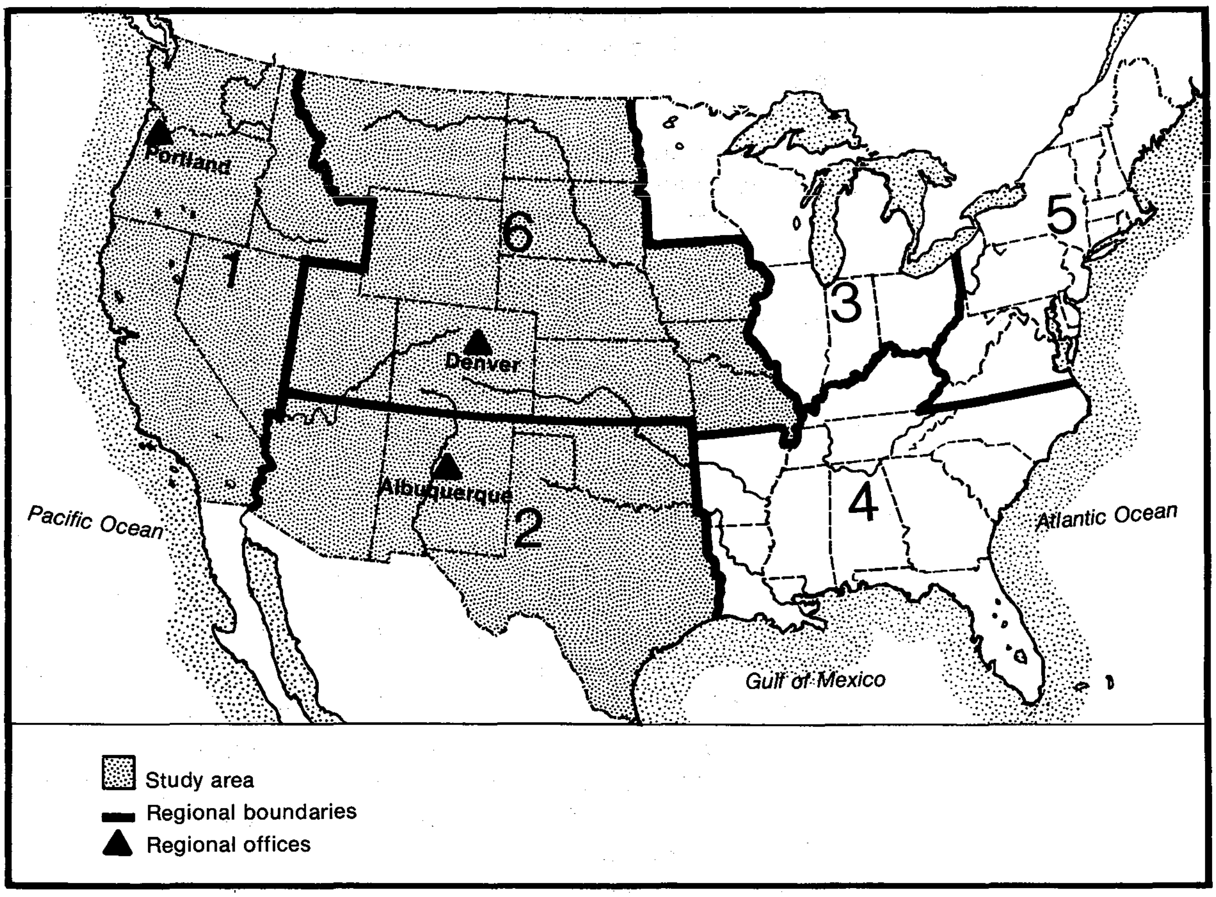


Exhibit 1. FWS regional boundaries and project study area.

Federal agencies——the Bureau of Reclamation, Corps of Engineers, Federal Energy Regulatory Commission (formerly Federal Power Commission), Soil Conservation Service, and Bureau of Indian Affairs. These projects were among over 300 candidates proposed to the FWS Project Officer and Regional Activity Leaders for Western Water Allocation. For the 90 projects they selected for detailed study, the Task 1 report presented Enviro Control's findings from project–by–project investigations which ascertained the recommended measures and the status of their acceptance and implementation. Where recommendations failed to be accepted or, once accepted, failed to be implemented, reasons were suggested wherever possible.

In the Task 2 report, the critical evaluation of the effectiveness of those implemented measures identified under Task 1 was presented in terms sufficiently detailed to determine whether the recommended measures accomplished their intended purpose. In preparing the interim guide during the third task, the information on comparative cost and output and the design specifications obtained under Tasks 1 and 2 were reflected there; so was information on the additional measures identified under Task 4, although in much less detail. While the Task 2 evaluation utilized data acquired in Task 1 that is project–specific, Task 4 information was obtained from a general literature review, a brief survey of research in progress, and interviews with agency staff members or research investigators.

Research Methodology

The methodology used in performing Task 1 consisted of a two–step process. First, candidate projects were identified for which habitat or population improvement measures were recommended by the FWS. Second, after selection of 90 candidates by the FWS Project Officer and Regional Activity Leaders, the status of acceptance and implementation was determined for each measure recommended for a selected project.

The methodology employed in Task 2 consisted of a design for the evaluative process and for gathering and analyzing the information required by the process. First, a five–step process to critically evaluate the success of implemented measures identified under Task 1 was designed by Enviro and approved by the FWS. Second, the requisite information was gathered and analyzed by Enviro investigators to determine the demonstrated success of 286 individually implemented habitat or population improvement measures associated with recommendations by the FWS.

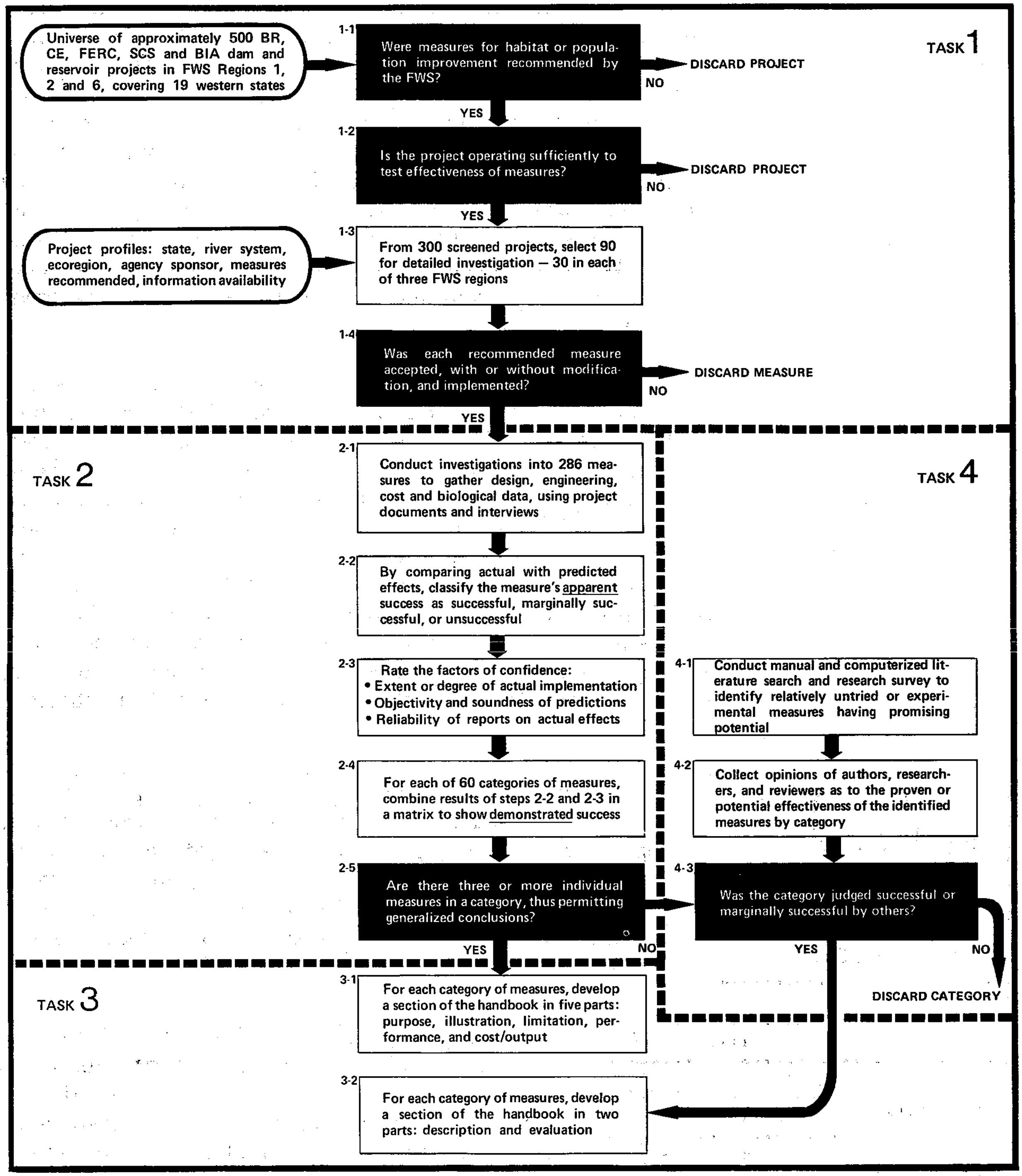


Exhibit 2. Summary of research methodology.

Under Task 4, the approach to making a survey of published and ongoing research into habitat and population improvement measures associated with dams and reservoirs called for a Document Search and Preliminary Evaluation. The document search identified the physical features and management practices which were currently under investigation, while the preliminary evaluation gathered the opinion of authors, researchers and reviewers as to the proven or potential effectiveness of the identified measures.

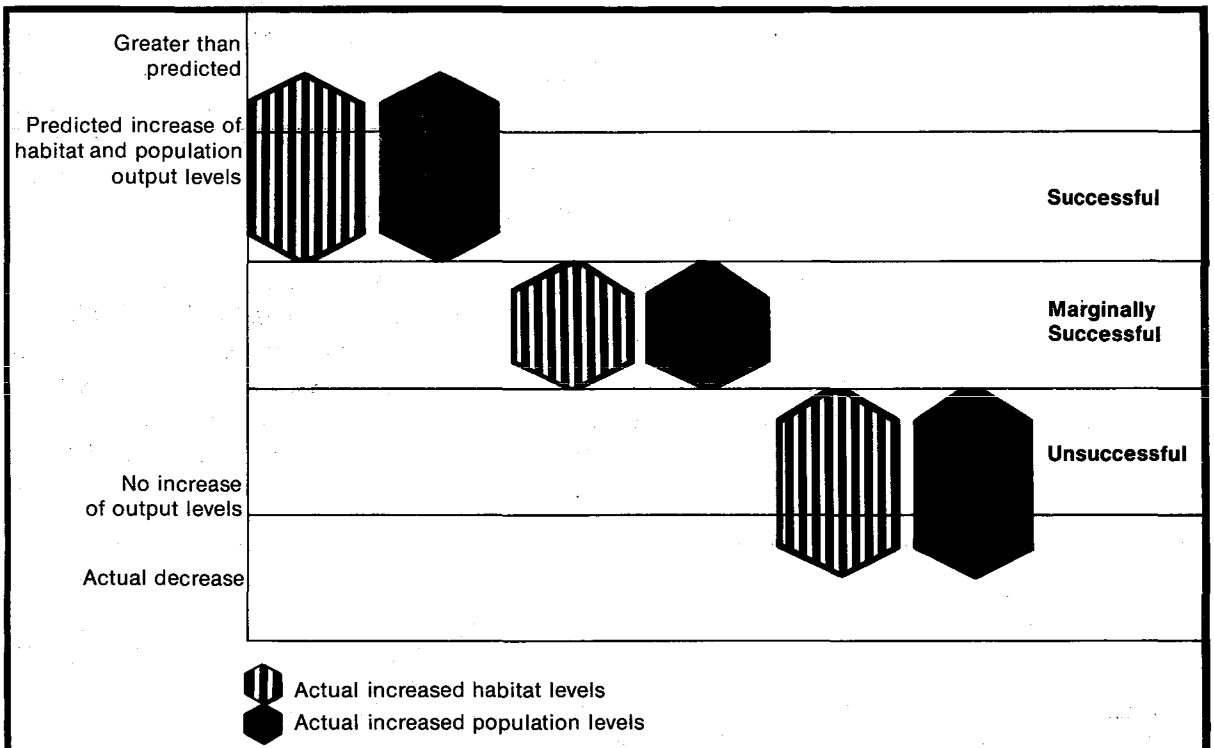
The respective task reports for Tasks 1, 2 and 4 furnish the detailed explanation of study methodology. For this introduction to the handbook, Exhibit 2 has been prepared to summarize the methodological approach. Exhibit 3 presents a sample of the standardized matrix used for every category of improvement measure having a detailed five–part format in the handbook. Where a category contains three or more individual measures, this matrix is the basic evaluative tool for reporting the past success of implemented measures recommended by the FWS. The terms used in the matrix are explained in the following discussion.

Each application of an improvement measure was classified as successful, marginally successful, or unsuccessful (see Exhibit 4). If an individual measure apparently accomplished a major proportion of its intended purpose, it was classified as successful. If only a moderate part of its intended purpose was attained, it was classified as marginally successful. A measure was deemed unsuccessful if only a minor portion of its intended purpose was realized.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: *high*			*medium*			*low*		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	8	7	5	5	0	3	3	1	0	0
	Population	7	7	5	5	0	2	2	0	0	0
Marginally Successful	Habitat	3	2	0	0	1	3	2	0	0	1
	Population	5	2	0	0	1	4	4	2	1	1
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 3. Success and confidence matrix for reservoir pool maintenance.

Whenever possible, at least two complementary criteria for success were applied——one concerned with habitat improvement, and another with population improvement. For example, the habitat improvement criterion for a seasonal minimum instream flow might be "amount of streamflow necessary for the spawning migration of salmonids"; the population improvement criterion might be "increase of juvenile salmonids in the affected stream reach." The number of cases or applications involving either criterion is reported in the matrix.



If a measure for improvement actually produced a *major* portion of (or greater than) the increased habitat and/or population output levels predicted to result from its implementation, it was classified as *successful*; if a moderate portion, it was classified as *marginally successful*; if only a minor portion or none of the predicted increase or an actual decrease occurred, it was classified as *unsuccessful.*

Exhibit 4. Classification of apparent success.

The degree of implementation (high, medium, low) of any measure for habitat or population improvement is a major factor affecting confidence in the assessment of apparent success. Obviously, a poorly implemented measure cannot be assessed objectively or with certainty; its true success will remain in doubt. Also, a sound, well—

informed prediction of habitat or population improvement to be expected will depend on the ability to predict comparative biological effects with and without the measure for improvement. Confidence in an assessment of success was also lowered if a prediction of improvement was markedly liberal or conservative. Lastly, confidence in the estimate of success as a function of the reliability of reports on actual biological effects was rated high, medium, or low. This rating was determined by whether the reported effects of a habitat or population improvement measure were derived quantitatively from field measurements or qualitatively from direct field observations or indirect reports of anglers and hunters.

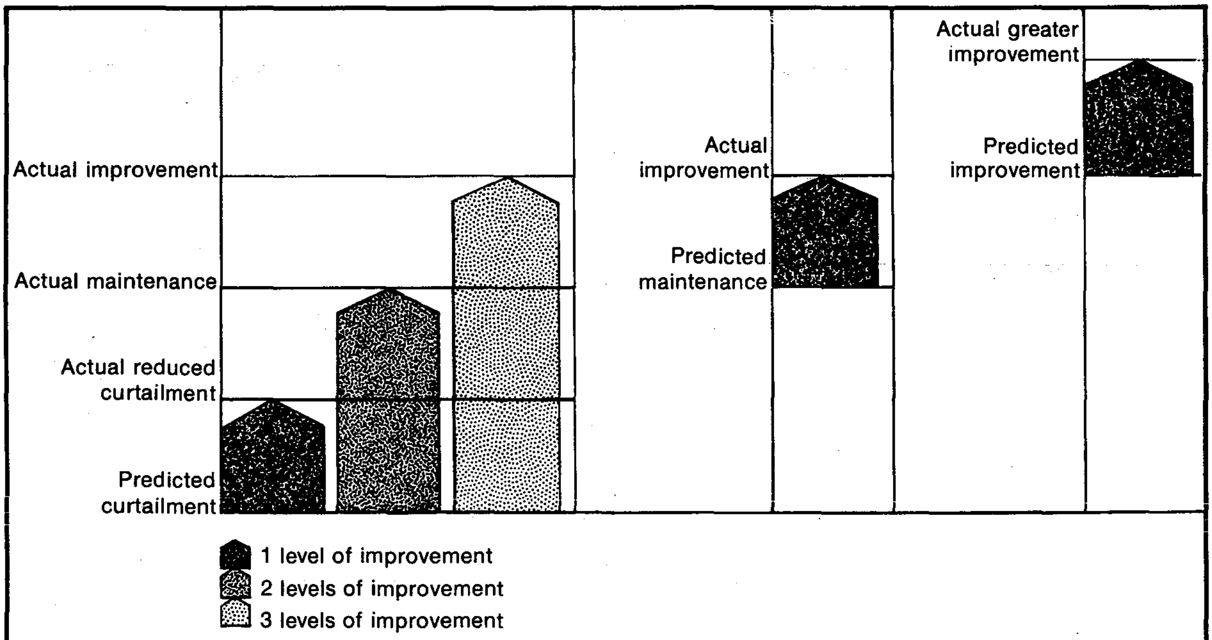
Guide to Performance

The interim handbook guide developed under Task 3 was used during the fifth task to validate the findings of Tasks 1, 2, and 4. Under the guidance of the FWS Project Officer and Regional Activity Leaders for Western Water Allocation, FWS personnel and allied agency staff engaged in planning and evaluating water resource development projects participated in the regional technical review and supplied additions as well as refinements to the interim handbook for its final preparation in Task 6.

Throughout the guide to the performance of improvement measures, there are two alternative formats employed in presenting the 60 types of measures. One format is in five parts:

- **Purpose** — the intended biological effects of the measure on habitats and populations
- **Illustration** — to show an actual application of the measure, report a range of design or performance characteristics, and cite basic reference documents providing detailed specifications
- **Limitation** — the important environmental, biological, engineering and administrative constraints on implementing the measure and achieving its successful performance
- **Performance** — to report the past performance of the measure toward achieving the intended levels of habitat and population improvement, including the degree of confidence placed in the performance assessment
- **Cost/Output** — the range of actual or surrogate monetary costs of applying the measure, along with the associated increases in biological output.

In the fifth part dealing with cost and associated output, increased biological output is estimated by "levels" of habitat or population improvement predicted by FWS biologists to result from implementing a recommended measure. For example the biologist may predict that a measure, if applied, will produce "maintenance" of habitat or population as compared to "curtailment" if not applied. Exhibit 5 explains these distinctions.



Levels of improvement were estimated by reporting the *actual* biological effects associated *with* implementing the measure for improvement as compared with the change of pre-project habitat or population *predicted* to result from operating the project *without* the measure.

Exhibit 5. Improvement in biological output.

The five–part format is used for describing and evaluating every measure recommended by the FWS where that measure was implemented in three or more cases at dam and reservoir projects selected for investigation under Task 2. Where only one or two cases of implementation occurred with some success, and/or where information for describing and evaluating the measure was obtained from the literature search and survey of current research under Task 4, a less detailed two–part format is employed. There is a description which combines the purpose and illustration of the measure, and an evaluation presenting limited or preliminary findings on performance or the potential effectiveness of the measure.

A scheme for classifying the 60 categories of habitat and population measures has been refined successively under Tasks 1, 2, 4, and 5. It is shown in the table of contents of this document and provides the organization of the handbook. There are six divisions and 36 subdivisions (called Sections) of Habitat Improvement Measures under Part One of the handbook; five divisions and 24 subdivisions of Population Improvement Measures under Part Two. Measures are classified as Habitat or Population Improvement Measures, depending on their predominant purpose; no measure is exclusively for one purpose or the other.

Contents

H6.0 General Practices

PART TWO: POPULATION IMPROVEMENT MEASURES

Reservoir Flood Basins

Selective Clearing H1.1

Purpose

The purpose of selectively clearing reservoir flood basins, as opposed to complete clearing, is to preserve or produce habitats for fish and other wildlife. Inundated trees and brush provide cover and feeding areas for fish, while exposed tree branches provide roosting and nesting habitat for a variety of wildlife including waterfowl, raptors and other non–game birds (see Exhibit 1). Of course, this habitat improvement measure is not a permanent one; as remaining vegetation decays, other measures may become necessary (see the following sections dealing with fish shelters and Section P4.1 on nesting structures). An additional purpose of selective clearing may be to aid in the reduction of debris in a reservoir. Often the greatest influx of fallen timber and other vegetative debris is from the watershed above the reservoir basin. By retaining some timber and brush in the upper end of a reservoir, the inflow can be screened to trap the debris.

Illustration

Selective clearing is usually recommended in terms of prohibiting clearing below or above certain reservoir contours such as that of the conservation pool or the annual average maximum pool. Some recommendations cite specific elevations more or less independent of operational levels. For example, at Tiber Reservoir in Montana, timber and brush were retained above the elevation of 3,000 feet. Other requests relate to restrictions on clearing in specific portions of a reservoir such as coves or the vicinity of the upper inlet. In some parts of the country, selective tree clearing is dependent on the species. Water–tolerant trees such as silver maple and oak are generally retained while others such as walnut are removed.

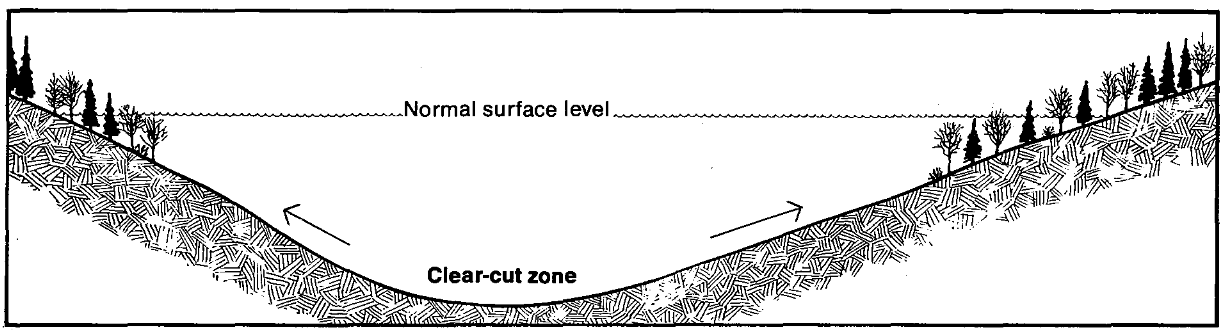


Exhibit 1. Cross-section of reservoir showing submerged and exposed trees and brush retained for fish and waterfowl habitats.

Limitation

The retention of standing trees within a reservoir may constrain recreational uses such as boating and water skiing. Sometimes, however, this practice can be beneficial as an alternative to zoning for preventing conflicts among recreational activities such as water skiing and fishing. Safety of recreationists also should be a consideration since wind can blow down limbs from dead standing trees. The aesthetics of a reservoir may be affected adversely by retention of trees and brush, particularly if dead or dying timber is silhouetted against the skyline. Fallen or dislodged trees and brush can create problems in the operation of a reservoir if they become free—floating.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high			medium			low		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	11	5	7	3	6	3	6	0	1	2
	Population	11	5	7	3	6	3	6	0	1	2
Marginally Successful	Habitat	6	1	0	1	3	5	3	2	1	2
	Population	6	2	0	2	2	6	2	2	0	2
Unsuccessful	Habitat	1	0	1	0	0	0	0	1	0	1
	Population	1	0	1	0	0	0	0	1	0	1

Exhibit 2. Success and confidence matrix for selective clearing of flood basins.

Performance

Review of 19 cases involving this type of improvement measure showed 11 of the applications reported as successful (Exhibit 2). Only one application was indicated as unsuccessful in producing habitat and population improvement. Apparent success of this measure was strongly correlated with factors and ratings of confidence, especially the soundness of habitat and population predictions used in classifying the extent of success.

Cost/Output

Selective clearing has little, if any, direct cost associated with its implementation. Unless specific trees are marked and saved, selective clearing will reduce construction costs because less area of the flood basin is cleared. However, recreational and other uses of the reservoir may be limited or precluded when trees are left standing. Therefore, the foregone benefits from these uses would constitute surrogate value for the cost of selective clearing. For the applications of this measure reviewed as part of the handbook preparation, data were not available for estimating this cost.

Project Review

CALIFORNIA:	Oroville, Stampede
IOWA:	Rathbun
KANSAS:	Glen Elder, Lovewell, Wilson
MONTANA:	Tiber
NEBRASKA:	Merritt, Trenton
OKLAHOMA:	Broken Bow, Fort Gibson, Optima
OREGON:	Prineville
SOUTH DAKOTA:	Angostura, Cold Brook
TEXAS:	Benbrook, Pat Mayse, Somerville, Town Bluff

The projects underlined had successful applications of this improvement measure.

Brush Shelters H1.2

Purpose

The purpose of brush shelters is to provide additional cover and feeding habitat primarily in warmwater fisheries. The shelters also serve as substrate and cover for periphyton and zooplankton. The available food and cover attracts small fish which in turn attract larger fish. Some spawning activity also has been observed in and around brush shelters.

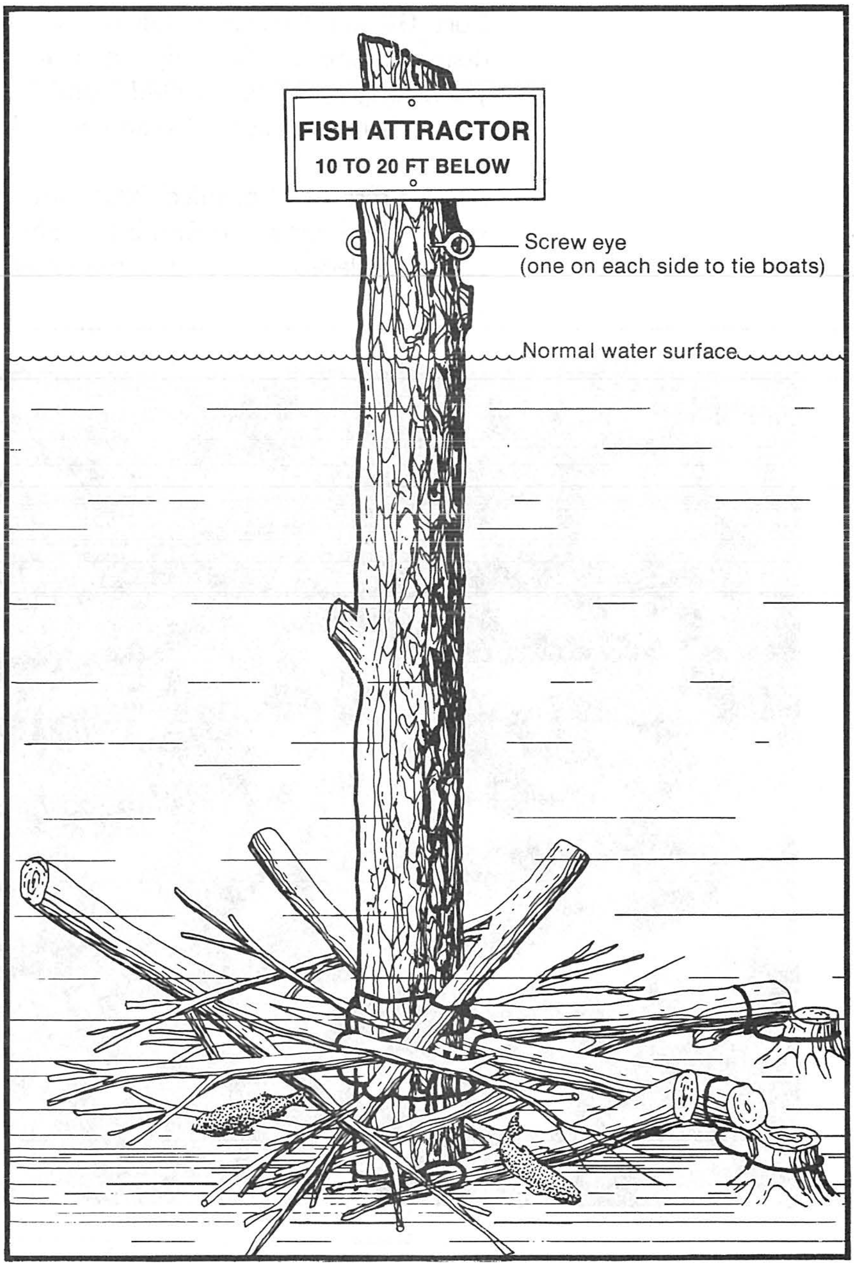


Exhibit 1. One type of brush shelter.

Illustration

The shelters can be made by a variety of methods. Exhibit 1 shows a method using one tree trunk to anchor trees and brush cut from the surrounding area. As indicated, signs or other markers and buoys should be used to indicate the location of all shelters for public use. If the reservoir basin must be cleared prior to filling, the trees and brush can be collected in piles using galvanized cables and screw—type telephone pole anchors to secure the shelter. At Fort Gibson Reservoir, Oklahoma, brush piles 30 to 40 feet in diameter and 20 feet high as well as windrow piles 250 to 300 yards long were constructed from the cleared material. These shelters were built about 1950 and are still in use today.

After a reservoir has filled, brush shelters still can be added by using the method shown in Exhibit 2. Shelters are constructed and strategically placed on ice—covered lakes. When the ice melts in spring,

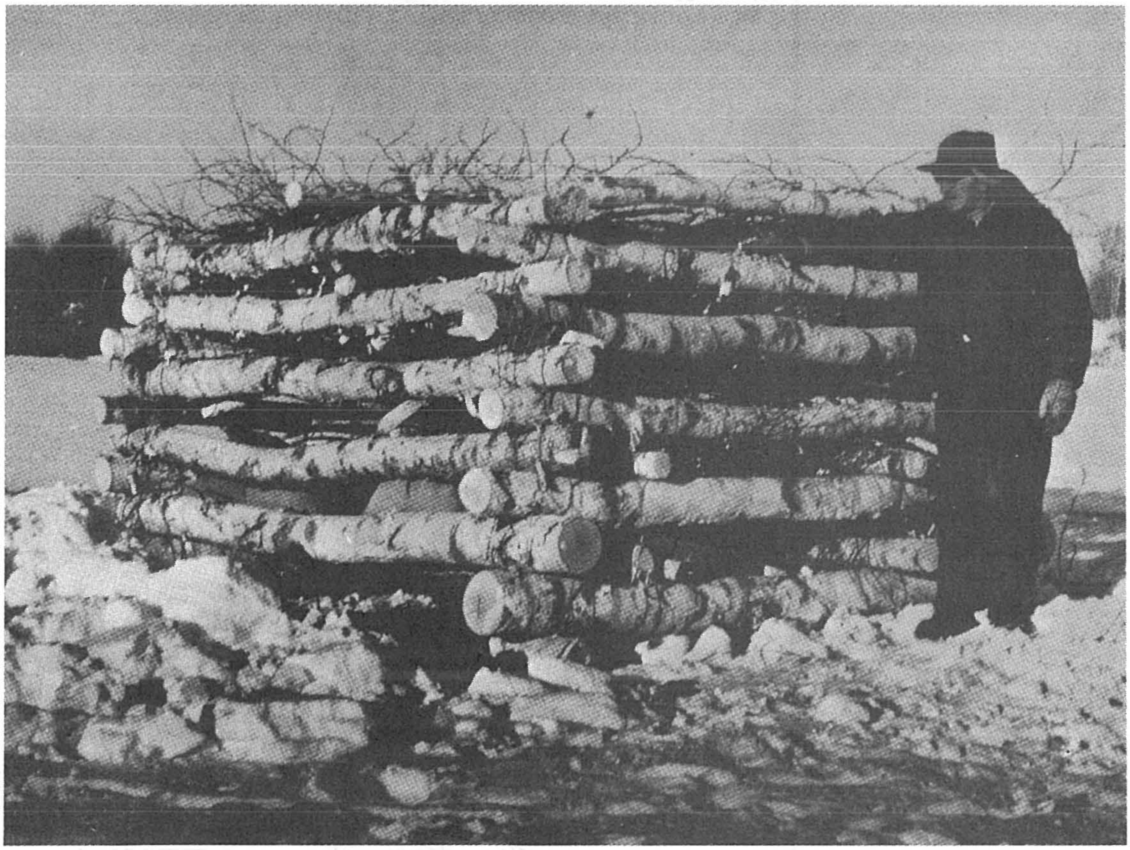


Exhibit 2. Brush shelter placed on ice-covered lake.

the weighted structures sink. The U.S. Forest Service recommends that brush shelters be installed in 10 to 15 feet of water and at least 150 feet apart on weed–free, hard–bottom sites.

Limitation

The primary constraint on the use of brush shelters is their effect on restricting boat traffic or other uses of the reservoir. For this reason, the shelters must be anchored securely in deep water or in shallow coves and other seldom–used areas. Brush shelters should be placed above zones of summer and winter stagnation, but should not be subjected to repeated wetting and drying because of resulting increased rates of decomposition. These requirements may make the shelters unusable in reservoirs with widely varying surface levels. Excessive siltation in and around brush shelters also can limit their effectiveness.

Performance

Most of the brush shelters assessed in the project investigations were judged to be successful (Exhibit 3). In the one application that was marginally successful, the confidence in both the degree of implementation and the reliability of reports of actual effects was rated low. Information from literature sources also indicates that brush shelters are generally successful in attracting fish, particularly sunfish, bass, and crappie. The shelters were found to be least effective in lakes and reservoirs with abundant natural cover. The effective

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high			medium			low		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	2	2	1	1	0	1	1	0	0	0
	Population	2	2	1	1	0	1	1	0	0	0
Marginally Successful	Habitat	1	0	1	0	0	0	0	1	0	1
	Population	1	0	1	0	0	0	0	1	0	1
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 3. Success and confidence matrix for brush shelters.

life of brush shelters may be as long as 20 to 25 years when oak and other long—lived trees and brush are used.

Cost/Output

Exhibit 4 lists the capital expenditure and operation and maintenance costs in 1977 dollars for a single brush shelter at two of the projects investigated, along with the increased biological output associated with each.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Glen Elder	$100	$5	Maintenance	Improvement	1
Fort Gibson	$ 25	$4	Maintenance	Improvement	1

Exhibit 4. Cost and associated biological output for brush shelters.

Project Review

KANSAS: Glen Elder

OKLAHOMA: Arbuckle, Fort Gibson

The projects underlined had successful applications of this improvement measure.

Tire Shelters H1.3

Description

Tire shelters, like brush shelters (Section H1.2), provide additional habitat for many types of fish, primarily warmwater species. Tire shelters serve as substrate for periphyton and provide cover and feeding habitat for zooplankton and fish. The shelters are constructed by binding tires together in various conformations (Exhibit 1) which are then sunk to form a reef or other structure on the reservoir bottom. Concrete or other ballast can be used to weight the structures and the tires are usually slashed so that air is not trapped.

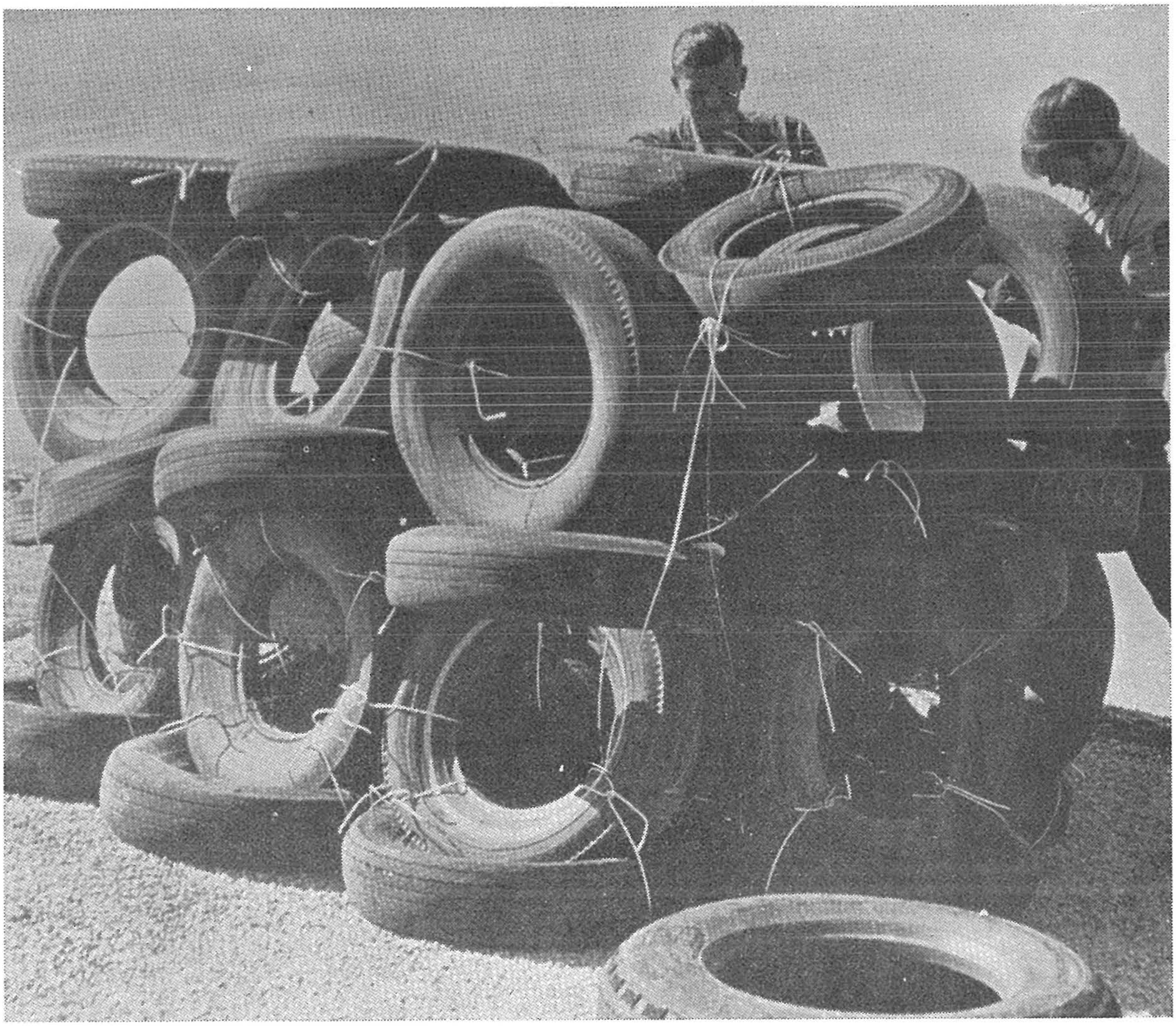


Exhibit 1. One form of tire shelter.

Evaluation

Tire shelters are considered by some authorities to have the most potential among the possibilities for fish shelters. Used tires are generally available and do not deteriorate rapidly when used in underwater shelters.

Prince and Maughan (1978) summarize evidence indicating the effectiveness of tire shelters or "artificial reefs" in concentrating fish and in improving the quality and productivity of a fishery. They also report that the reefs are economically practical, citing data from Smith Mountain Lake, Virginia, where 7,000 tires were used to form reefs covering 9,500 m^2. The total project cost was $4,998 of which $2,852 was donated as labor and materials by the surrounding community. Prince and Maughan conclude that in lacustrine environments tire shelters are an effective fishery management tool. As with brush shelters, however, excessive siltation and pool fluctuations may limit that effectiveness.

Reference

Prince, E. D. and O. E. Maughan, "Freshwater Artificial Reefs: Biology and Economics," Fisheries 3(1):5–9, January – February 1978.

Other Fish Shelters H1.4

Description

A variety of materials other than brush and tires (Sections H1.2, H1.3) have been used to construct fish shelters. Most of the first work with shelters or artificial reefs was done in coastal marine habitats. Stone (1978) summarizes much of this work. Building reefs from old tires originally was for saltwater application. Car bodies also have been used to provide shelter in both fresh water and saltwater. Commonly used materials are building rubble, concrete pipe, cement blocks, and quarry stone.

Artificial kelp beds have been experimented with in the Salton Sea by California fishery researchers. The beds consist of strip plastic weighted at one end so the strips stand vertically, resembling kelp beds. The strips are 1 to 1½ inches wide, 3 to 4 feet long, and are placed in water about 16 feet deep. Another technique is the construction of stake beds for fish shelters. Stake beds are built by driving 4 to 6-foot-long wooden slats about 1 to 2 feet apart into a reservoir bottom. The slats are usually about 1 inch by 2 inches in cross section, though sawmill strips and pipes also have been used.

Evaluation

Of the possibilities discussed above, concrete pipe and the artificial kelp beds appear to have the most potential. Concrete pipe or drain tiles provide good spawning habitat for catfish when one end of the pipe is closed or the pipe is partially buried in a reservoir bank (see Exhibit 1). Artificial kelp beds have been reasonably successful

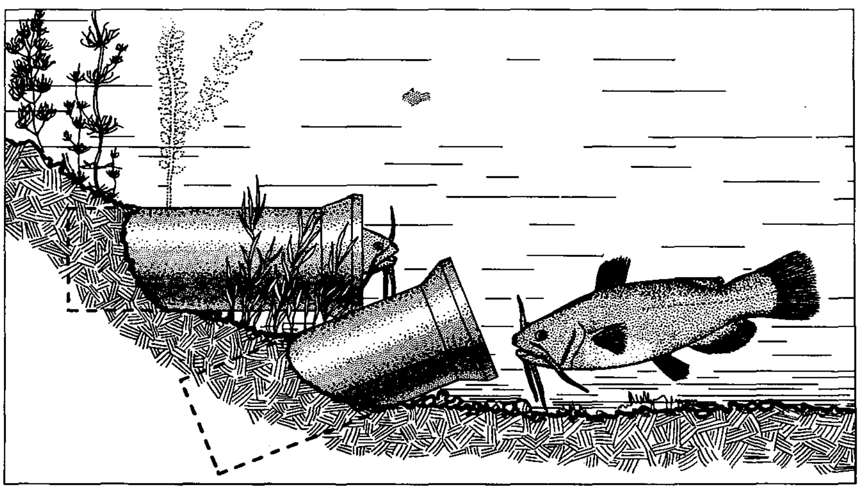


Exhibit 1. Drain tiles used for fish shelter and spawning habitat.

at providing habitat in saltwater and further experimentation soon will be started in fresh water. Different authorities do not agree on the effectiveness of stake bed shelters. In some cases, they have been successful in attracting crappie but the shelters are relatively expensive and also difficult to build and handle. Car bodies are also expensive and difficult to handle; in saltwater they deteriorate in 3 to 5 years. Building rubble, cement blocks and quarry stone all have been more or less unsuccessful. When used alone, they tend to sink into the bottom and do not create much habitat diversity.

Reference

Stone, R. B., "Artificial Reefs and Fishery Management," Fisheries 3(1): 2-4, January – February 1978.

Exposed Area Planting H1.5

Description

This measure involves planting in areas exposed by reservoir drawdown. To be effective, this measure must be combined with a plan for seasonal manipulation of the reservoir pool (see Section H2.3). The purposes of exposed area planting include the provision of waterfowl food and cover in the fall and fish spawning and nursery habitat in the spring. Planting can also improve water clarity by reducing bank erosion and controlling turbidity from colloidal clay. Bank erosion is reduced because the roots of the vegetation help to stabilize the soil along the shoreline, thus decreasing the effects of wave action. Clay turbidity is controlled because, as the vegetation decomposes, organic compounds are released which are oppositely charged from the clay particles. As a result, the organic and clay particles tend to associate and settle out. The decomposing vegetation also will add nutrients to the water, thereby increasing overall lake productivity.

Planting is usually done during a major drawdown in midsummer. The drawdown is held until the vegetation matures in the fall, after which it is partially flooded to provide waterfowl food and cover. After a winter drawdown, the vegetation is reflooded in the spring to provide improved habitat for fish spawning and early growth of the fry. The types of vegetation planted include Japanese millet, hybrid sudan–sorghum, annual rye grass, wheat, and rye. Wheat and rye are normally seeded at 75 to 100 pounds per acre while the others range from 10 to 20 pounds per acre. Seeding has been done by hand and from an airplane.

Evaluation

Work by the Kansas Fish and Game Commission has shown that exposed area planting in conjunction with seasonal manipulation of reservoir pools will produce desirable results in the managed reservoirs. Several Kansas reservoirs, including Council Grove and Elk City, have had greater fish production of both game and forage species since these management plans have been implemented. Waterfowl usage and water clarity also have improved. Proposals for future reservoir operation include both planting of exposed areas and water level manipulation on a seasonal basis.

Raised Spillways H1.6

Description

The obvious purpose of raising a dam spillway is to increase the area and depth of a reservoir. With suitable dam sites becoming scarce, it may become economically feasible and necessary to enlarge existing reservoir flood basins for increased water storage. Such increases generally will benefit reservoir fisheries. With more habitable area, total lake production will increase. In colder parts of the country, a larger reservoir may prevent winterkill which historically has plagued the lake. In warmer areas, a larger reservoir may provide new habitat for a coolwater fishery. In the only project reviewed at which this measure was implemented (Cold Brook Dam, South Dakota), the spillway was raised 7 feet. This addition increased the reservoir size by 10 surface acres, a gain of almost 30 percent.

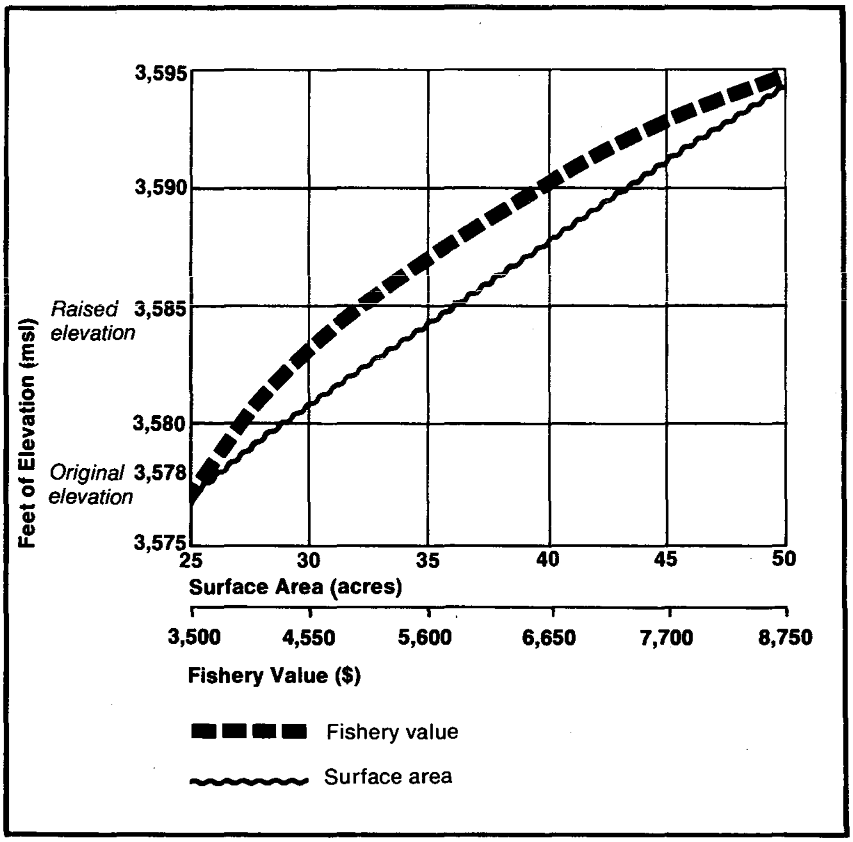


Exhibit 1. Potential annual fishery value of Cold Brook Reservoir, South Dakota, at various normal pool elevations (adjusted to 1977).

Exhibit 1 presents the estimated potential annual values of the reservoir fishery at Cold Brook Dam for various normal pool elevations raised above the height originally planned. The increased fishery value is projected on the basis of increased surface area.

Evaluation

The single application of this measure was assessed to be successful (Cold Brook Dam, South Dakota). Constraints on carrying out this measure include the obvious hydrographic and engineering as well as cost limitations on increasing the size of a dam and reservoir. In addition, wildlife habitat surrounding the reservoir would be affected adversely by further flooding and encroachment.

Reservoir Conservation Pools

Stage Filling H2.1

Description

Stage or incremental filling is a management option which can be employed when the immediate need for water impoundment is less than the available storage capacity of a new reservoir. Many reservoirs are constructed with most of the capacity set aside for anticipated future water needs. In most of these cases, the reservoirs are filled as soon as possible and the water is held and not used. Stage filling is an alternative to this practice and it should be proposed early in the planning process. Upon completion, a reservoir is partially filled to meet immediate demands. Water needs are then reassessed periodically on the basis of a short–term projection. It has been recommended that this projection not exceed 5 years into the future. When deemed necessary, the reservoir is filled in increments based on the projected demands of succeeding 5–year periods.

A proposed incremental filling program for Millican Lake in Texas is presented as Exhibit 1. The program, as originally promoted by

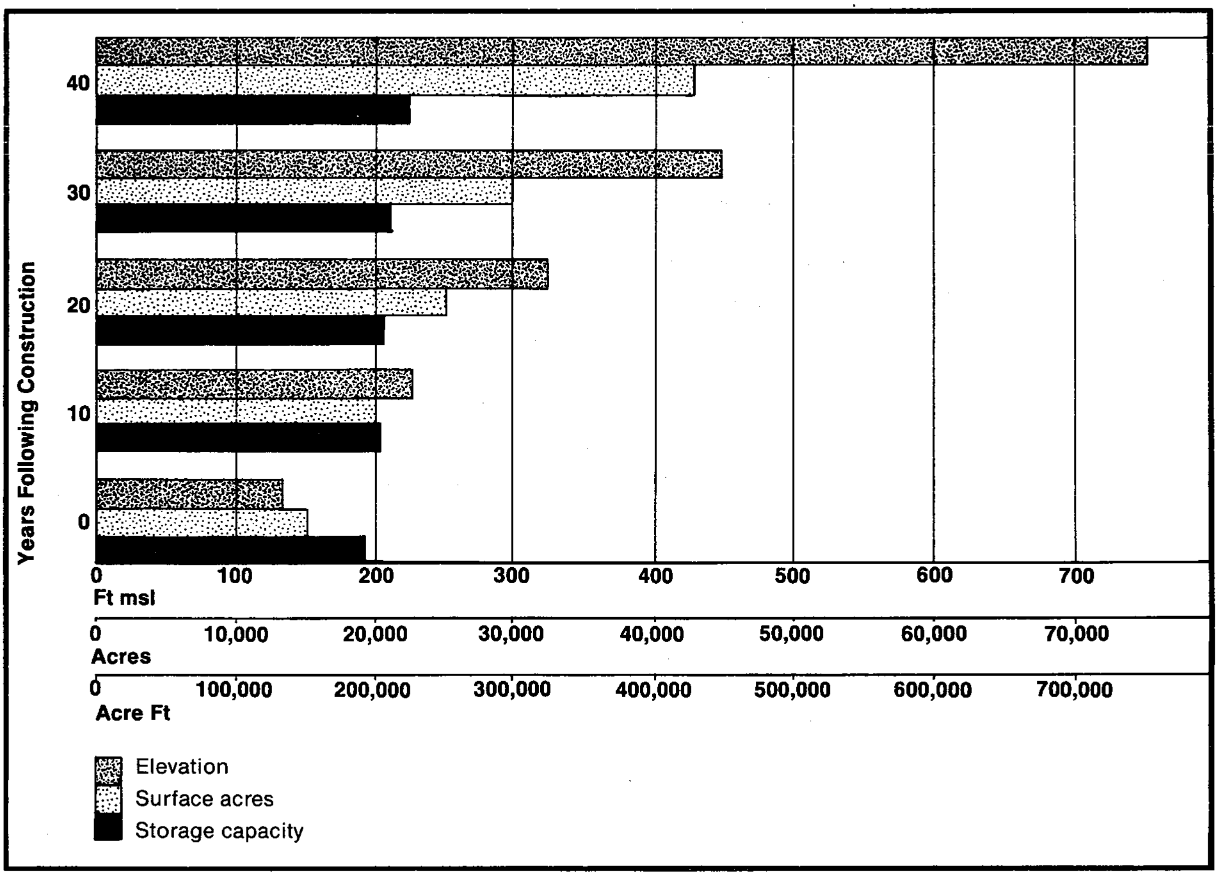


Exhibit 1. Proposed incremental filling program for Millican Lake, Texas.

the U.S. Fish and Wildlife Service, assumed that 20% of the reservoir yield would be needed initially and that demand would increase by an additional 20% for each of the succeeding 10–year periods.

The habitat benefits of stage filling are many. The ultimate loss of wildlife habitats to be flooded by the reservoir can be delayed, resulting in extended public and wildlife use. The extensive flooding of stream habitat above the dam can also be delayed. Furthermore, the reservoir fishery will increase in both quality and quantity with stage filling. A long recognized but complex problem is the decline of sport fish production a few years after initial reservoir impoundment. This apparently is related to the decomposition of materials originally inundated in the flood basin. By incrementally filling a new reservoir, new materials are inundated with each change of pool elevation. This practice will result in sport fish production nearly as high as with a full impoundment, but spread out and sustained over a greater period of time. Freshly inundated vegetation provided in stages also will increase waterfowl and other wildlife benefits.

Evaluation

In the long run, periodic review and revision of a filling program are more efficient than entirely filling a new reservoir and foregoing the possibility of modification if original projections of water demand turn out to be in error. The major advantage of stage filling is that it greatly increases flexibility for coping with unforeseen events. Stage filling is a relatively new and untried management option. Consequently, there are few cases where it can be evaluated. However, Melvern Reservoir in Kansas was filled incrementally over a 3–year period. Despite the relative brevity of this filling period, good year classes of northern pike were produced, utilizing newly–flooded prairie grasses.

Some problems in the implementation of stage filling have been noted. Where the sustained yield from a watershed has high annual variability, increased projection spans and larger increments of storage capacity may be warranted. Another problem concerns the acquisition of land for the reservoir site. In many situations, land–owners sell only a portion of their property because the remainder of their land will benefit from the new lakefront. By delaying reservoir filling, land acquisition may become more difficult and more expensive. However, early planning may avoid this pitfall.

Fluctuation Control H2.2

Purpose

Sudden and severe reservoir pool fluctuations often are the result of the operation of hydroelectric power plants (see Section H4.2 on flow fluctuation control). Other pool fluctuations, such as those due to seasonal variations in watershed yield and water diversion or consumption, are generally much slower; those due to pool manipulation for habitat improvement purposes may be highly beneficial (see Section H2.3). The purpose of minimizing sudden fluctuations, particularly downward movements, is to prevent dewatering of benthic fauna, fish spawn, and riparian vegetation. Excessive bank sloughing also can result from sudden pool depletions.

Illustration

For each of the projects assessed where this measure was requested, recommendations were made in qualitative terms such as asking for pool fluctuations to be "kept to a minimum" or pool levels to be maintained "as stable as possible". The control of streamflow fluctuations often is requested with specified limits to variability such as a maximum change in wetted perimeter in inches per hour or feet per day. Where possible, similar recommendations for pool fluctuation control would aid in understanding and applying the improvement measure. The implementation of fluctuation control usually is accomplished administratively by placing restrictions in the adopted operating procedures. However, at Angostura Dam in South Dakota, pool fluctuations are controlled hydraulically by automatic spillway gates which open and close as the reservoir surface level rises and falls.

Limitation

The major constraints on limiting pool fluctuations are the resulting losses of reservoir operating flexibility for water supply, irrigation, power production, and flood control. These constraints impose a serious limitation on implementing related recommendations.

Performance

While this measure was not implemented successfully at any of the projects reviewed, three applications were deemed marginally successful (Exhibit I). Apparently, where this improvement measure was fully implemented as recommended, it tended to be more successful, and the converse appears to be true. The heavy constraints cited under Limitation are inclined to discourage full implementation.

Cost/Output

The cost for controlling reservoir pool fluctuation is equivalent to the quantity of water use forgone, such as for hydroelectric power production, times the unit price of the water. However, for the four applications reviewed, this type of cost surrogate could not be calculated because pool fluctuation control was recommended in such general terms.

Project Review

IDAHO: Cascade

KANSAS: Kirwin

SOUTH DAKOTA: Angostura

WYOMING: Boysen

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high			medium			low		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	0									
	Population	0									
Marginally Successful	Habitat	2	1	1	1	1	0	1	0	1	0
	Population	3	2	1	1	1	0	2	0	2	0
Unsuccessful	Habitat	1	0	0	0	0	1	0	1	0	1
	Population	1	0	0	0	0	1	0	1	0	1

Exhibit 1. Success and confidence matrix for pool fluctuation control.

Seasonal Manipulation H2.3

Description

The habitat improvement purposes of manipulating reservoir pool levels are to improve fish spawning habitat and feeding conditions for fish and wildlife, as well as to improve water quality. A typical water level manipulation plan for a warmwater fishery is presented in Exhibit 1. Seasonal manipulation primarily pertains to warmwater and coolwater fisheries because of the general dependence of these fish on shallow-water lacustrine habitat for spawning and rearing. As shown in Exhibit 1, the water level is raised gradually, beginning around the first of March. The rise should be high enough to cover some terrestial vegetation, rocks and gravel. This will provide excellent spawning habitat for bass, sunfish, walleye, northern pike, and various species of forage fish, as well as stimulating increased production because of the greater available habitat. In addition, the stoppage or reduction of flow from the dam outlet, to allow the water level to rise, will prevent the downstream loss of walleye which congregate near the dam to spawn on the rocks.

From approximately mid—May through the beginning of July, water levels should be held stable or slightly increased to maintain nursery habitat for the development of fry. The inundated vegetation provides excellent cover for the young fish in addition to stimulating production of zooplankton, a major component of fish diets. As the vegetation decays, it returns nutrients and organics to the water. The organic molecules are positively charged because of partial decomposition while colloidal clay particles, which suspend easily in water and can cause high turbidity, tend to be negatively charged. As a result of the opposite charges, the clay particles and organic molecules will bond together and precipitate out of solution, thereby increasing water clarity.

An abrupt decrease in water level should occur next, during the first half of July. This exposes mudflats and other shoreline areas for natural revegetation and additional planting (see Section H1.5). Besides providing cover, the vegetation will stabilize shorelines and reduce erosion. The drop in water level will also tend to limit reproduction by rough fish, particularly carp, because they usually spawn early in July and their eggs will be exposed by the receding water. This low pool level should be held through September for two purposes: it allows newly planted vegetation time to mature; and it forces forage fish out of shallow—water weedbeds into open water where they can be attacked more successfully by piscivorous gamefish. This stimulates increased growth of gamefish and inhibits the tendency for overpopulation by forage fish.

Beginning in October, the pool level is gradually raised again to partially inundate the new crop of vegetation. This benefits waterfowl by providing additional food and cover. This level is held until the waterfowl migrate from the reservoir. The final step of the annual plan is to lower the water level in December to prepare the shoreline for next season's flooding. This decrease in level provides reservoir capacity for spring runoff and flood flows and also reduces the damage to shoreline vegetation by ice and waves. In addition, the low level provides time for rocky areas to be cleaned of silt and algae by the elements. This will benefit egg adhesion and survival of next year's spawn of species such as walleye.

The management plan outlined here is a generalized version for warmwater fisheries derived from several plans reported by the Kansas Fish and Game Commission. While this outline should apply to other warmwater fisheries, unique plans for individual reservoirs are necessary. The individual plans should consider species present, timing of various lifecycle stages, and the operational requirements of the specific reservoir. Amounts of drawdown vary but Kansas reservoirs generally reduce total reservoir surface area by 10 to 20 percent. However, excellent results have also been reported in reservoirs drawn down by 80 percent.

Evaluation

The following information is also based on results reported by the Kansas Fish and Game Commission and on a review of the effects of water level management presented by Groen and Schroeder (1978). The effectiveness of water level manipulation is sometimes difficult to discern. Several cycles of operations may be needed to show results. In some cases, it is impossible to maintain strict control of water levels because of weather patterns and the use of the reservoir for other purposes.

Council Grove Reservoir was the first Kansas impoundment where water level manipulation was implemented. The results included decreased turbidity, increased waterfowl use, and improved production of game and forage fish. Walleye as well as other piscivorous species showed increased recruitment and growth due to better nursery conditions and greater abundance and vulnerability of forage species. The population percentage by weight and numbers increased for gamefish and decreased for rough fish. Total catch and catch per unit effort increased.

Calendar Period	Level Manipulation	Habitat and Population Improvement Purposes
Jan 1 – Feb 28	Hold low	Provide spring runoff and flood capacity; allow weather to clean rocky shorelines of algae, silt.
Mar 1 – May 15	Increase gradually	Inundate vegetation and rocks for improved spawning; reduce walleye losses through dam outlets.
May 16 – Jun 30	Hold high	Maintain fish nursery habitat; decompose vegetation for nutrients and turbidity control.
Jul 1 – Jul 15	Decrease abruptly	Expose shorelines for revegetation; dessicate rough fish spawn.
Jul 16 – Sep 30	Hold low	Expose forage fish to predation; allow vegetation to mature.
Oct 1 – Nov 15	Increase gradually	Partially inundate vegetation for increased waterfowl food and cover.
Nov 16 – Dec 15	Hold intermediate	Maintain for maximum waterfowl use.
Dec 16 – Dec 31	Decrease gradually	Reduce ice and wave damage to vegetation; prepare for next season.

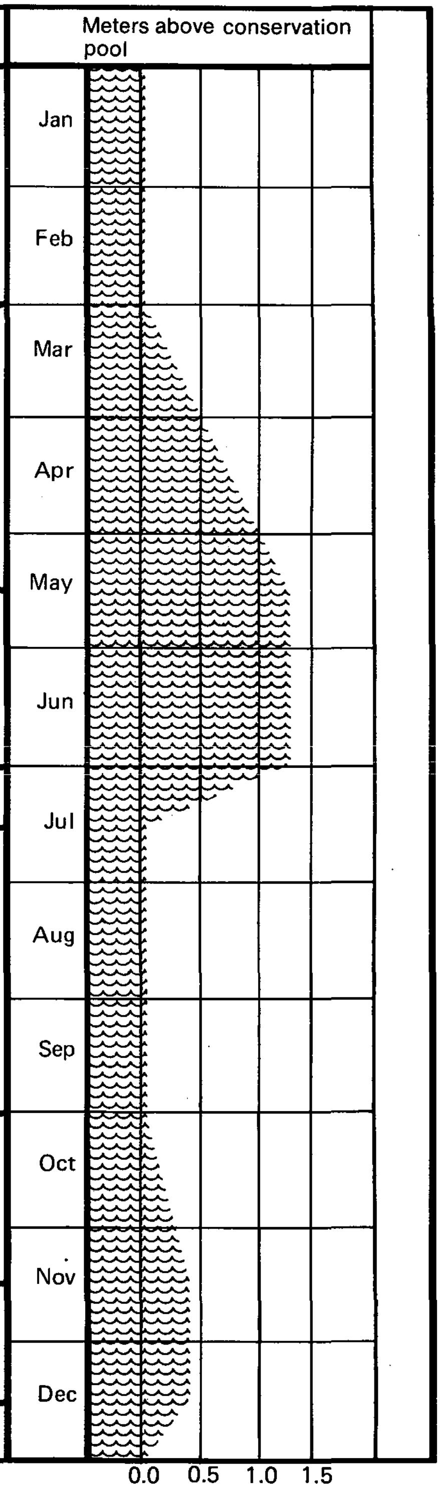


Exhibit 1. Graph and synopsis of a typical water level manipulation plan for a warmwater reservoir (from Groen and Schroeder, 1978).

Other Kansas reservoirs showed similar results. Pomona Reservoir had increased recruitment of largemouth bass and a decrease in the carp population. Waterfowl conditions also improved. John Redmond Reservoir had good growth and survival of stocked walleye fry compared to poor results of previous years without a water level management plan. Water clarity improved as evidenced by Secchi disk transparency values which increased 2 to 4 times following level manipulation and revegetation of shorelines. Milford Reservoir had a 375-percent increase in the number of spawned walleye in addition to increased survival of stocked northern pike fingerlings with a level management plan.

Reference

Groen, C. L., and T. A. Schroeder, "Effects of Water Level Management on Walleye and Other Coolwater Fishes in Kansas Reservoirs," presented at the North American Coolwater Fisheries Symposium, St. Paul, Minnesota, March 1978.

Minimum Pools H2.4

Purpose

Minimum pools are requested for some reservoirs to provide an amount of water considered essential for the survival of fish populations. Maintenance of a minimum reservoir pool reduces fish losses and thereby reduces the need for annual restocking to maintain adequate populations. Minimum pools improve the holdover capacity of a reservoir, which will result in increased yield because smaller fish can be stocked.

Illustration

For the projects examined, minimum reservoir pools ranged from 1,300 acre–feet at Lemon Reservoir in Colorado to 50,000 acre–feet at Cochiti Reservoir in New Mexico. This range represented approximately 1 to 12 percent of the total live storage capacity. Exhibit 1 presents the distribution over this range for nine applications which were analyzed.

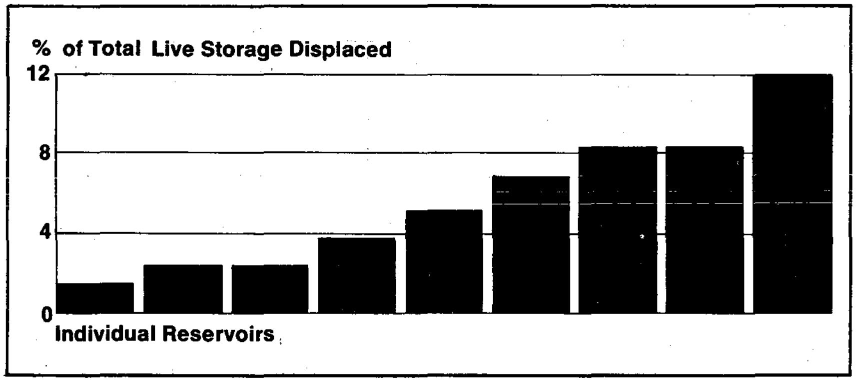


Exhibit 1. Distribution of live reservoir storage capacity displaced by minimum pool reservations at nine reservoirs.

Limitation

The major constraints on the sizes of the pools reserved are the resulting loss of water storage capacity for irrigation and power production or the decrease in reservoir capacity for flood control. The size of minimum pools only allows for survival of the fish populations. If the reservoir is held at this low level for extended periods, loss of year classes and other population degradation may result. An additional constraint concerns trade–offs between maintaining a minimum pool for habitat and population protection and providing sufficient reservoir releases to maintain the downstream fishery, depending on the comparative resource values downstream and in the reservoir.

Performance

Most applications of this improvement measure were judged to be successful with a high degree of confidence; no cases were judged to be unsuccessful (Exhibit 2). Successful cases were generally associated with a high degree of implementation.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high — Degree of implementation	high — Soundness of predictions	high — Reliability of reports	medium — Degree of implementation	medium — Soundness of predictions	medium — Reliability of reports	low — Degree of implementation	low — Soundness of predictions	low — Reliability of reports
Successful	Habitat	8	7	5	5	0	3	3	1	0	0
	Population	7	7	5	5	0	2	2	0	0	0
Marginally Successful	Habitat	3	2	0	0	1	3	2	0	0	1
	Population	5	2	0	0	1	4	4	2	1	1
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 2. Success and confidence matrix for minimum pools.

Cost/Output

To derive an equivalent cost of reservoir storage capacity reserved as a minimum pool, the following assumptions were made:

- The specified minimum pool, exclusive of dead storage in the reservoir, represents the actual storage reserved for conservation
- Total live capacity (total capacity minus dead storage) represents the storage repayment potential
- Potential repayment by irrigators, power producers, and municipal/industrial users is a surrogate for the cost of live storage forfeited to maintain a minimum pool.

Therefore, for each reservoir a dollar value per acre—foot of capacity was derived by dividing expected repayment over the project life by the amount of live storage minus the amount of the conservation pool. This figure was then multiplied by acre—feet of conservation storage exclusive of dead storage. For the seven applications lending to this analysis, costs ranged from $30 thousand to $7.9 million with an average cost of $1.8 million (Exhibit 3).

Minimum Pools H2.4

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Pueblo	$7,980,000	––	Curtailment	Improvement	3
Sugarloaf	$2,100,000	––	Maintenance	Improvement	1
Reudi	$1,545,000	––	Curtailment	Maintenance	2
Stampede	$ 608,000	––	Curtailment	Maintenance	2
Joe's Valley	$ 585,000	––	Curtailment	Improvement	3
Lemon	$ 46,000	––	Curtailment	Maintenance	2
Meeks Cabin	$ 30,000	––	Maintenance	Maintenance/ Improvement	0.5

Exhibit 3. Cost and associated biological output for minimum pools.

Project Review

CALIFORNIA Sacramento River (2 cases), Stampede

COLORADO: Lemon, Pueblo, Ruedi, Sugarloaf

MONTANA: Beaver Creek

NEW MEXICO: Abiquiu, Cochiti

NORTH DAKOTA: Baldhill

UTAH: Joe's Valley

WYOMING: Meeks Cabin (successful for habitat improvement)

The projects underlined had successful applications of this improvement measure.

Aeration-Destratification H2.5

Description

Aeration can be described as a process by which oxygen is added to or assimilated by water. Destratification is a process by which the density layering of a body of water is disrupted. By forcing the colder, denser water from the bottom of a reservoir to circulate with water from the surface, temperature and density differences are decreased, allowing wind and convection currents to further mix the impoundment. The processes of aeration and destratification are usually interdependent, i.e., when one occurs, the other does also. The extent of this, however, depends on the method used to effect aeration or destratification.

Several objectives may be met by aerating and destratifying a reservoir. Ice formation can be prevented by raising warmer water from the bottom to melt holes at the surface. This will benefit a winterkill—prone reservoir by allowing reaeration from the atmosphere. Ice has also been melted to provide an open channel across a reservoir for deer and other big game to swim through so they do not become trapped by falling through the ice. Destratification will lower surface water temperatures during the summer, which can reduce evaporation losses and control algae growth. Aeration can reduce the effects of eutrophication by providing critical oxygen to the water for metabolism and decomposition. Lake productivity can be increased by circulating nutrient—rich water from the bottom strata. In addition, the quality of discharge water can be improved by aeration and destratification in the reservoir. This can benefit fish and wildlife downstream and provide better raw water for a drinking supply.

Many types of equipment and methods have been used for aerating and destratifying. Some of the techniques are discussed below, but a more complete review can be found in King (1970) and Toetz, Wilhm, and Summerfelt (1972). The injection of compressed air is one technique which has been used. The air can be released using a diffuser such as perforated pipe anchored to the bottom of the reservoir. An example of this system is shown in Exhibit 1. Some immediate aeration results from the air bubbles, but the primary function is the "chimney effect" by which water from the bottom is raised in a current established by the rising bubbles. This produces destratification and additional aeration when the water comes in contact with the atmosphere at the surface.

Another device utilizing compressed air is the aerohydraulic gun. Exhibit 2 presents a model devised by the Bureau of Reclamation. The bubble trap at the bottom collects air from a compressor and intermittently releases a single large bubble into the plastic pipe. As the bubble rises in the pipe, it acts like a piston and pushes the water above it towards the surface. The frequency of bubbles is controlled by the air flow from the compressor.

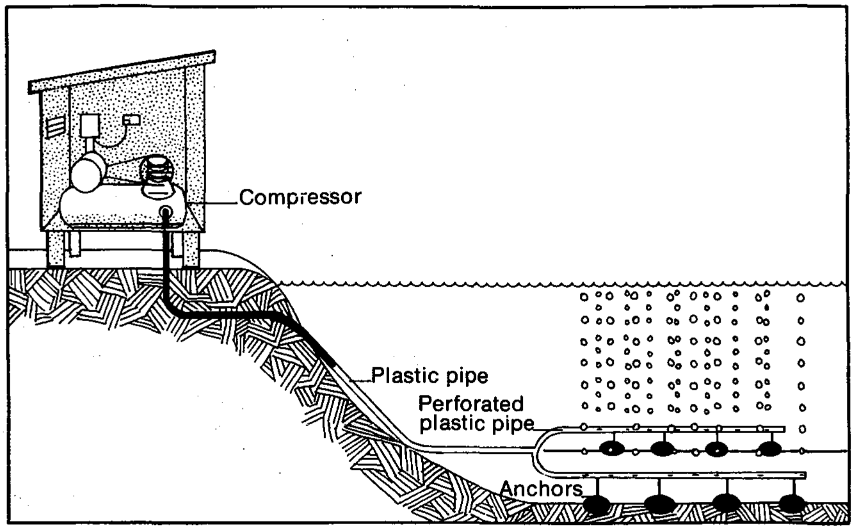


Exhibit 1. Compressed air diffusion system for aeration-destratification.

Liquid oxygen can be used as a means of reservoir aeration. Molecular oxygen is released through a diffuser, such as a perforated pipe or ceramic plate, which breaks the flow into small bubbles. As the bubbles rise through the water, the oxygen is absorbed directly. Stratification in the reservoir is maintained because only small amounts of gas are released. The injection of pure oxygen in front of penstocks or directly into turbines has been suggested as a means of improving downstream water quality below hydroelectric dams. The effects on structural components are unknown.

A technique for destratification uses a high–volume, low–pressure pump. An original design of a water mixing pump is presented in Exhibit 3 (from Symons, 1969). The impeller draws water through the suction line from near the bottom and discharges it at the surface. The velocity of the discharge flow causes sufficient turbulence to mix the cold bottom water with large amounts of surface water. Because the water is not raised above the surface, high volumes of water can be pumped with relatively little power. A different version of the pump forces water down from the surface to the bottom.

Other techniques for aeration and destratification include surface spraying, cascade weirs in inflow streams, submerged weirs, mechanical agitators, and "U–tubes". The reports mentioned above (King; Toetz, et al) provide reviews of these techniques as well as bibliographic references.

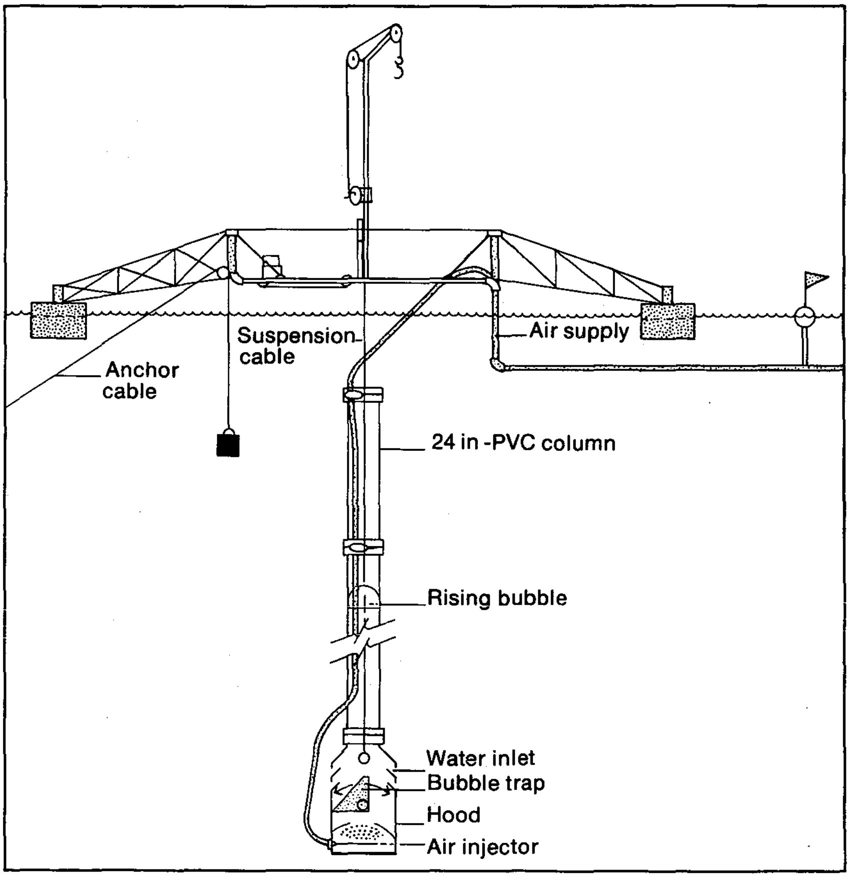
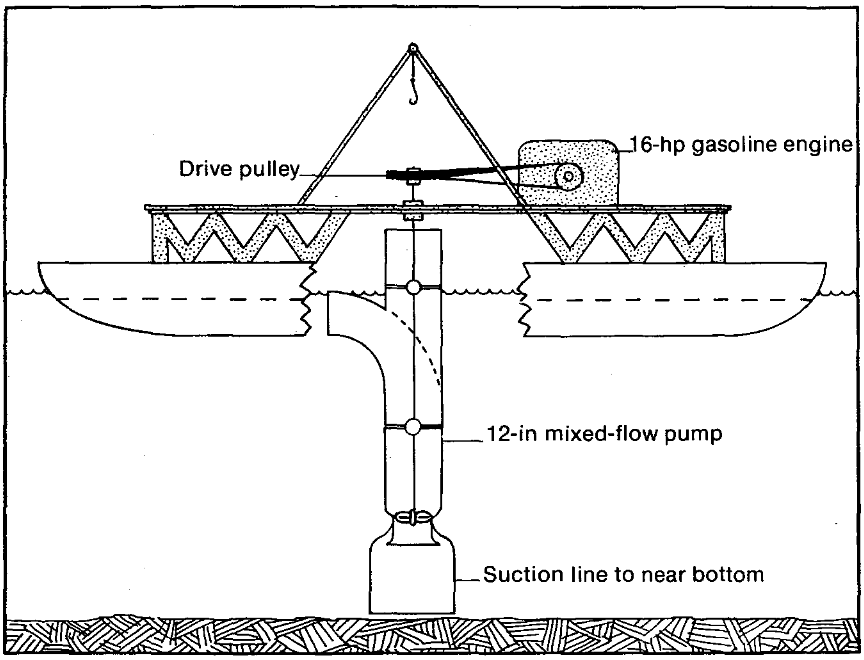


Exhibit 2. Aerohydraulic gun for aeration-destratification.

Evaluation

Aeration and destratification have usually been successful towards increasing dissolved oxygen concentrations, decreasing levels of carbon dioxide, hydrogen sulfide and ammonia, and increasing survival and production of zooplankton and fish. Additional habitat has been provided by the prevention or reduction of anoxic conditions in some reservoirs. A more indepth analysis of physical and biological reactions to aeration and destratification is provided in Toetz, et al. Constraints on these procedures include the costs for equipment, materials, and operation. The labor necessary to maintain some of the devices such as pumps and compressors may be a limiting factor. Costs for aeration and destratification may be

Exhibit 3. Water mixing pump for aeration-destratification.



offset by reduction in the need for annual stocking due to summer or winter fish kills; the increased yield of the fishery because smaller fish can be stocked without fear of seasonal kills; and the reduced need for extensive filtering and chlorination for an adequate drinking water supply.

Additional constraints include the possibility of promoting anoxic conditions by the resuspension of decomposing sediments. This is particularly critical during the first year of operation, though the possibility of anoxia should decrease as seasons of aeration continue. Also, by destratifying a reservoir, overall water temperature or the heat budget will fall below normal during the winter and climb above normal during the summer. This may reduce or eliminate some of the resident biota of the reservoir. A solution to this problem may lie in hypolimnetic aeration. With this technique, only the hypolimnion is aerated while the temperature regime and stratification pattern are not altered significantly. Thus it may be possible to maintain a "two–story" fishery, i.e., a warmwater fishery in the epilimnion and a coldwater fishery in the hypolimnion. Again, Toetz, et al provide further discussion.

Reference

King, D. L., "Reaeration of Streams and Reservoirs, Analysis and

Bibliography," U.S. Bureau of Reclamation Report No. REC–OCE–70–55, December 1970.

Symons, J. M., (ed.), Water Quality Behavior in Reservoirs, U.S. Public Health Service Publication No. 1930, 1969.

Toetz, D., J. Wilhm, and R. Summerfelt, "Biological Effects of Artificial Destratification and Aeration in Lakes and Reservoirs — Analysis and Bibliography," U.S. Bureau of Reclamation Report No. REC–ERC–72–33, October 1972.

Dam Discharge Systems

Low-Level Intakes H3.1

Purpose

The primary function of a low—level intake is to allow discharge water to be drawn from the lower strata of a reservoir. The lower layers are generally colder than near the surface and will provide a coldwater fishery habitat downstream where this is desirable. In smaller reservoirs, low—level intakes also may be used to release fish such as Kokanee salmon into the stream below the dam or to lower the pool for better control of undesirable fish populations. In larger reservoirs, a low—level intake will usually draw water from the hypolimnion which fewer fish inhabit, thus providing a means to protect the lake fishery. Other purposes of these intakes may include the release of sediment—enriched water for the preservation or enhancement of downstream habitats such as marshlands and draining or flushing a reservoir for safety and maintenance reasons.

Illustration

Recommendations for low—level intakes generally specify a particular elevation at which to draw stored water. The intake at Navajo Dam, New Mexico, for example, was requested to draw from a level 40 feet below the prescribed minimum pool elevation of 5,990 feet. The intake is an inverted bell—type structure which decreases the inadvertent release of fish from the reservoir. Other recommendations did not specify elevation or depth; the intake at Rock Creek Diversion Dam, California, was requested to be as low as "practicable".

Limitation

One of the major factors to consider in recommending a low—level intake is the limitation of benefits to the downstream fishery. Since only cold water may be discharged, resident warmwater species may be affected adversely. It is also possible that discharge water may be too cold to effectively trigger the spawning migration of some coldwater species. In addition, with the limited flexibility of this system, all of the suitably cold water may be discharged before the start of the spawning season.

Other limitations to the effectiveness of low—level intakes mostly pertain to water quality problems. In some reservoirs, the possibility of discharging large amounts of silt which collect on the bottom may be prevalent. While the flushing action will benefit the reservoir, the downstream fishery may be damaged severely due to silting of gravel beds and higher stream turbidity. Also, water remaining in the hypolimnion of a lake may be low in dissolved oxygen and high in carbon dioxide, hydrogen sulfide, and dissolved heavy metals, which may worsen the downstream impact. It is possible, however, to design stilling basins to reaerate this water as it is discharged (see Section H3.4).

Performance

Exhibit 1 indicates there were no unsuccessful applications of this measure among the projects investigated. Confidence in the reported effects, however, was rated medium, indicating there were no quantitative follow–up studies. Overall success of low–level intakes is questionable, primarily because of the lack of flexibility in operation, as described in the sub–section on Limitation. In situations where water temperature selectivity is desirable, multi-level intakes (Section H3.2) should be considered as a project feature.

Exhibit 1. Success and confidence matrix for low-level intakes.

Classification of Success Using Habitat and Population Improvement Criteria		*number of cases*	Confidence Factors and Ratings: *high* — Degree of implementation	*high* — Soundness of predictions	*high* — Reliability of reports	*medium* — Degree of implementation	*medium* — Soundness of predictions	*medium* — Reliability of reports	*low* — Degree of implementation	*low* — Soundness of predictions	*low* — Reliability of reports
Successful	Habitat	4	4	1	0	0	3	4	0	0	0
	Population	3	3	1	0	0	2	3	0	0	0
Marginally Successful	Habitat	1	1	0	0	0	0	1	0	1	0
	Population	0									
Unsuccessful	Habitat	0									
	Population	0									

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Navajo	$1,704,000	$ 6,000	Curtailment	Reduced Curtailment	1
Beaver Creek	$ 275,000	$14,000	Maintenance	Improvement	1

Exhibit 2. Cost and associated biological output for low-level intakes.

Cost/Output

Construction costs were available for two of the five low–level intake installations reviewed in the project investigations; these and the respective annual operation and maintenance costs are reported in Exhibit 2 in 1977 dollars.

Project Review

CALIFORNIA: Rock Creek

MONTANA: Beaver Creek, Tiber

NEW MEXICO: Navajo

WYOMING: Boysen

The projects underlined had successful applications of this improvement measure.

Multi-Level Intakes H3.2

Purpose

The purpose of multi-level intakes is to permit selection of discharge water from various reservoir strata primarily to optimize downstream water temperatures for particular fish species. The mechanism for this purpose may be located on the dam face or within a tower in the reservoir. Intakes may be at fixed depths with closable ports or a variable–level system with sliding shutters may be used. Multi–level intakes can be retrofitted to existing structures as was done on Flaming Gorge Dam, Utah. Secondarily, these intakes can aid in the control of downstream water quality parameters other than temperature, such as the amount of dissolved gases and dissolved solids. Mathematical models for the prediction of reservoir thermal stratification are available (King and Sartoris, 1973) to assist in the design of intake elevations and operation.

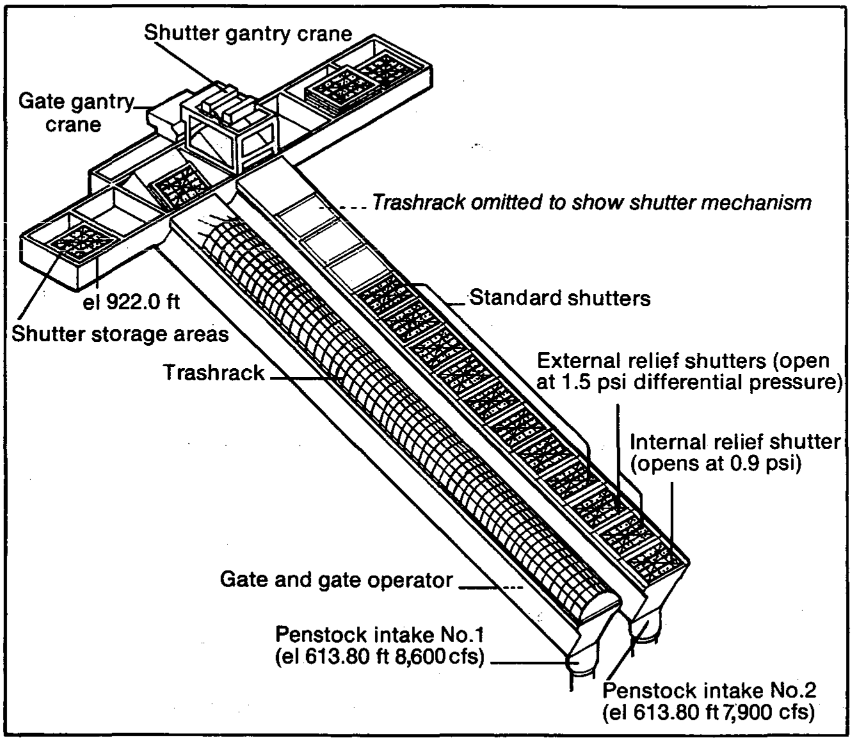


Exhibit 1. Multi-level intake structure at Oroville Dam, California.

Illustration

Exhibit 1 is a schematic drawing of the multi–level intake system at Oroville Dam, California, which provides variable level intakes. The temperature control capability is provided by steel shutters which can be lowered from the storage bays at the top of the dam into the intake channels by the shutter gantry crane. The shutters rest one above the other in the channels and prevent water from discharging below the uppermost shutter. Thus, by adding or withdrawing shutters, water may be drawn from varying reservoir strata depending on the desired temperature of the discharge water. Due to effects of specific gravity, water is drawn principally from approximately a 20 foot stratum centered at the top of the uppermost shutter.

As shown in Exhibit 1, the bottom three shutters are special pressure relief devices. The lowermost shutter is constructed to relieve internal overpressures caused by pumping or load rejection by motor–generators. The next two shutters relieve external overpressures caused when the pump–turbine or other turbines pick up load. Once the transient overpressures are relieved, these shutters close and function the same as the remainder of the shutters.

Limitation

The major constraint on the use of multi–level intakes, as with low–level intakes, is handling the trade–offs between temperature requirements of coldwater and warmwater fisheries downstream from the reservoir outlet. Also, multi–level intakes are considerably more expensive to construct than standard discharge systems. An additional consideration in some reservoirs is the increased difficulty in screening multi–level intakes to prevent loss of fish in the released water.

			Confidence Factors and Ratings								
			high			*medium*			*low*		
Classification of Success Using Habitat and Population Improvement Criteria		*number of cases*	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	2	1	0	0	1	1	2	0	1	0
	Population	3	2	1	0	1	1	3	0	1	0
Marginally Successful	Habitat	0									
	Population	0									
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 2. Success and confidence matrix for multi-level intakes.

Multi-Level Intakes H3.2

Performance

The information on performance, shown in Exhibit 2, indicates that all multi–level intakes evaluated in the project investigations were assessed to be successful. The lack of quantitative follow–up data led to ratings of only medium confidence in the reports of actual effects.

Cost/Output

Exhibit 3 reports available costs and associated biological output for multi–level intakes covered by the project investigations, with dollars adjusted to 1977. In addition, the retrofitted multi–level intake on Flaming Gorge Dam cost approximately $4.5 million (1977 dollars) according to the Bureau of Reclamation.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Oroville	$16,400,000	––	Curtailment	Maintenance	2
New Bullards Bar	1,400,000	––	Curtailment	Reduced Curtailment	1

Exhibit 3. Cost and associated biological output for multi-level intakes.

Project Review

CALIFORNIA: New Bullards Bar, Oroville

OREGON: Fall Creek

The projects underlined had successful applications of this improvement measure.

Reference

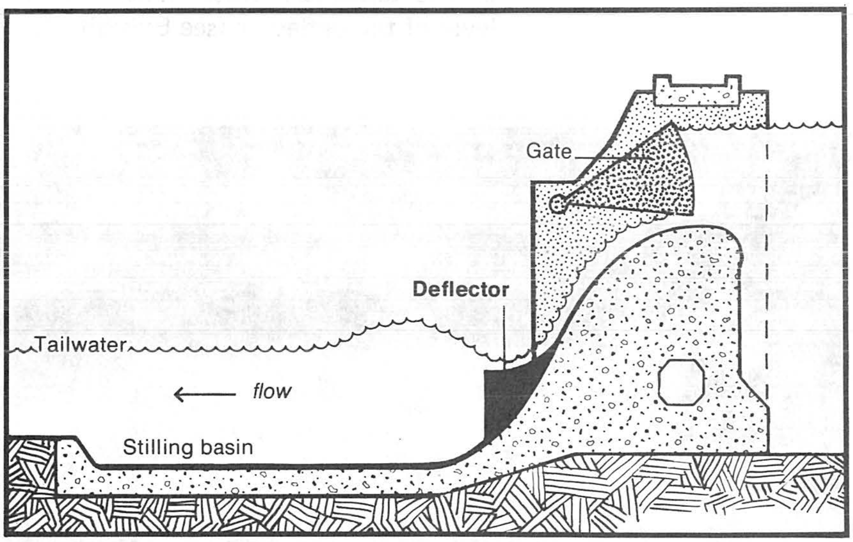
King, D. L., and J. J. Sartoris, "Mathematical Simulation of Temperatures in Deep Impoundments – Verification Tests of the Water Resources Engineers, Inc. Model – Horsetooth and Flaming Gorge Reservoirs," U.S. Bureau of Reclamation Report No. REC–ERC–73–20. November 1973.

Spillway Deflectors H3.3

Description

A spillway deflector, sometimes called a "flip—lip", is a structure built near the base of a dam spillway (Exhibit 1) to prevent the formation of supersaturated water by redirecting the flow horizontally along the surface of the tailwater. Conditions for supersaturation occur when discharged water flows down the spillway and air is entrained in the high velocity flow. Without a deflector, the flow plunges deeply into the stilling basin where high pressures exerted by the deep water force the entrained air to dissolve. As the flow moves out of the stilling basin into shallower areas, the water becomes supersaturated with the dissolved air because the pressure is reduced. Since air is mostly nitrogen, this condition is often referred to as "nitrogen supersaturation".

Exhibit 1. Cross-section of spillway with deflector (flip-lip).



Dissipation of the air from the water will take place naturally but the rate is dependent primarily on the amount of turbulence in the flow. In some instances, this may not be sufficient to avoid critical levels of supersaturation. Effects of supersaturated water on fish vary with species and age, but Ebel, et al (1975) report significant mortality in trout and salmon of all ages over levels of approximately 110% of normal saturation. In the Columbia River basin, these effects are particularly evident during periods of high flow (and high spill) in the spring which coincide with the downstream migration of juvenile trout and salmon.

Evaluation

Spillway deflectors have proven to be an effective device for reducing supersaturation caused by water discharged over spillways. Deflectors have been installed primarily on dams in the Columbia and Snake Rivers as a protection for the resident and anadromous fisheries there. Also, the auxiliary outlet at Navajo Dam, New Mexico (Exhibit 2), was modified to provide a deflection of the spillway flow for control of supersaturation (Johnson, 1976).

The capability for modifying existing structures or retrofitting with spillway deflectors is one of the advantages of this control technique. Costs, however, would be less if the deflector were included in the original spillway design. To aid in the design process, a report by the Bureau of Reclamation (Johnson,1975) presents a method for predicting levels of dissolved gas at various hydraulic structures. The effectiveness of any spillway deflector depends on the elevation of the tailwater, which must be held constant at the approximate level of the deflector (see Exhibit 2).

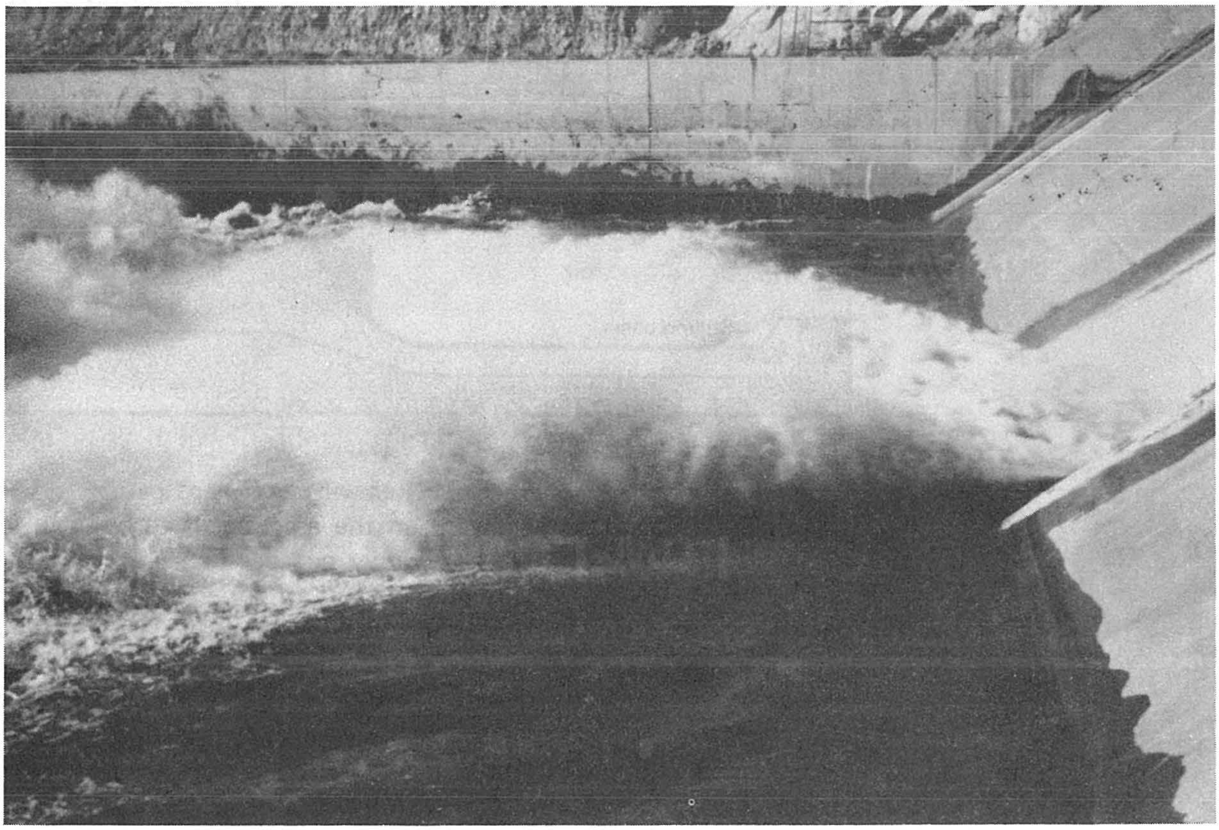


Exhibit 2. Spillway, modified auxiliary outlet, deflected flow (1,600 cfs) and tailwater at Navajo Dam, New Mexico.

Reference

Ebel, W. J., H. L. Raymond, G. E. Monan, W. E. Farr, and G. K. Tononaka, "Effect of Atmospheric Gas Supersaturation Caused by Dams on Salmon and Steelhead Trout of the Snake and Columbia Rivers," National Marine Fisheries Service Processed Report, January 1975.

Johnson, P. L., "Hydraulic Model Studies of Navajo Dam Auxiliary Outlet Works and Hollow–Jet Valve Bypass – Modifications to Reduce Dissolved Gas Supersaturation," U.S. Bureau of Reclamation Report No. REC–ERC–76–5, April 1976.

Johnson, P. L., "Prediction of Dissolved Gas at Hydraulic Structures," U.S. Bureau of Reclamation Report No. GR–8–75, July 1975.

Stilling Basins H3.4

Description

Stilling basins are normally incorporated into the design of dam and other water discharge structures to dissipate the high–energy forces of the flowing or falling water (see Exhibit 1). In terms of habitat benefits, the basins protect downstream channels from excessive scouring and erosion, thereby controlling turbidity and silting of streambed gravel. They also may be designed to control levels of dissolved gases by preventing or dissipating supersaturated water or by reaerating water that is low in dissolved oxygen (Johnson, 1975). In some instances, stilling basins can protect a fishery by providing a survival pool when streamflow discharge is insufficient. At such times, some flow is necessary to maintain the basin pool (see Section H4.1 on minimum flows).

Evaluation

Stilling basins are an accepted feature for dissipating the energy of high–velocity flows. When properly sized and designed, they are an effective means of preventing downstream erosion. Beichley (1976) and authors of other Bureau of Reclamation reports provide evaluations of several designs and the factors controlling their effectiveness. Since nitrogen supersaturation can occur from deep plunging of discharged water (see Section H3.3 on spillway deflectors), depth of stilling basins is a critical factor in controlling this condition (U.S. Bureau of Reclamation, 1975).

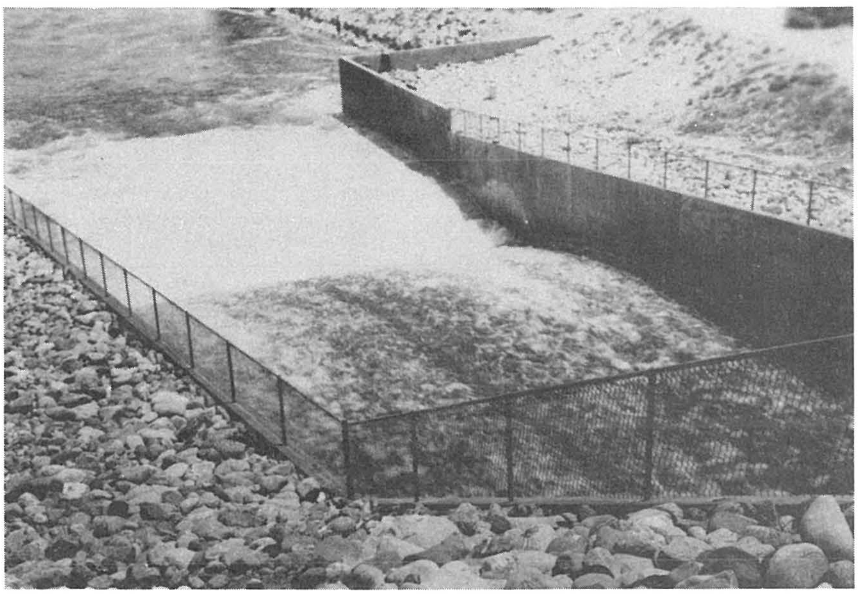


Exhibit 1. Dam spillway and stilling basin at Shadow Mountain,Colorado, with a 1,150-cfs flow.

Reference

Beichley, G. L., "Hydraulic Design of Stilling Basin for Pipe or Channel Outlets," U.S. Bureau of Reclamation Research Report No. 24, 1976.

Johnson, P. L., "Prediction of Dissolved Gas at Hydraulic Structures," U.S. Bureau of Reclamation Report No. GR–8–75, July 1975.

U.S. Bureau of Reclamation, "Reaeration and Control of Dissolved Gases – A Progress Report," by Reaeration Research Program Management Team, Report No. REC–ERC–75–1, March 1975.

Streamflows, Riffles and Pools

Minimum Flows H4.1

Purpose

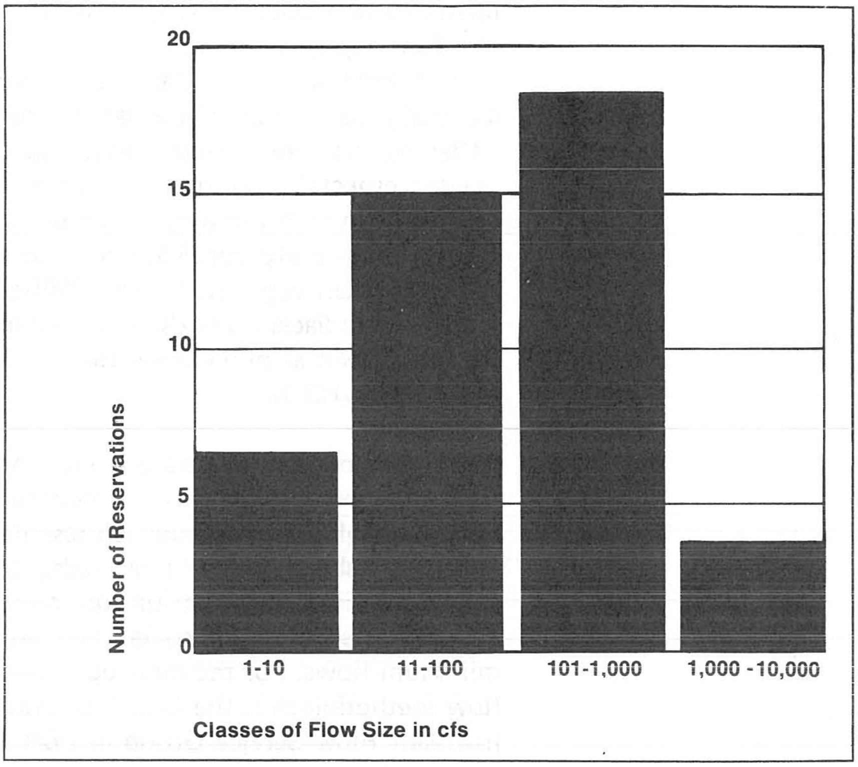
Minimum instream flows –– continuous, seasonal, or at specified times such as the closure of a dam –– provide for fish passage upstream and downstream, maintenance and propagation of existing fish populations, and establishment of different populations than existed prior to a dam and reservoir project. Minimum flows are designed to maintain a satisfactory combination of pools and riffles for fish food production, fish cover and escape. Flows are needed especially during the summer to prevent dewatering which can result in high fish mortality from stranding in streambeds. Also, though frequently receiving less emphasis, instream flows help retain riparian vegetation and wildlife habitat, provide sources of water for adjacent ponds and wetlands (see Sections H6.4 and H6.5), as well as providing water to stilling basins for fish survival (see Section H3.4).

A number of methods have been proposed to determine instream flow requirements for fish and wildlife. An excellent summary and discussion of these methods is presented by Stalnaker and Arnette (1976). Orsborn and Allman (eds., 1976) present papers from a state–of–the–art symposium on instream flow needs, emphasizing an awareness of legal, social, and technical aspects of preserving minimum flows. For the most up–to–date information on instream flow methodologies, the U.S. Fish and Wildlife Service Cooperative Instream Flow Service Group in Fort Collins, Colorado, should be contacted.

Illustration

Among the reservoir projects investigated while preparing this handbook, the adopted minimum instream flows ranged from 5 cfs at Angostura Dam, South Dakota, to 5,000 cfs at Hell's Canyon Dam on the Idaho–Oregon border. The reserved flow in Hell's Canyon was established primarily for navigation with nominal fishery protection. Exhibit 1 summarizes the frequency of minimum instream flow reservations for four classes of flow size. Seasonal flows were reserved for two–fifths of the cases reviewed. For example, at the Oso Diversion Dam (Colorado), a seasonal flow regime was established by Congressional authorization. Exhibit 2 displays the sequence of minimum flows required to be bypassed at the diversion dam, although the amount of the natural inflow to the reservoir may be substituted if less than specified minima. A short–term emergency flow sometimes is provided as evidenced by "Fish Flow '77" in the Columbia Basin. In 1977, State and Federal fish and wildlife agencies, Federal reservoir operating agencies, and private power companies coordinated their respective

Exhibit 1. Frequency of minimum instream flow reservations.



operations in response to a threat to the survival of juvenile salmonids migrating to the ocean. Temporary trade–offs were made possible without significant loss either to power companies or to reservoir operations (Committee on Fishery Operations, 1977).

Exhibit 3 is part of a "photographic regression analysis" of the Missouri River below Holter Dam in Montana, showing the differences in water surface between flows of 3,000 cfs (55% of the average flow) and 2,000 cfs (37% of the average flow). The vertical drop resulting from reducing the flow by one–third was 7 inches. Apparently, reducing the flow around midnight will reveal differences in wetted perimeter when photographed the next morning (Tennant, 1975). The dark fringe is the substrate exposed by flow loss.

Limitation

Western State water laws and administrative regulations frequently place severe limitations on water allocations for fish and wildlife. In many States, an instream flow for protection of fish and wildlife is not recognized as a beneficial water use. Therefore, water cannot be appropriated or reserved, or water rights purchased, for fish and wildlife instream needs. Even where such flows are recognized as a beneficial instream use, they still may be legally challenged. For a discussion of these laws, regulations, and problems as they pertain to instream flow needs for fish and wildlife, see Dewsnup and Jensen (1977), Orsborn and Allman (eds., 1976), and Lamb (ed., 1977). Strategies for reserving minimum instream flows have been researched and formulated. Nelson, et al (1978) have prepared thirteen Western State reports identifying, illustrating, and evaluating twenty—one legal and administrative strategies based on Federal and State laws and regulations.

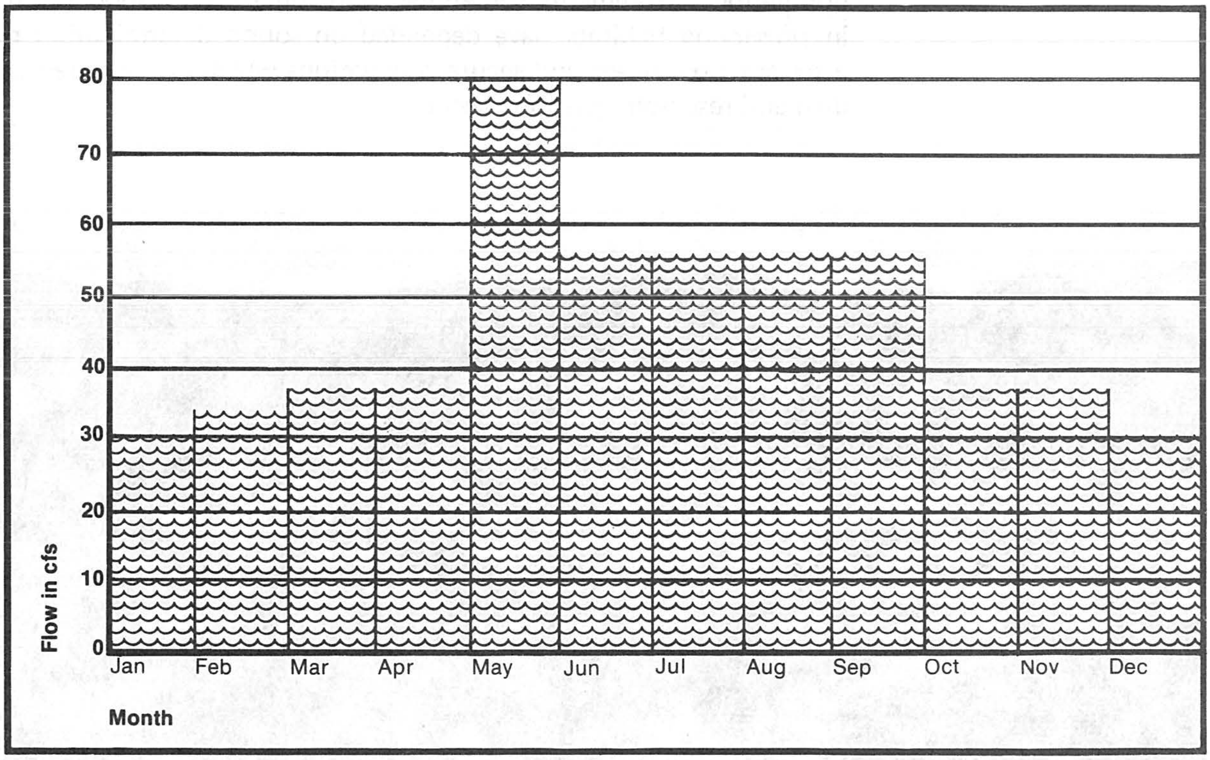


Exhibit 2. Minimum instream flow regime at Oso Diversion Dam, Colorado.

Another major constraint on reserving instream flows for fish and wildlife preservation is the resulting loss of reservoir storage capacity and yield for irrigation, power production, water supply, and other economic purposes. However, as demonstrated by "Fish Flow '77", a serious threat to a significant fish and wildlife resource can drastically alter reservoir operations, at least for short intervals. Still, in the absence of strong public pressure or obvious economic benefits from instream flow protection for fish and wildlife, economic development interests such as irrigation, hydroelectric, and water supply needs, have generally prevailed over recreation and preservation interests.

Performance

Most of the cases where recommended instream flows were implemented to a high degree were judged to have a successful outcome, using both habitat and population criteria for success. Only one case was rated unsuccessful in achieving habitat improvement. Other case study investigations, particularly those by Nelson, et al (1976) and Hazel (1976), have reported that minimum instream flows generally have maintained fish and wildlife habitats, although population curtailments sometimes were significant. Good results in preserving habitats have depended on sound determination of instream flow needs and secure reservations which are honored by dam and reservoir operating agencies.

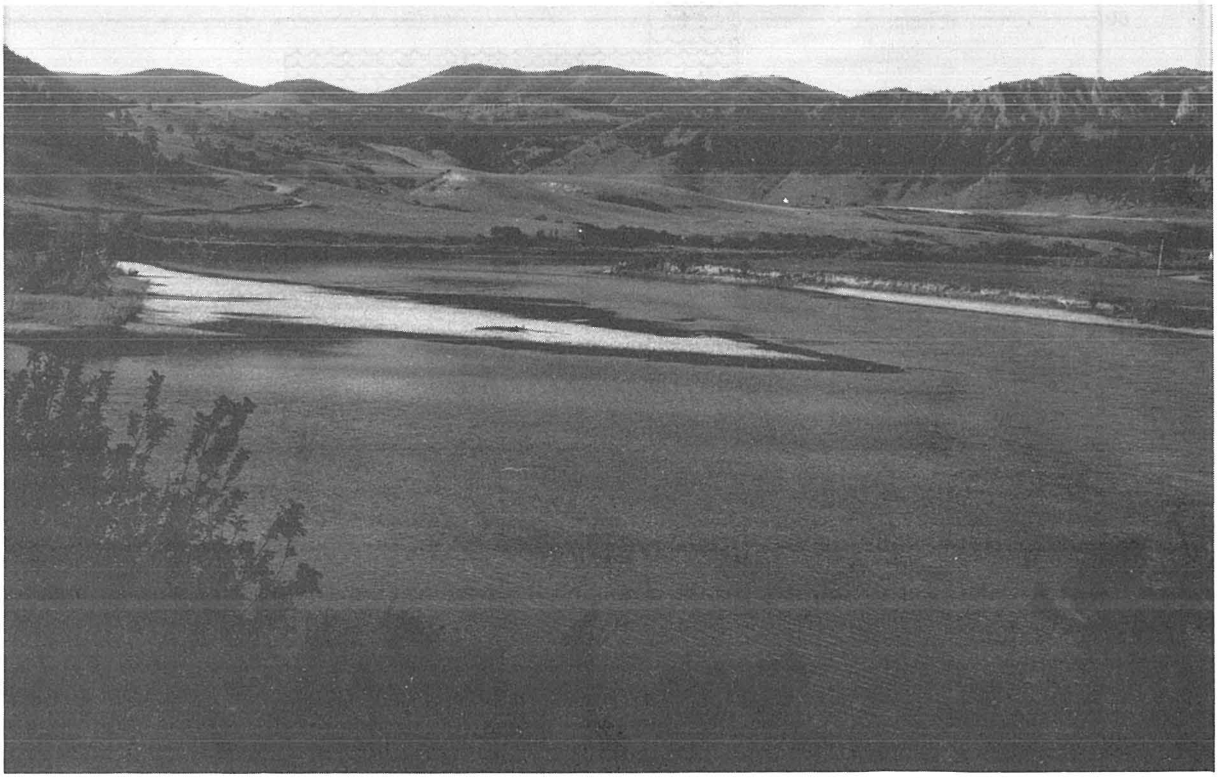


Exhibit 3. Missouri River below Holter Dam, Montana, at 2,000 cfs ("photographic regression analysis" by Don Tennant).

Minimum Flows H4.1

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high			medium			low		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	23	17	9	11	5	13	12	1	1	0
	Population	27	18	9	12	8	17	15	1	1	0
Marginally Successful	Habitat	13	4	3	4	6	9	7	3	1	2
	Population	17	5	4	7	9	12	8	3	1	2
Unsuccessful	Habitat	1	0	0	1	1	1	0	0	0	0
	Population	0									

Exhibit 4. Success and confidence matrix for minimum instream flows.

Cost/Output

Costs for meeting minimum instream flow requirements are difficult to isolate since the specified flow quantities may partly or wholly meet other downstream project needs such as furnishing water for irrigation, municipal use, and water quality management. However, the amounts of reservoir storage or stream diversions forfeited solely to ensure instream flows for fish and wildlife, multiplied by the market value of forfeited water use, represents a surrogate value for instream flow maintenance. An operations study of each dam and reservoir project could be conducted to calculate the quantity and value of flow forfeited solely for fish and wildlife purposes.

In some States, the direct purchase of appropriative water rights for fish and wildlife purposes is permissible. For example, a 1—cfs water right was purchased along Boulder Creek, Colorado, for $18,000 (1977 dollars). The cost of water rights will range widely depending on factors such as the location, prior use, and seniority of the right.

Project Review

ARIZONA: Glen Canyon

CALIFORNIA: <u>Iron Gate</u>, <u>Nimbus</u> (2 cases), <u>Oroville</u>, Rock Creek, <u>Shasta</u>, Stampede, <u>Tehama—Colusa</u>, Trinity—Lewiston

COLORADO:	Blanco, Lemon, Oso, Ruedi, Sugarloaf
IDAHO:	Dworshak, Hell's Canyon, Lucky Peak, Palisades
IOWA:	Rathbun
KANSAS:	Glen Elder, Wilson
MONTANA:	Beaver Creek, Clark Canyon, Libby, Tiber (3 cases), Yellowtail
NEBRASKA:	Merritt
OREGON:	Clearwater, Fall Creek, Foster, Mason, Prineville
SOUTH DAKOTA:	Angostura
TEXAS:	Canyon, Town Bluff
UTAH:	Flaming Gorge, Joe's Valley
WYOMING:	Boysen, Fontenelle, Gray Reef, Meeks Cabin

The projects underlined had successful applications of this improvement measure.

Reference

Committee on Fishery Operations, "Special Drought Year Operation for Downstream Fish Migrants," Columbia River Water Management Group, October 1977.

Dewsnup, R. L., and D. W. Jensen, "State Laws and Instream Flows," U.S. Fish and Wildlife Service, Office of Biological Services, Library of Congress Catalog Card No. 77–90892, March 1977.

Dewsnup, R.L., D. W.Jensen, R. W. Nelson, G. Horak, M. Lewis, and E. Hoban, "Promising Strategies for Reserving Instream Flows," U.S. Fish and Wildlife Service, Office of Biological Services, Library of Congress Catalog Card No. 77–95068, October 1977.

Hazel, C., "Assessment of Effects of Altered Stream Flow Characteristics on Fish and Wildlife, Part B: California, Final Report," U.S. Fish and Wildlife Service, Office of Biological Services, Library of Congress Catalog Card No. 77–81612, December 1976.

Lamb, B. L., "Guidelines for Preparing Expert Testimony in Water Management Decisions Related to Instream Flow Issues," U.S. Fish and Wildlife Service, Office of Biological Services, Library of Congress Catalog Card No. 77–83281, Instream Flow Information Paper: No. 1, July 1977.

Nelson, R. W., G. Horak, J. Solomon, M. Lewis, and S. Wilsey, "Strategies for Reserving Instream Flows for Fish and Wildlife in [13 States*] Under State and Federal Authority," U.S. Fish and Wildlife Service, Office of Biological Services, 1978.
*Separate reports are published for Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.

Nelson, R. W., G. Horak, M. Lewis, and J. Colt, "Assessment of Effects of Altered Stream Flow Characteristics on Fish and Wildlife, Part A: Rocky Mountains and Pacific Northwest, Final Report," U.S. Fish and Wildlife Service, Office of Biological Services, Library of Congress Catalog Card No. 77–81612, December 1976.

Orsborn, J. F., and C. H. Allman (eds.), Instream Flow Needs, Volumes I and II, American Fisheries Society, September 1976.

Orsborn, J. F., B. W. Mar, J. W. Crosby III, and J. Crutchfield, "A Summary of Quantity, Quality and Economic Methodology for Establishing Minimum Flows," State of Washington, Water Research Center, June 1973.

Stalnaker, C. B., and J. L. Arnette (eds.), Methodologies for the Determination of Stream Resource Flow Requirements: An Assessment, U.S. Fish and Wildlife Service, Office of Biological Services, 1976.

Tennant, D. L., "Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources," U.S. Fish and Wildlife Service, 1975.

Fluctuation Control H4.2

Purpose

Flow fluctuation control is requested primarily below hydroelectric power projects where power peaking operations can result in severe diurnal fluctuations in reservoir releases. Fluctuating flows may be evenly redistributed by major structures (see Section H4.3 or reregulating dams or afterbays) or through non–structural alternatives discussed in this section. Fluctuation control is intended to preserve fish habitats and populations and protect nesting waterfowl by moderating rates of change in reservoir discharge. Control of fluctuations also reduces direct destruction or damage of fish, benthos, and streambanks. Sudden significant changes in flows may strand fish and organisms important in the food chain; these changes are inimical to fish spawning and migration.

Thompson (1970) reports that salmon fry, newly emerged from the gravel, tend to seek the quieter waters near the river banks. During periods of high flow, the river bars are submerged, but a sudden decrease in flow can expose the bars and strand the fry before they can swim to the deeper sections. Once stranded, they are susceptible to predators and exposure. In an opposite way, the nesting success of waterfowl such as Canada geese can be largely dependent on the magnitude, timing, and fluctuation of reservoir releases. Canada geese may nest on islands in a river channel or connecting lake. They prefer nesting sites on steep banks adjacent to the water at the upstream and downstream points of the islands. If the geese nest while the water elevation is low during the early spring, a large increase in flows from spring floods or other causes will inundate the nesting sites.

Illustration

Control of flow fluctuation was requested either in general terms or as a maximum change over a specific time period. For instance, limitations of changes in stream level to no more than 4 inches in 1 hour or 12 inches in 24 hours were requested and subsequently stipulated for Clearwater Dams No. 1 and 2 (Oregon). However, other requests for many projects failed to define fluctuation limits, using expressions such as "gradual changes", "fluctuations be kept to a minimum", or "regulated evacuation". Some of these general terms carried the implication of operations studies and quantitative refinement at a future date. It has been suggested that flow fluctuation control be requested on the basis of wetted perimeter. Where the water surface significantly decreases or increases in elevation within a critical habitat, the change in wetted perimeter should be confined to a maximum rate such as a percentage over 12 hours.

At Palisades Dam in Idaho, the Fish and Wildlife Service originally requested that large changes in the volume of releases be made gradually. This vague recommendation has been refined over the years into an annually negotiated release schedule to protect waterfowl production. The South Fork of the Snake River below Palisades Dam supports an important breeding population of Canada geese and ducks where most of the shoreline and over 1,000 acres of islands are suitable for nesting. Typical release patterns from Palisades Dam prior to 1970 provided rather small releases (2,000 – 5,000 cfs) during the nest selection period in late March and early April, followed by large releases in May for flood control and irrigation purposes. Exhibit 1 shows a nest at the water's edge which ensures good visibility for the geese but is easily susceptible to flooding. In fact, an incubating goose moved this nest up the bank to escape flooding. Another hazard in holding a low water elevation during the nesting season is that predators such as coyotes, skunks and foxes can reach the islands and cause significant losses.

Parker (1973) reports that the key factor influencing nesting success is maintaining adequately high flows during the nest selection period and nesting season while preventing extremely high flows until late May. In 1973, the Fish and Wildlife Service, Bureau of Reclamation, and Idaho Department of Fish and Game agreed that an 8,000–cfs flow below Palisades would be maintained from March 15 to May 15 or 20. This level would be optimum for island nesting habitat, flood control, and power production, and it would fill and sustain existing river channels. At the 8,000–cfs level, 95% of the islands in the river are formed. Unfortunately, recent nesting success has been low because of very low flows in 1977 and 1978 and very high flows in the latter year (DeShon, 1978).

Limitation

The major constraint on the magnitude of flow fluctuation control is the resulting loss of hydroelectric power production capacity during periods of peak demand. Also, flows cannot be constrained to the degree that flood control operations are affected adversely. Fluctuation control to protect waterfowl nesting also may be limited by the annual runoff predictions which can affect negotiations for a schedule of reservoir releases.

Performance

The outcome of more than half of the flow fluctuation control cases was judged to be successful; two applications were concluded to be marginally successful. Two other applications proved unsuccessful in terms of population improvement even though they had been fully implemented. The populations below these two dams have been severely reduced because other habitat and population improvement measures such as minimum instream flows (Section H4.1) were either rejected or incompletely implemented.

Exhibit 1. Goose nest susceptible to flooding.

Cost/Output

The opportunity cost for controlling flow fluctuation can be considered equivalent to the amount of peak power production foregone, multiplied times the difference between the price of

Exhibit 2. Success and confidence matrix for flow fluctuation control.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high — Degree of implementation	high — Soundness of predictions	high — Reliability of reports	medium — Degree of implementation	medium — Soundness of predictions	medium — Reliability of reports	low — Degree of implementation	low — Soundness of predictions	low — Reliability of reports
Successful	Habitat	3	2	1	0	1	2	2	0	0	1
	Population	5	3	2	1	1	3	4	1	0	0
Marginally Successful	Habitat	3	2	1	1	1	1	2	0	1	0
	Population	3	1	0	1	2	2	2	0	1	0
Unsuccessful	Habitat	0									
	Population	2	2	1	0	0	1	1	0	0	1

peak–period power and the price of off–peak power. For the four applications of specific flow fluctuation controls, this cost could not be calculated because the quantity of peak power not generated due to flow control could not be determined. However, at Palisades Dam where annual negotiations currently determine the flow levels and fluctuation limits contained in the release schedule, the annual lost hydroelectric power revenue has been approximately $11,500 (1977 dollars).

Project Review

CALIFORNIA: Iron Gate, Nimbus

IDAHO: Palisades

OREGON: Clearwater, Fall Creek, Lemolo

SOUTH DAKOTA: Angostura

WASHINGTON: Wynoochee

WYOMING: Boysen, Gray Reef

The projects underlined had successful applications of this improvement measure.

Reference

DeShon, F., "A Survey of Canada Goose Nesting on the South Fork of the Snake River, Idaho," State of Idaho, Department of Fish and Game, March 1978.

Parker, T. L., "South Fork Canada Goose Study (1973)," Idaho Fish and Game Department, June 1973.

Thompson, J. S., "The Effect of Water Flow Regulation at Gorge Dam on Stranding of Salmon Fry in The Skagit River 1969–1970," State of Washington, Department of Fisheries, Management and Research Division, December 1970.

Reregulating Dams H4.3

Description

Reregulating dams are constructed primarily below hydroelectric power generating dams to stabilize reservoir releases for the benefit of irrigation, recreation, and fish and wildlife interests. Streambank protection is an ancillary concern. A dam built to regulate the uneven flows from a number of dams in a system usually is a very substantial structure, whereas a structure to regulate the flows below a single dam may be minor. For example, the Yellowtail afterbay below Yellowtail Dam in Montana has a concrete gravity dam 36 feet high and a total storage capacity of 3,150 acre–feet.

In contrast, Iron Gate Dam (California) was built and is operated as a flow reregulating dam to moderate the fluctuating releases from two upstream power dams. Its main purpose is to minimize the numbers of juvenile salmon and steelhead that were stranded and killed as the result of these fluctuations. Iron Gate Dam is about 160 feet high and creates a reservoir about seven miles long with a total capacity of 58,000 acre–feet. The dam contains a powerhouse which has one generating unit with a capacity of 19,000 kilowatts. This project has enabled flows to be stabilized, thus reducing destruction to benthos, fish, waterfowl, and furbearers.

Evaluation

Where reregulating dams are feasible, they allow upstream hydroelectric dams to achieve full power production and downstream areas to benefit from stabilized flows for fish and wildlife and other purposes. The cost of these structures may be a limiting factor as well as site suitability. Gray Reef Dam in Wyoming was built in 1961 to regulate the releases from Alcova Dam. Gray Reef stabilizes flows of the North Platte River in the 147–mile reach between Alcova and Glendo Reservoirs. As a result of the reregulating dam, minimum flows have been increased more than threefold —— from 100 cfs to 330 cfs. The improved flows have resulted in considerable benefits to fish, waterfowl and furbearers such as beaver, mink, and muskrat. The 24–foot–high Gray Reef Dam with a reservoir capacity of 1,800 acre–feet cost over one million dollars; nevertheless, the Fish and Wildlife Service reported that the dam would be more than justified if built and operated solely for fish and wildlife protection.

The Yellowtail afterbay dam has significantly improved the fishery of the lower Bighorn River as anticipated, although some adverse effects on river habitats have been reported (Martin, 1977). Reregulating dams can be retrofitted as Iron Gate Dam was to a project which was causing severe destruction to fish and wildlife. The operations of Iron Gate Dam have resulted in a fairly uniform flow during most of the year. Furthermore, the minimum flows secured by interagency agreement have been maintained with few exceptions since the Iron Gate Project began operations.

Reference

Martin, P., "Furbearers on the Yellowstone," Montana Outdoors, Vol. 8, No. 2, March 1977.

Maximum Flows H4.4

Description

Extremely high flows below dams may prove as detrimental to fish and wildlife populations and their habitats as other environmental pressures such as very low flows (Section H4.1) and severely fluctuating flows (Section H4.2). Such high flows harm fish by dislocating them and destroying benthic biota. Also, a fish habitat is damaged by bank erosion, stream siltation, and channel shifting associated with high flows, resulting in the loss of spawning gravel and feeding areas. Furthermore, waterfowl nesting sites may be flooded if high flows occur during nesting season (see Section H4.2). The proper safeguard is aimed at incorporating in the operating manual a stipulation limiting controlled releases to a specified maximum.

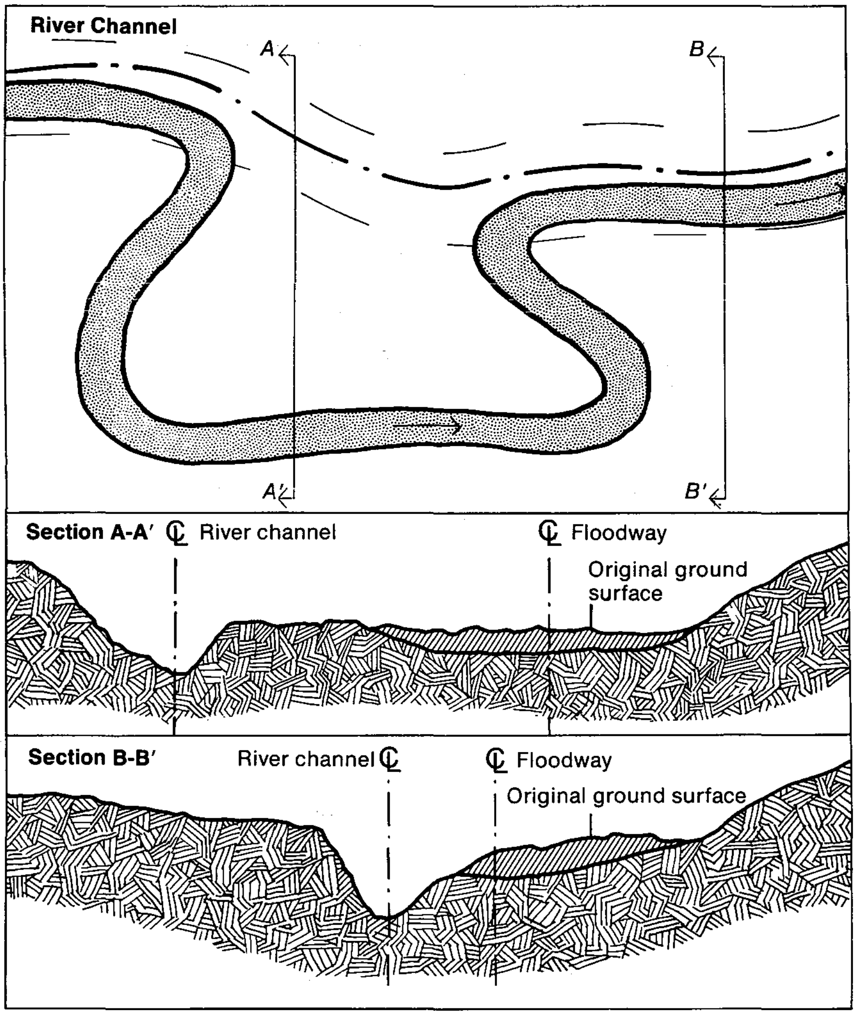


Exhibit 1. Illustration of floodway concept.

For example, at Tiber Dam in Montana the discharge of flood waters into the Marias River is manipulated to avoid flows greater than 10,000 cfs. Of course, when extreme flooding occurs this stipulation would be relaxed.

A very high flow may be accommodated safely along a stream segment having limited flow capacity by using buried conduits or other bypass structures to divert portions of the higher flows away from the natural channel. This has been characterized as the floodway concept illustrated in Exhibit 1. The bottom of the floodway would be at a higher elevation than in the natural channel and, therefore, water in the system during low flow would be conveyed only by the natural channel. The floodway would convey only those higher flows which spill into it from the natural channel. Once the surplus water is diverted into the floodway, it would be conveyed downstream and reenter the natural channel after bypassing the low—capacity stream segment.

Evaluation

The stipulation of a maximum flow below Tiber Dam was judged successful toward improving fish habitats and populations; this measure reached a high degree of implementation. However, a major constraint on full implementation is the occasional need to release excessive flood waters when they cannot be safely retained in the reservoir. Also, a maximum flow should be set high enough to permit a beneficial flood flow which may be required periodically to flush accumulated sediment from the streambed.

Floodways incur substantial costs associated with land acquisition, channel construction, and the inlet and outlet works in the channel. The floodway design capacity should equal the difference between the total flow at the desired flood protection level and the flow at bankfull capacity of the natural channel.

Current Deflectors H4.5

Description

Current deflectors, or wing dams, direct and concentrate streamflows to improve fish habitats and reduce bank erosion. They may be the best device for modifying stream channels since they are less susceptible to destruction by high flows and, if properly located, cause less disturbance to the streambed and banks. Deflectors are built within the channel at an angle to the flow, using logs, rock, or wire baskets filled with rock (called gabions) for construction material. Several forms of deflector may be considered, including the peninsular wing, peninsular wing with chute, and triangular wing (see Exhibit 1). White and Brynildson (1967) recommend use of the triangular wing because it reduces the tendency for erosion of the streambed and bank behind the wing during high flows.

Where practical, current deflectors should be constructed in an alternating series from bank to bank to keep the current swift and the channel deep. This scheme of construction will produce the natural, sinuous pattern of the stream channel. Deflectors should not be built at the head of a riffle but below it where the current may be directed toward a bend to scour a deeper pool. This placement promotes protective deepwater cover for fish as well as preserving the spawning habitat of the riffle. The deflectors should be low enough to allow the bulk of a flood flow to pass over, and they should have no protrusions that accumulate debris.

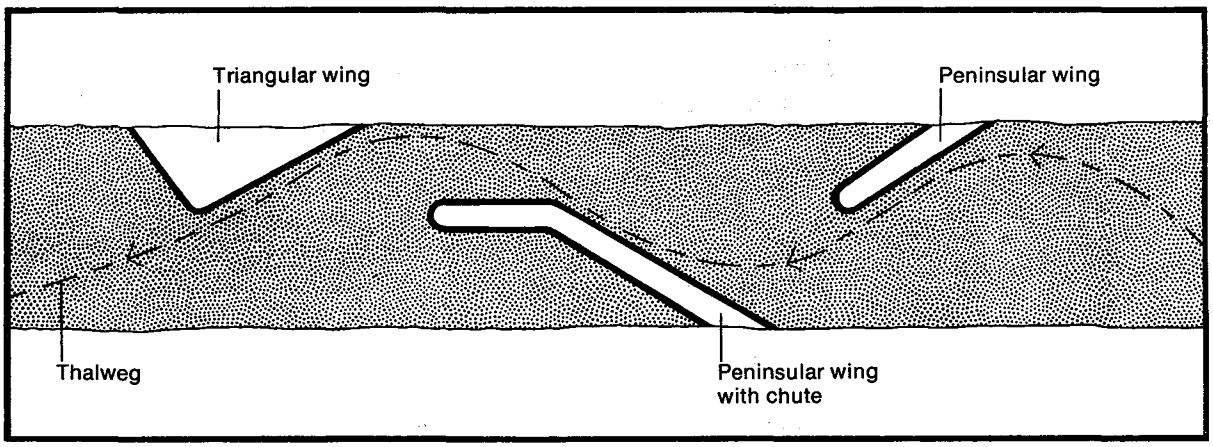


Exhibit 1. Several forms of current deflectors.

Evaluation

The feasibility of current deflectors, as well as other instream devices (see Sections H4.6, 4.7), may be questionable. Calhoun (1966) maintains that such devices are impractical in California because they are too expensive, too temporary, and generally infeasible for large amounts of stream mileage. Any program for installation of deflectors or other devices should consider only those sites having a conspicuous need for these improvement measures. A study on the Diamond Fork Creek in Utah, reported by Kimbal and Savage (1977), concluded that even for a highly degraded stream with poor fish habitats, management of grazing on adjacent rangeland was more effective at improving aquatic habitats than instream structures.

On the other hand, Barton and Winger (1973) found that instream structures, including deflectors, improved stream conditions and aided the reestablishment of fish and macroinvertebrates in a channelized segment of the Weber River in Utah. Most of the structures built were effective (35 out of 45) over the four–year period of study. The structures caused pools and riffles to be formed to the extent that few differences between the channelized and undisturbed river segments could be discerned. Failure of a structure generally resulted from poor siting. Some current deflectors were placed in slack water immediately upstream from check dams or on the inside of river bends, allowing sediment to cover the structures and fill pools. Other deflectors were built on soft streambed which eroded away and caused the structures to collapse.

The U.S. Forest Service (1969) cautions against using instream devices such as current deflectors where stream gradients exceed 3 percent or where flow fluctuations are extreme (Section H4.2 discusses fluctuation control). Opposing deflectors, or V–deflectors, are not recommended because of the tendency for the chute to clog and completely dam the stream (White and Brynildson).

Reference

Barton, J. R., and P. V. Winger, "A Study of the Channelization of the Weber River, Summitt County, Utah," Utah Division of Wildlife Resources and Utah State Department of Highways, Final Report, May 1973.

Calhoun, A., "Habitat Protection and Improvement," in Inland Fisheries Management, A. Calhoun (ed.), State of California, The Resources Agency, Department of Fish and Game, April 1966.

Kimbal, J., and F. Savage, "Diamond Fork Aquatic and Range Habitat Improvement," U.S. Forest Service, Region 4, August 1977.

U.S. Forest Service, Wildlife Habitat Improvement Handbook,

Current Deflectors H4.5

Catalog No. FSH 2609.11, August 1969.

White, R. J., and O. M. Brynildson, "Guidelines for Management of Trout Stream Habitat in Wisconsin," Wisconsin Department of Natural Resources, Division of Conservation, Technical Bulletin No. 39, 1967.

Check Dams H4.6

Description

Check dams are low barriers to streamflow used to improve fish habitat by creating or deepening pools. They can be placed in high—gradient streams, though the U.S. Forest Service (1969) recommends their use be limited to streams having flood flows less than 100 cfs. Current deflectors (Section H4.5) are preferred for low—gradient, slow—moving streams because damming of their flows should be avoided. The pools scoured out below check dams are the most important in terms of habitat improvement as opposed to pools impounded above the dams. White and Brynildson (1967) state that in no case should the upper pool be longer than 5 times the channel width, and that check dams should be located where the least amount of water will be impounded.

As with current deflectors, logs, rock, or gabions can be used to construct check dams; several varieties are shown in Exhibit 1. Anchoring the ends of the dams is critical, so existing trees or boulders should be used as a brace where possible. Otherwise, bracing should be set at least 6 feet into the bank. Also, it is important not to force flood waters onto the bank at either end of the dam because resulting erosion could damage the structure. Check dams elevated about 12 inches above the streambed should be adequate to produce the desired scouring downstream. Wide notches, greater than one—fourth of the total dam width, may be necessary to produce scouring during low—flow periods. Care must be taken during construction to prevent the dams from collapsing into the scoured holes (U.S. Forest Service).

Evaluation

Most of the evaluation provided under current deflectors (Section H4.5) is applicable to check dams because, in the studies cited, both structures were used. Planning should consider only those streams where structures are most needed. Sites should favor sound construction, having straight sections of narrow channel with trees or boulders available to brace the dam.

Reference

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

White, R. J., and O. M. Brynildson, "Guidelines for Management of Trout Stream Habitat in Wisconsin," Wisconsin Department of Natural Resources, Division of Conservation, Technical Bulletin No. 39, 1967.

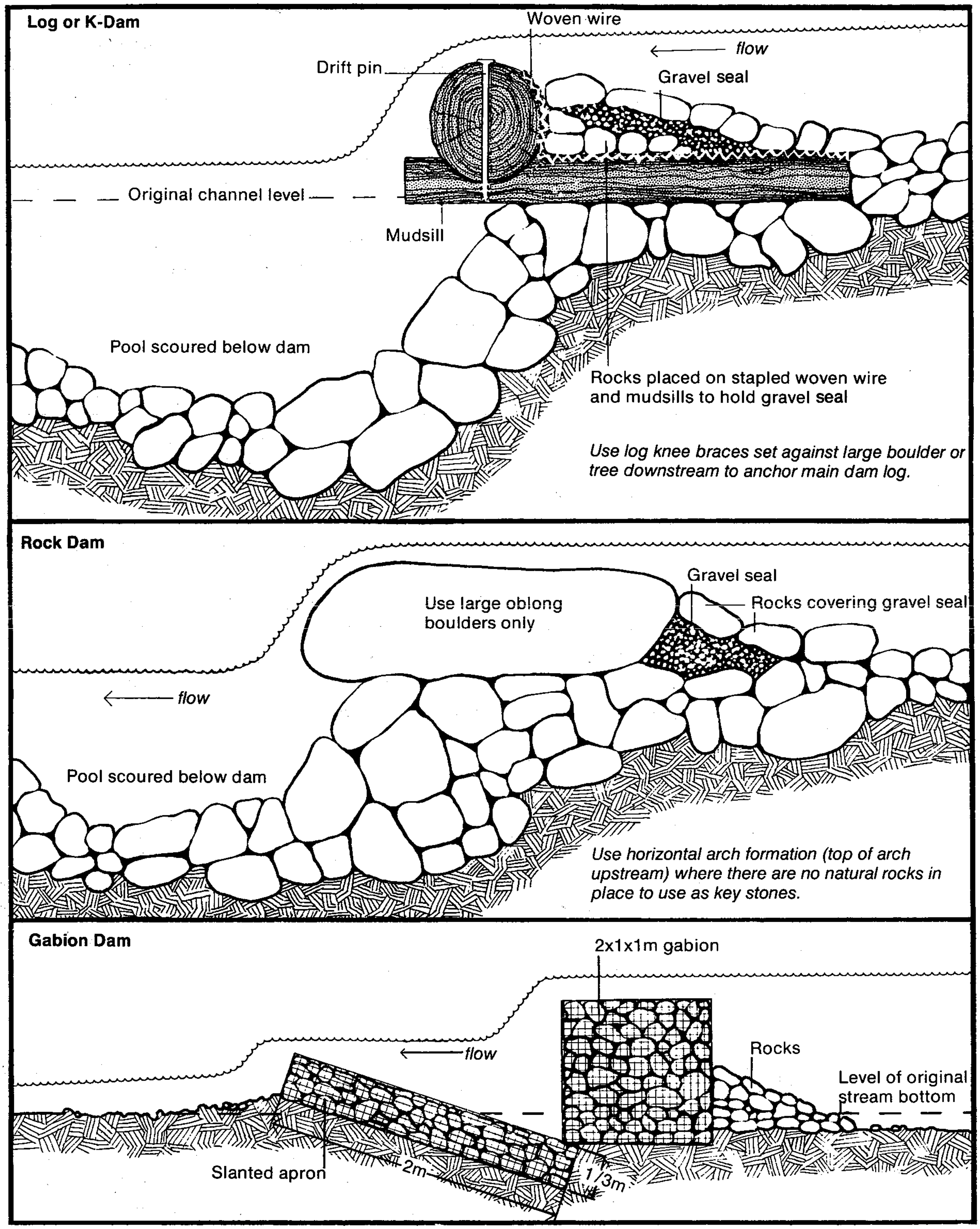


Exhibit 1. Several types of check dams.

Other Instream Devices H4.7

Description

Several other devices can be used to improve fish habitats in streams by creating pools and reducing current velocities. Large boulders can be placed in wide, shallow, fast streams, causing small pools and quiet areas to form on the downstream side. Boulders about two–thirds of a cubic yard or larger should be used, with placement by heavy equipment such as a crane or front–end loader. Access points for the equipment should be chosen carefully to minimize damage to the stream and its banks. Site selection is also important as boulders should not direct currents into soft streambanks nor should they be placed on easily eroded streambed because they will roll into the scoured holes and become buried.

An alternative to large boulder placement was developed on Black's Fork River below Meeks Cabin Dam in Wyoming (Wesche and Cooper, 1974). The river is characterized by extremely high flow velocities and little or no deep, slow–moving water. The structure developed consists of two rectangular gabions (each 6½ x ½ x ½ ft), one on top of the other, with the long axis perpendicular to the stream flow (Exhibit 1). The upstream edge of the gabions is set into the streambed, providing an upward slope from front to back. A rubber mat extends from just in front of each structure into a slot and through the top gabion. The mat reduces scour and directs the water flow up and over the structure. This produces a plunge pool and quiet water downstream which can be partially sheltered with an artificial overhang. The Black's Fork structures created pools varying from 4 to more than 16 feet in length.

Other instream devices developed for similar purposes include notched weirs and wing deflectors, low rock sills, and mid–channel or A–deflectors –– arrowhead–shaped deflectors placed in the center of the channel pointing upstream.

Evaluation

Placement of large boulders can be an effective means of improving a fish habitat. Barton and Winger (1973) found them to be successful in forming holes in the Weber River in Utah. Boulders will have the greatest effect on fish populations when employed in streams having less than 20 percent area in pools (U.S. Forest Service, 1969). Where access is reasonably easy and boulders are available, this can be an inexpensive and aesthetically pleasing improvement measure.

Seven of the Black's Fork structures were evaluated over a one–year period. The devices withstood the first year's runoff flows in excess of 1,000 cfs with only one destroyed by ice–out (Wesche,

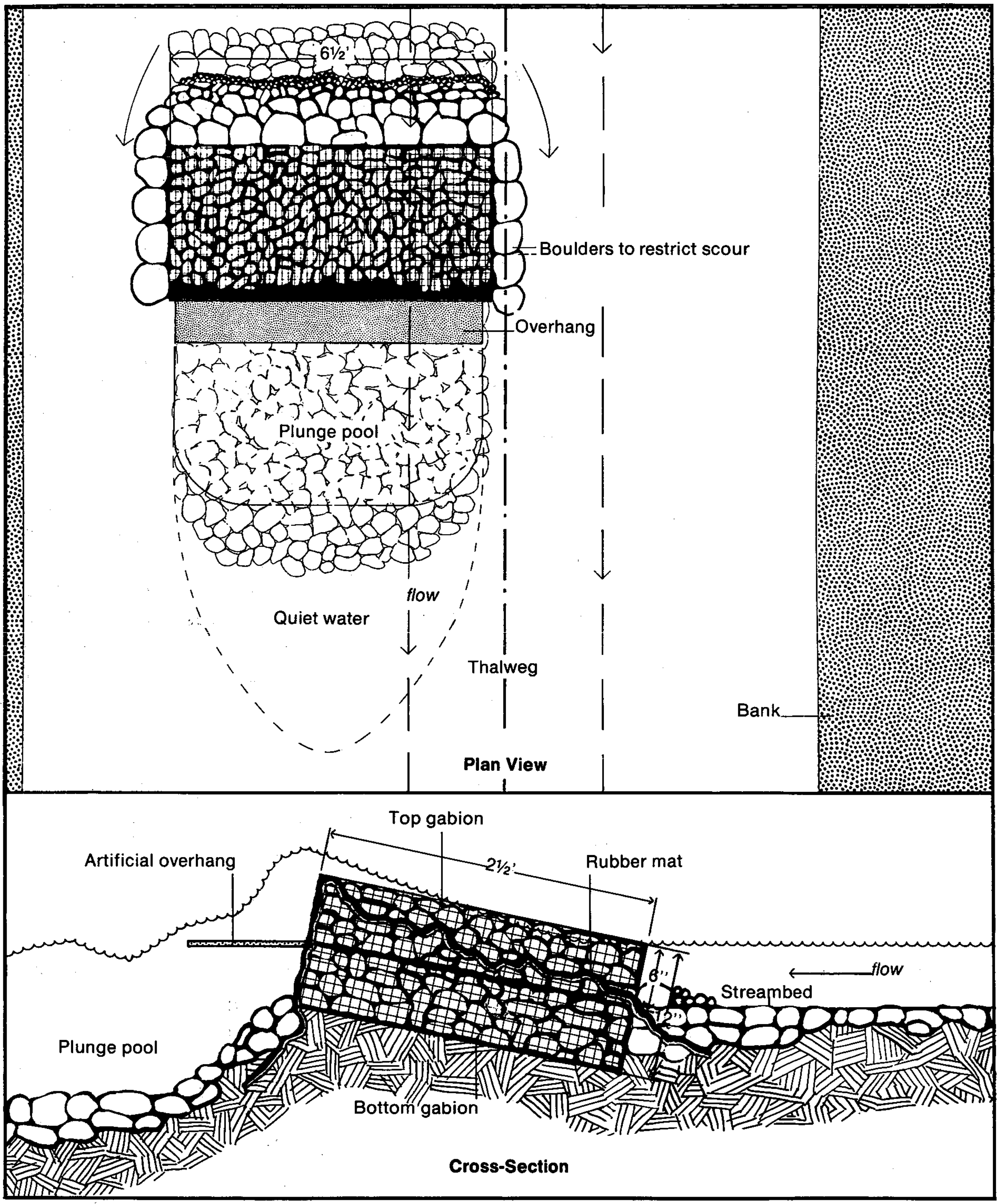


Exhibit 1. Black's Fork River instream device.

1976). Minor problems such as rusting and loss of rocks from the gabions were reported. Pools in addition to gravel bars farther downstream were formed behind the structures, though actual use by fish could not be confirmed. The effective lifespan of these devices also remains to be determined.

Notched weirs and deflectors have been used in streams in several States including Missouri and Kansas to produce habitat improvement and diversity. In many cases, however, they have contributed to excessive bank erosion. Rock sills have been used with some success in the Gila River in Arizona to improve pool habitat for catfish and bass. The use of A–deflectors is not recommended because of their tendency to clog and cause erosion of both streambanks.

Reference

Barton, J. R., and P. V. Winger, "A Study of the Channelization of the Weber River, Summit County, Utah," Utah Division of Wildlife Resources and Utah State Department of Highways, Final Report, May 1973.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Wesche, T. A., and C. O. Cooper, "Design and Construction of Habitat Improvement Structures on the Black's Fork River," University of Wyoming Water Resources Research Institute, November 1974.

Wesche, T. A., "Fall 1975 Evaluation of Black's Fork River Improvement Structures," University of Wyoming Water Resources Research Institute, February 1976.

Artificial Meanders H4.8

Description

Artificial meanders can be constructed to restore fish habitats in stream segments subject to relocation or partial channelization. By installing meanders, habitat diversity in channelized sections can be increased, which should increase fish production as compared to an unimproved channelized stream. This measure was employed along the Clark Fork River in Montana where construction of a 15–mile segment of Interstate Highway I–90 had forced channel changes, resulting in the loss of approximately 1,800 feet of the river (Hunt and Graham, 1972). Two artificial meanders, each 2,600 feet in length, replaced existing channel segments of 1,500 feet each. The streambed was excavated to reduce the gradient of the two meanders from 12.1 to 7.4 feet per mile for one, and from 17.5 to 9.5 feet per mile for the other. The hydraulic characteristics of the new meanders as well as their acceptability as habitat by resident fish species were then evaluated. Exhibit 1 is an aerial view of one

Exhibit 1. Artificial meander in the Clark Fork River, Montana.

meander, also showing the course of the original streambed.

Evaluation

Hunt and Graham found the Clark Fork artificial meanders to have hydraulic and fish habitat characteristics similar to those of natural river meanders. Fish of the same size and species as in the natural river were found in the constructed meanders. Hunt and Graham recommend using a uniform cross—section typical of the natural stream and relatively flat gradients interspersed with steeper sections to accelerate the process of attaining a natural state. Also, riprap containing a high percentage of boulders larger than 1 cubic yard each should be used to provide bank stability and improve habitat diversity. The riprap should be placed as steeply as practicable and extend below the streambed level to prevent undercutting. Fine material should be placed on the banks above the high water level to promote vegetative cover and a more natural appearance.

Reference

Hunt, W. A., and R. J. Graham, "Preliminary Evaluation of Channel Changes Designed to Restore Fish Habitat," Montana Departments of Highways and Fish and Game, October 1972.

Isolated Oxbows H4.9

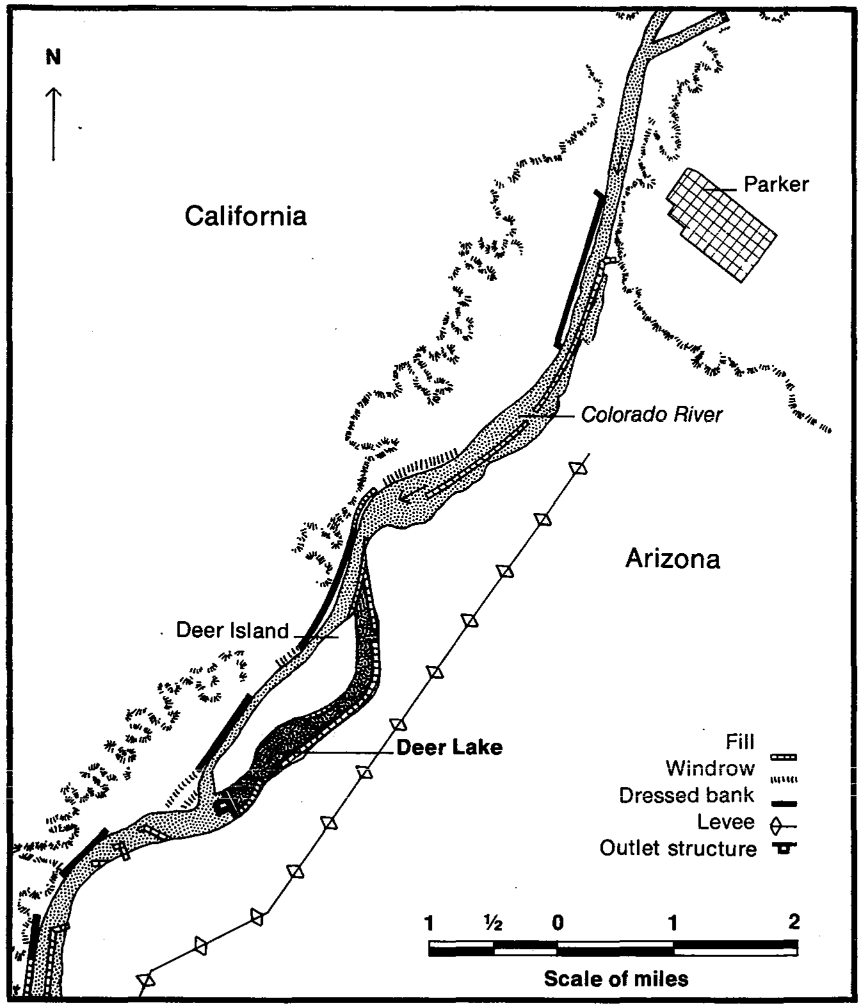


Exhibit 1. Isolated oxbow (Deer Lake) along the Colorado River.

Description

A river oxbow may be cut off from the main flow by construction of a levee. By incorporating a water outlet structure, a shallow impoundment may be developed into improved aquatic and riparian habitats for fish and wildlife. Where the main river channel is characterized by shifting streambed material, isolated oxbows can provide the necessary stabilized habitat for fish production. Most oxbows will need to be dredged, but the benefits will include preserving a greater amount of shoreline habitat and reduction of turbidity within the oxbow.

One location where this measure has been implemented is in a section of the Colorado River near Parker, Arizona. Exhibit 1 shows Deer Lake which was created from an oxbow during channelization of the river. The oxbow was dredged to increase water depth and a dike and outlet structure were installed to maintain the water level. Total new lake surface is approximately 100 acres.

Evaluation

The development of Deer Lake by isolating a Colorado River oxbow is an outstanding success providing excellent habitats for fish and small game. Construction costs were approximately $777,000 (adjusted to 1977) with annual operation and maintenance costs estimated at 1 percent of the capital outlay.

Some constraints on applying this improvement measure include the difficulty of controlling entrance by undesirable fish species and the possibility of extensive construction to provide sufficient water depth and water level management. Also, in arid parts of the country, a diversionary water right may be necessary to replace the additional evaporation from standing water.

Streamside Protection

H5.0

Bank Cover H5.1

Description

Bank cover is an important element of fish and wildlife habitats. Riparian vegetation binds the streambanks so they erode less (see Section 5.2); trees and shrubs adjacent to the stream provide both direct and indirect cover for fish and wildlife. When roots extend into the stream or branches overhang, direct fish cover is created, whereas tall vegetation makes shade which camouflages the fish and lowers water temperature. Well–vegetated banks can withstand some undercutting which produces excellent cover for fish. Riparian vegetation also provides resting, feeding and breeding habitat for wildlife as well as for insects which are a substantial portion of fish diets.

Bank cover may be provided by planting or by constructing streamside devices for protection. Grasses such as reed canary grass and sedges can be planted for development of food–producing turf on the bank. Willows and alders may be planted to produce cover. The dense mass of willow roots forms a bank with many ledges and grooves that fish utilize for cover, while alder branches usually drape into the water to create submerged hiding cover. Artificial bank covers in the form of overhanging ledges can be constructed along the outside of stream bends where the current sweeps along the bank; these make good hiding places for fish. Exhibit 1 depicts a cross–sectional view of a bank cover device.

Evaluation

White and Brynildson (1967) report that grasses and low brush provide excellent overhanging cover for fish, but they should be protected from shade and grazing (see Section H6.3 on grazing control). Trees and high brush shade out the plants composing this beneficial turf. Furthermore, a heavily shaded stream is nearly barren; it produces little food. Trees should be planted for temperature control only where there is reasonable evidence that summer water temperatures are lethally high for fish and they can be reduced only by shading with trees (White and Brynildson). Also, controlled burning may be practiced along streambanks to hinder trees and promote grasses and low shrubs (see Section H6.1 on food and cover planting).

White and Brynildson found that reed canary grass has proved highly successful for stabilizing the soils of Wisconsin streambanks and for producing overhanging cover for fish. This grass, which grows in stands 2 to 8 feet in height, withstands a wide range of moisture conditions and even can grow under water for extended periods. However, reed canary grass will not withstand heavy grazing. If it is planted along a stream less than 4 feet wide, it may

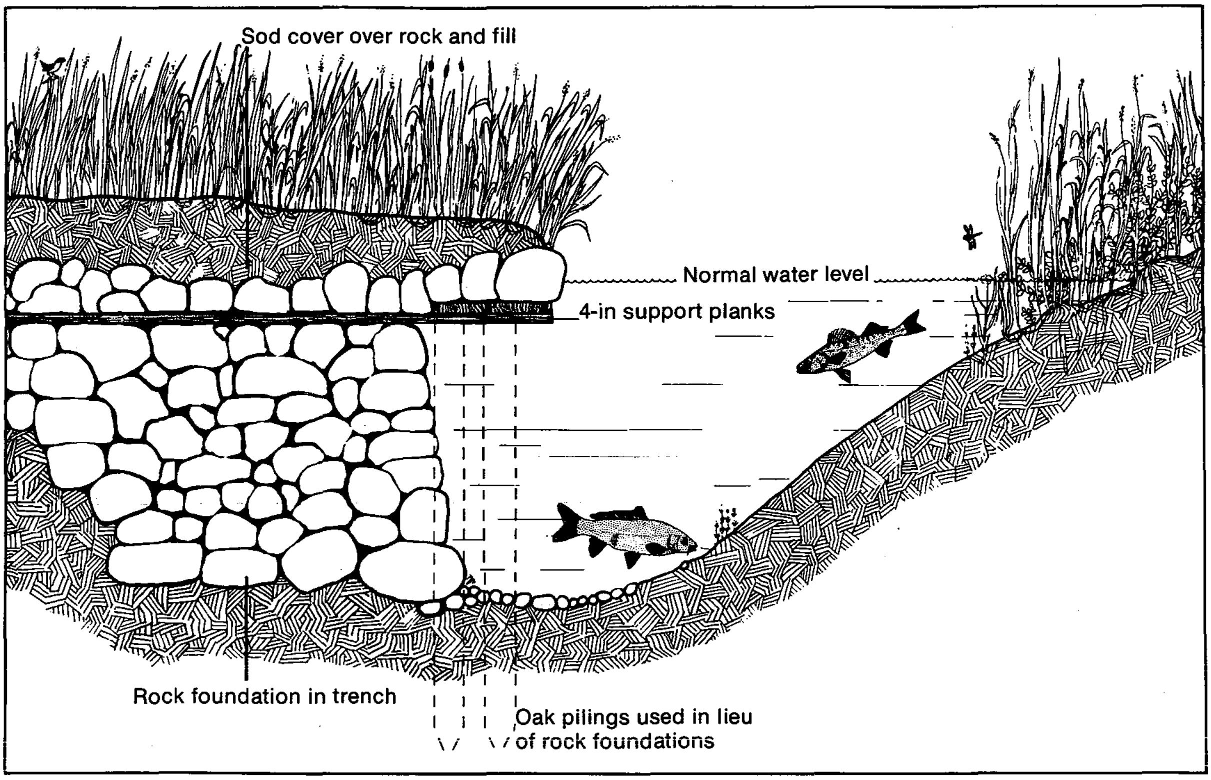


Exhibit 1. Overhanging bank cover device (from White and Brynildson, 1967).

dam the channel. Sedges may be utilized effectively along narrow channels where reed canary grass is inappropriate.

Willows have proved to be excellent bank cover if periodically controlled by basal pruning (White and Brynildson) which should be done every three years. The U.S. Forest Service (1969) reports that fresh cuttings of willows should be made while the trees are dormant and planted as soon as possible. Rooting success may be increased by dipping the cutting stub into a commercial root—growth hormone. The Forest Service recommends that best results from willow cuttings are obtained when they are planted on mud or silt bars, or along exposed banks, where the lower end of the cutting is in permanently wet soil. However, large willow trees can damage a stream habitat by shading understory vegetation, thus limiting growth. White and Brynildson advise that alders should be planted along streams wider than 40 feet because next to smaller streams they can totally shade the streambed. Also, alders should not be planted in climates where the beneficial lower branches would become encased with ice during the winter and torn away.

Bank Cover H5.1

Exact siting of bank cover is essential for accomplishing desired results. Heding (1964) reports that when an artificial bank cover is located correctly the bulk of the streamflow will follow closely along the face of the structure. An open pool beneath the cover device and a flow of drifting food organisms past the areas inhabited by fish is maintained by the free–flowing current. Bank cover devices are more permanent and provide more cover than natural undercut banks (Heding). Moreover, Heding has observed that, based on electrofishing surveys, brook and brown trout prefer the artificially created habitat as compared to adjoining unimproved stream banks.

Reference

Heding, R. B., "Stream Improvement Techniques," presented at the 26th Midwest Wildlife Conference, Bloomington, Indiana, December 6–9, 1964.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

White, R. J., and O. M. Brynildson, "Guidelines for Management of Trout Stream Habitat in Wisconsin," Wisconsin Department of Natural Resources, Division of Conservation, Technical Bulletin No. 39, 1967.

Bank Stabilization H5.2

Purpose

Banks are stabilized to prevent bank erosion and subsequent sedimentation which can be highly destructive to a stream habitat. Valuable bank cover (Section H5.1) is lost when banks are eroded or severely undercut and slough into the stream. Streambanks are stabilized by revegetation, riprap, fences, gabions, logs, erosion—control matting, and some less environmentally sound techniques. (For a comprehensive review of these techniques, see Keown, et al, 1977.)

Illustration

At Libby Dam, Montana, normal bank stabilization measures were applied to eroding areas resulting from project construction as well as railroad and highway relocation. The cleared banks were reseeded. Experiments have demonstrated that the ability of grass to reduce stream velocity, and hence retard erosion, is directly related to the length, width, and density of the blade, the areal density of the grass, and the depth of the root system (Keown, et al). Furthermore, a well—established stand of selected grass can reduce the stream velocity as much as 90 percent at the boundary layer between the water and soil. The selection of grass species is based on soil and air temperature, total rainfall and rainfall distribution, the slope of the bank, type of soil available for planting, and the ability of the soil to store water for plant growth during dry periods.

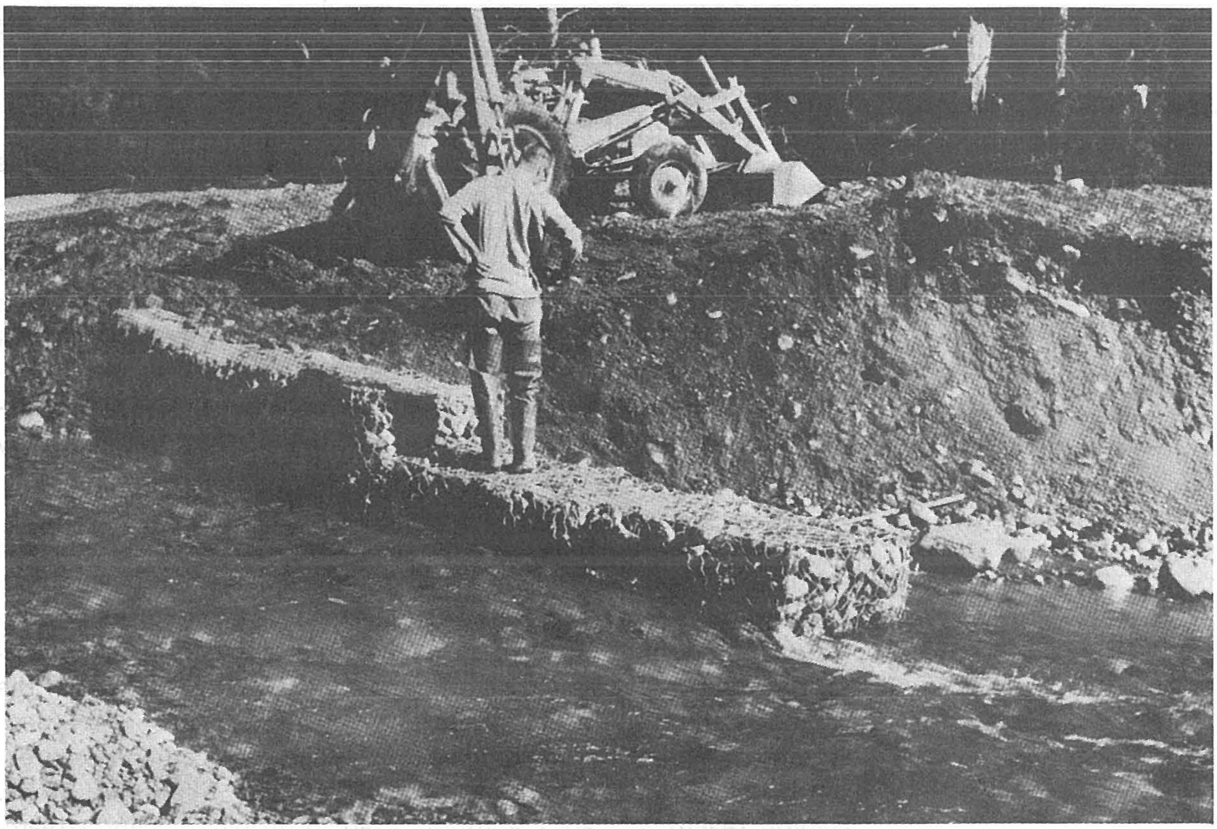
Riprap was used at Parker Dam in Arizona to stabilize the streambanks. The rock was placed not less than 18 inches below waterline along the Colorado River. The rock proved to be too small because the intervening spaces were silted within a few years. Also, the alignment was too regular; it did not allow for sharp curves to simulate former backwaters which allow rearing places for small fishes (see Section H4.9 on isolated oxbows). Use of a riprap revetment can cause deepening of the stream bend pool, and if properly constructed will provide fish hiding places between the rocks (White and Brynildson, 1967). The higher portions of the revetment may be vegetated (see Section H5.1 dealing with bank cover).

Other devices to stabilize banks include fences, gabions, logs, and erosion—control matting. Keown, et al, report that fences constructed parallel to the banks generally serve as a temporary erosion control measure; they allow sufficient time to establish bank vegetation and prevent sloughing of the bank. The basic element of the gabion is the cage or basket. The cage is a rectangular wire—mesh structure divided by diaphragms. Each cage is placed and securely wired to an apron or adjacent cage and then filled with stone. Gabion revetments are commonly used to protect eroding streambanks, landslips, and bridge abutments (U.S. Forest Service, 1969). Exhibit 1 illustrates the placement of gabions for streambank protection. Logs also have been used as a revetment for bank stabilization. The logs are secured parallel to the bank. Erosion—control matting is only a temporary device installed by hand and secured to the bank with stakes or staples. In come cases all materials used are biodegradable. The matting is structured in the form of a web and allows vegetation to grow through it.

Limitation

The main limitation on bank stabilization techniques is that erosion, sedimentation, and other stream channel processes are natural phenomena which can be modified but not controlled. Also, certain techniques for bank stabilization can impose adverse effects on fish and wildlife. For example, construction work on revetments can cause excessive erosion, sedimentation, and turbidity in the stream. Sometimes this work must be halted during high runoff periods. Revegetation is limited by the length of time required for plants to

Exhibit 1. Streambank protection using gabions.



become established on the slope of the bank. Some species having physical attributes that provide optimum resistance to erosion often must be excluded in regions where the growing season is too short or where the banks are subject to prolonged periods of submergence (Keown, et al). Woody plants usually have a greater initial cost than grass and require a longer time to become established; however, they offer more effective long–term protection.

Riprap usage is limited by the availability of suitable stones which must be sufficient in shape, size, and weight to withstand severe hydraulic conditions. Also, spaces between the stones must be large enough so they will not become clogged with silt. The lids of gabion baskets must be closed in a downstream direction to avoid snagging by floating debris (see Section H5.3 on snag clearing). Debris also may clog fences and will have to be removed periodically. Log or wood revetments deteriorate rapidly when exposed to air (White and Brynildson).

Performance

Of the three applications of bank stabilization techniques reviewed during the project investigations, none was judged to be successful, although two were rated marginally successful. One of these applications involved the use of riprap; the other employed revegetation. Of all the bank stabilization techniques, vegetation is the only naturally renewable method and in many cases the most economical and aesthetically pleasing (Keown, et al). Riprap has been used

Classification of Success Using Habitat and Population Improvement Criteria		*number of cases*	Confidence Factors and Ratings: *high*			*medium*			*low*		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	0									
	Population	0									
Marginally Successful	Habitat	2	0	0	0	1	1	2	1	1	0
	Population	1	0	0	0	1	0	1	0	1	0
Unsuccessful	Habitat	1	1	0	0	0	1	1	0	0	0
	Population	0									

Exhibit 2. Success and confidence matrix for bank stabilization.

effectively in channel stabilization and realignment. Gabion structures are somewhat flexible and therefore able to accommodate minor changes in streambank geometry. White and Brynildson determined that materials other than rock have proven much less effective. For instance, log barriers are reported to give an artificial appearance, are not durable and are ineffective because flood flows scour between the barrier and the bank. Fencing is not considered one of the most effective ways to stabilize banks but is commonly used since it is easy to install. Erosion–control matting has proved effective when used in conjunction with revegetation.

Cost/Output

No cost figures were available for the three applications of this habitat improvement measure. However, Exhibit 3 summarizes costs for various bank stabilization techniques; these figures were supplied by the Corps of Engineers Divisions and Districts.

Technique	Unit	Cost Per Unit
Grass vegetation	100 ft^2 (acre)	\$ 1.25 – 1.60 (\$ 540 – 700)
Grass & woody vegetation	100 ft^2 (acre)	\$ 3.75 – 4.80 (\$1,620 – 2,100)
Stone riprap	yd^3	\$ 3.75 – 32
Gabions	yd^3	\$ 43 – 50
Fencing	lin ft	\$ 30 – 50
Erosion–control matting	100 ft^2	\$ 5.95 – 7.73

Exhibit 3. In-place cost summary for bank stabilization techniques (from Keown, et al, 1977).

Project Review

ARIZONA: Parker

MONTANA: Libby (2 cases)

Reference

Keown, M. P., and N. R. Oswalt, E. B. Perry, and E. A. Dardeau, Jr., "Literature Survey and Preliminary Evaluation of Streambank Protection Methods," U.S. Army Engineer Waterways Experiment

Station, Hydraulics Laboratory, Mobility and Environmental Systems Laboratory, Soils and Pavements Laboratory, Technical Report H—77—9, May 1977.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

White, R. J., and O. M. Brynildson, "Guidelines for Management of Trout Stream Habitat in Wisconsin," Wisconsin Department of Natural Resources, Division of Conservation, Technical Bulletin No. 39, 1967.

Snag Clearing H5.3

Description

Dams of debris, beaver dams, and obsolete dams must be removed to renew fish passage and permit scouring spring flows to flush the silt and gravel deposited behind the dam. Inundated spawning areas must be opened and may have to be renovated (see Section P1.3 concerning spawning riffles). Debris jams usually develop when torrential storms cause blowdown and heavy flooding. Many obsolete small hydroelectric dams and dams once used to power grist mills and sawmills collect debris. Once these barriers are removed, valuable fish and wildlife habitats can be reclaimed through natural processes and improvement measures such as food and cover planting (see Section H6.1). Impounded water is detrimental to stream habitat in that it usually warms too much in summer and freezes in winter. Algae, which flourish in impoundments, can increase turbidity in the stream so that growth of rooted aquatic plants is inhibited (White and Brynildson, 1967).

Evaluation

Snag clearing has been used successfully to reduce flooding of surrounding land in lieu of channelization (East, 1977). In September 1976, work was completed on the renovation of 80 miles of the log–choked and flood–prone St. Joseph and Tiftin Rivers in Williams County, Ohio. The job required one year and cost $80,000, an average of $1,000 per mile. Many of the log jams stretched from bank to bank and were piled five or six feet above the surface at normal water level. The jams deflected the current and caused severe erosion along the banks.

When dams are removed, care must be taken to prevent further sediment deposition downstream. The possibility of downstream damage resulting from the release of accumulated sediments behind dams ought to be considered before removal. Removing a dam in autumn or winter, when downstream spawning could be disturbed and eggs smothered, should be avoided (White and Brynildson). Dams are best removed about the time grasses start to grow in spring. This will allow a full year's growth of vegetation to secure the exposed bottom silt. Removal of beaver dams requires that all sticks embedded in the stream bottom be removed by hand. Unless this is accomplished, all sediment will not be scoured away. Hand labor should be employed as much as possible where adverse effects on riparian and streambed habitats would result from the use of heavy equipment.

Reference

East, Ben, "Make The River Do The Work," Outdoor Life, October

1977.

White, R. J. and O. M. Brynildson, "Guidelines for Management of Trout Stream Habitat in Wisconsin," Wisconsin Department of Natural Resources, Division of Conservation Technical Bulletin No. 39, 1967.

General Practices

Food and Cover Planting H6.1

Purpose

The planting of food and cover combinations of vegetation provides habitats and nourishment for big and small game, bird life, and waterfowl. Plantings are made to increase the quantity and quality of existing habitats and food supply or to replace vegetation disturbed or destroyed. The most important considerations leading to a successful planting are site selection, site preparation, time of planting, planting depth, and soil moisture. In general, only native species should be planted; species selection will vary by climate, elevation, and soil type. Also, competition from existing vegetation should be eliminated or at least reduced (see Section H6.2 on browseway clearing). Much of the following discussion draws heavily on material presented by the U.S. Forest Service in its Wildlife Habitat Improvement Handbook (1969).

Wildlife food may be provided by the planting of trees, shrubs, herbaceous plants, and cereals. Trees and shrubs produce mast (acorns, for example), fruit, and browse. Mast is a primary winter food for game birds and other game, while understory fruit is an important food source for wildlife in the summer and fall months. Browse has particular importance to big game such as deer, elk, bighorn sheep, pronghorns, caribou, and moose because it is the mainstay of their winter diet. The diet of almost all game animals includes herbaceous plants and seeds. The winter food supply produced by grain is particularly valuable to upland game birds such as pheasant, bobwhite quail, Hungarian and Chukar partridge, sharptail grouse, turkeys, geese and ducks.

Grain plantings may be made by sharecropping to reduce cost to the management agency. Plantings for upland game do not have to be large; plots 1/8 to 1 acre will suffice. In most cases, row planting is preferred over broadcast seeding. Herbaceous plants are established most effectively by regular farming methods. The seeding of summer grasses and legumes should be timed to take advantage of the local rainfall pattern. Browse is planted either to introduce seed stock or to increase browse production. Transplanting nursery stock, wildings or seedlings is an effective method of establishing browse.

Wildlife needs cover for refuge, loafing, fawning or nesting, sleeping or roosting, and wintering. Cover for any animal must be sufficiently dense to prevent continued harassment from predators. The type, area, and density are dictated by the species involved. Cover may be planted in corridors or vegetative islands as well as on stream banks (see Sections H5.1 and H5.2 concerning bank cover and stabilization).

H6.1

Illustration

At Angostura Reservoir in South Dakota a number of sites were planted for food and cover. Exhibit 1 depicts the planting scheme for a 13½–acre cultivated site at Angostura Reservoir; included are the planting specifications. The entire site was fenced to exclude livestock and humans (see Section H6.3 on grazing control). Planting was in rows spaced 12 feet on center with plants 1½ to 4 feet apart, except for the herbaceous cover which was planted by broad-

Row	Row Length (Ft)	No of Plants	Species	Key to Diagram	Spacing (Ft)
1	3,293	2,196	Multiflora rose		1.5
2	1,216	609	Caragana		2
3	1,216	609	Wild plum		2
4	1,216	609	Wild plum		2
5	1,216	609	Wild plum		2
6	1,216	609	Chokecherry		2
7	1,216	609	Chokecherry		2
8	1,216	609	Buffaloberry		2
9	1,216	609	Caragana		2
10	1,281	321	Russian olive		4
11	1,281	641	Wild plum		2
12	1,281	641	Wild plum		2
13	1,281	321	Rocky Mtn. red cedar		4
14	1,281	321	Ponderosa pine		4
15	1,281	214	Siberian elm (Ulmus pumila)		6
16	1,281	214	Cottonwood		6
17	1,281	214	Cottonwood		6
18	1,281	214	Siberian elm (Ulmus pumila)		6
19	1,281	321	Ponderosa pine		4
20	1,281	321	Rocky Mtn. red cedar		4
21	1,281	321	Rocky Mtn. red cedar		4
22	1,281	321	Russian olive		4
23	1,281	321	Russian olive		4
24	1,281	641	Buffaloberry		2
25	1,281	641	Native rose		2
Herbaceous cover area					
	(45 lbs)	(3 acres)	Sweetclover		Broadcast

Food and Cover Planting H6.1

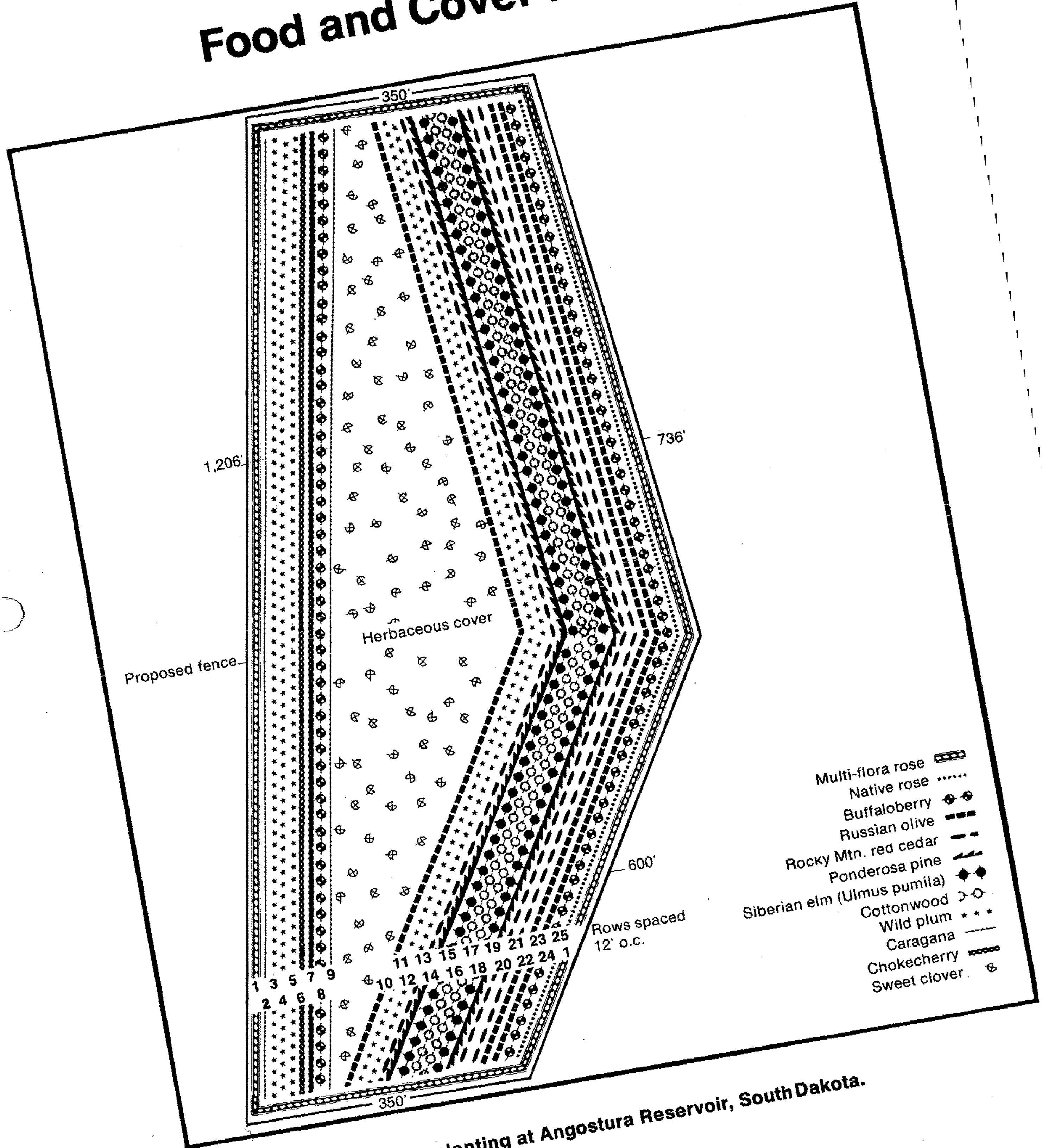


Exhibit 1. Food and cover planting at Angostura Reservoir, South Dakota.

cast seeding. The plantings provide fruit, browse, and herbaceous plant species. The site is designed to produce significant edge habitat for diversity of wildlife food and cover, where grass, forbs and shrubs form a narrow border around clearings. The edge zone receives optimum sunlight to stimulate fruiting of vines and shrubs. At other projects investigated, such as Trenton Dam, Nebraska, grassy strips and cover interspersed with cultivated fields were planted and maintained. This technique also provided for proportionately large amounts of edge habitat.

Limitation

The physiology and habitat requirements of many plant species are not well known. For example, relatively little is known about propagation of many mast–and fruit–producing plants. An important cause of planting failure is the competition for soil moisture between young plants and established vegetation. Even the establishment of native species may be unsuccessful if local environmental factors are not carefully evaluated. Planting and establishing food and cover for wildlife can be prohibitively expensive, depending on land, fencing, and site preparation costs, although sharecropping can alleviate some of these costs. If livestock is not excluded from the newly established planting, overgrazing can reduce or destroy escape and nesting cover and severely inhibit the long–term productivity of the site by reducing climax vegetation.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high — Degree of implementation	high — Soundness of predictions	high — Reliability of reports	medium — Degree of implementation	medium — Soundness of predictions	medium — Reliability of reports	low — Degree of implementation	low — Soundness of predictions	low — Reliability of reports
Successful	Habitat	10	8	4	4	2	6	5	0	0	1
	Population	9	7	4	3	2	5	5	0	0	1
Marginally Successful	Habitat	2	0	0	0	2	0	0	0	2	2
	Population	2	0	0	0	2	0	0	0	2	2
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 2. Success and confidence matrix for food and cover planting.

Food and Cover Planting H6.1

Performance

Of the twelve applications of food and cover planting at the projects studied in preparing this handbook, most were judged to be successful and none were considered unsuccessful. However, the success of wildlife population improvement is more difficult to ascertain; some population increases might have been due to in–migration. The successful applications were those having a high degree of implementation; whereas the marginally successful cases reflected a low degree of confidence in the soundness of predictions and reliability of reports.

Cost/Output

The costs of food and cover planting may include the cost of land acquisition, fencing, site preparation, nursery stock or seedlings, planting and seeding, and ongoing cultivation. Exhibit 3 presents the per–acre capital and operation and maintenance costs with the associated biological output. The initial costs per acre of food and cover planting varied from $26 to $175 (1977 dollars) with an average of $86. Per–acre operation and maintenance costs varied from $1 to $53 with an average of $21.

Exhibit 3. Cost per acre and associated biological output for food and cover planting.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Arbuckle	$175	$53	Curtailment	Reduced Curtailment	1
Baldhill	$ 90	––	Curtailment	Maintenance	2
Lovewell	$ 52	––	Curtailment	Maintenance	2
Trenton	$ 26	$ 1	Curtailment	Reduced Curtailment	1
Stampede	––	$ 9	Curtailment	Reduced Curtailment	1

Project Review

CALIFORNIA: Stampede

KANSAS: Glen Elder (2 cases), Lovewell, Wilson

NEBRASKA: Trenton

NORTH DAKOTA: Baldhill

OKLAHOMA: Arbuckle, Brushy–Peaceable (2 cases), Upper Red Rock

SOUTH DAKOTA: Angostura

The projects underlined had successful applications of this improvement measure.

Reference

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Browseway Clearing H6.2

Description

Many brush fields are so dense that deer and other mammals and birds cannot utilize them productively. They can be improved for wildlife by clearing paths or parcels to allow for the growth of brush sprouts and herbaceous plants. The principal benefits of wildlife openings are the production of forage and nesting sites, attraction of insects, access for the animals, and creation of habitat edge. Edge is the zone of transition between field and forest which provides greatest diversity of wildlife food and cover. This zone receives the right amount of sunlight to stimulate fruiting of vines and shrubs. The following discussion is based primarily on the Wildlife Habitat Improvement Handbook (U.S. Forest Service, 1969).

Selection of areas for clearing should be based on indigenous soils and vegetation, slopes and watershed effects, natural water supply, and wildlife usage. Browseways usually are cleared with bulldozers; heavy chain drags and rollers, heavy disks, rotary choppers, and mowers may be used also. Prescribed burning may be employed to remove dense stands of brush. Moreover, burning can be used to reduce competing plant species as a first step in seedbed preparation, to stimulate regeneration of sprouts and seedlings, and for other purposes. Browseways may be cleared to create an extensive network of lanes, checkerboards, and contour strips such as those displayed in Exhibit 1. The width and spacing of lanes or strips should be determined on the basis of soil erodibility; by species, age, and size of brush; and by the density of wildlife populations, especially deer. Once the browseway is cleared, the introduction or restoration of browse species may be done using transplants or direct seeding (also see Section H6.1 on food and cover planting).

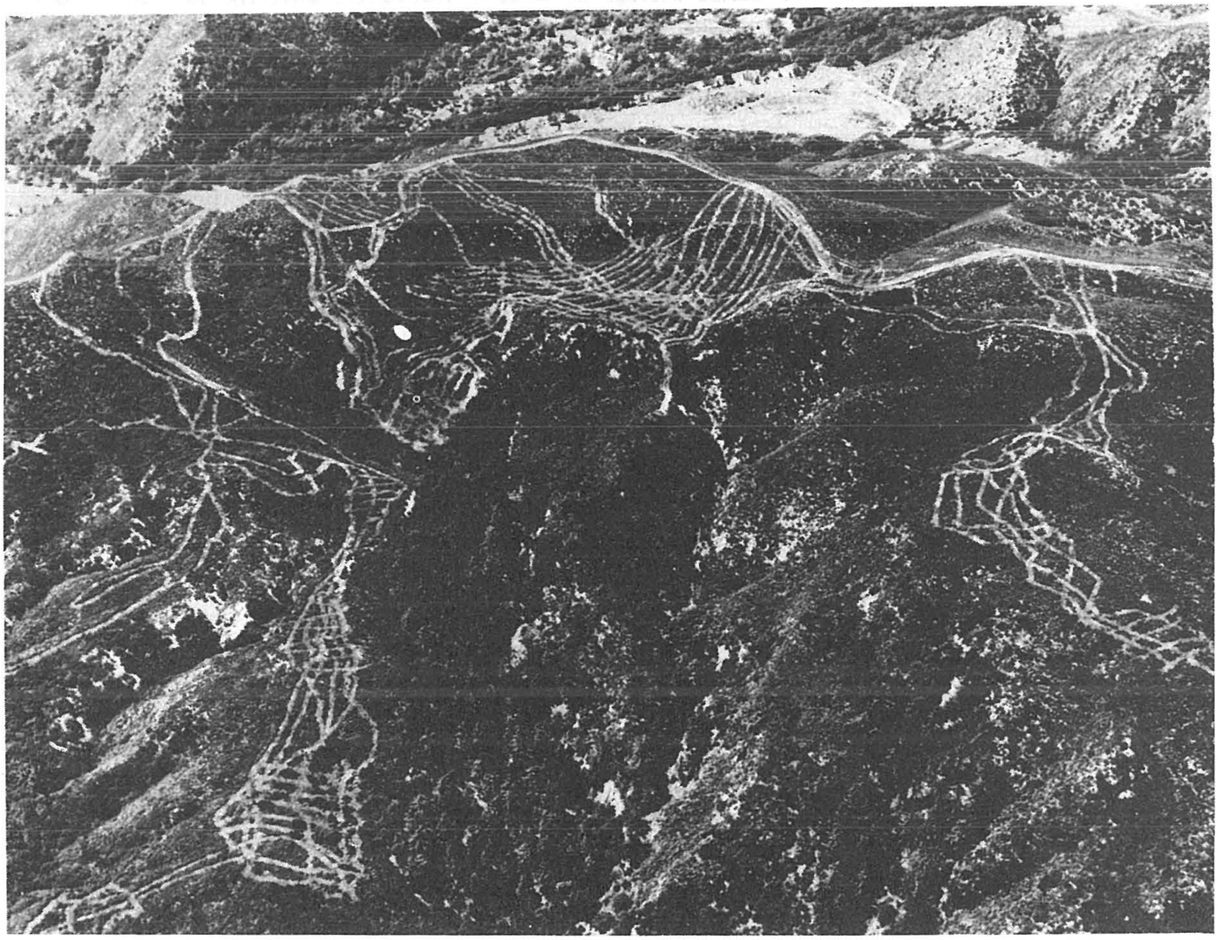
As an example of browseway development, 1,669 acres of California's Trinity River Project were modified in an attempt to increase the carrying capacity, primarily for deer. Brush was cleared both mechanically and manually, followed by planting of food and cover vegetation.

Evaluation

The application of this measure in the Trinity River Project (California) was rated marginally successful because only 1,669 acres of the original 7,445 acres planned for browseway clearing were actually cleared, and the results were mixed. Factors in not carrying out the original plan were poor soils, steep slopes, and restrictions against the use of prescribed burning (U.S. Fish and Wildlife Service, 1975). Other reasons for lack of success were the poor seed catch and survival, lack of reseeding attempts, lack of livestock control, and lack of control over deer population. A 20 percent overall increase in total deer use was found where evaluations were made using control plots. The work was completed over a seven–year period and cost approximately $150 per acre (1977 dollars), although some of this cost was for food and cover planting.

Browseway clearings scattered throughout a forested area bring about population increases due to improvement of the total habitat. The U.S. Forest Service reports that browseways should be cleared where 20 percent or more of the browse available is composed of desirable species; slopes and soils are favorable; density of the canopy is more than 70 percent; average height of desirable browse species is more than 5 feet; seasonal water is available within a reasonable distance for wildlife, especially deer; and browse is

Exhibit 1. Extensive network of browseway clearings.



generally unavailable in the area or else unpalatable due to age of the stand. On slopes from 20 to 30 percent, browseways should not be cleared unless the slope is protected by contour strips of brush or grass. If browseway clearing is greater than 50 percent, even the less erodible soils may be affected adversely. On slopes exceeding 30 percent, browseways should not be constructed except near ridgetops or where adequate drainage breaks exist.

Reference

U.S. Fish and Wildlife Service, "Deer Loss Compensation Program Resulting from Trinity River Division," April 1975.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FHS 2609.11, August 1969.

Grazing Control H6.3

Purpose

Grazing around reservoirs and along stream banks on project lands is regulated to protect and maintain wildlife habitats and populations. Planned livestock grazing permits managing the natural vegetation without detriment to wildlife and tends to minimize fire hazards. Fencing and the use of grazing leases are the primary management practices employed. Usually the leases are administered by the construction agency or the State fish and game agency.

Grazing leases specify the time of grazing as well as establishing the stocking rates and animal unit capacities. The stocking rate is the number of acres per animal unit permitted for grazing on various range sites under various conditions. An animal unit is the amount of forage necessary to feed a certain–weight animal for a specified grazing period. For each range site, the stocking rate and time of grazing must be set independently each year to avoid overgrazing. This flexibility in grazing rates is especially needed to allow for reduced rates during drought years. It has been suggested that rates be set so as to remove only one–half or less of the current year's growth. Furthermore, these rates should allow only for the use of excess forage over wildlife needs. Also, grazing on wildlife lands is usually confined to cattle because other livestock compete with wildlife for certain plant species.

Fencing is used in conjunction with leases to control grazing and to exclude livestock, some forms of wildlife, and humans from wildlife areas. For a detailed discussion of livestock fences designed to accommodate wildlife, see Section P4.3. Livestock are usually controlled by a three–wire fence; strands are 18, 28, and 40 inches from the ground. Besides standard fence designs, bulldozed trees and hedge rows can be used. Wildlife food and cover plantings (see Section H6.1) and nesting areas usually require complete protection where there is livestock grazing. Fencing along streambanks or reservoir shoreline should be set back a sufficient distance from the water to ensure protection for riparian vegetation (White and Brynildson, 1967). This important vegetation provides cover for insects and fish and helps protect against sedimentation and turbidity as well as bank sloughing (see Sections H5.1 and H5.2).

Illustration

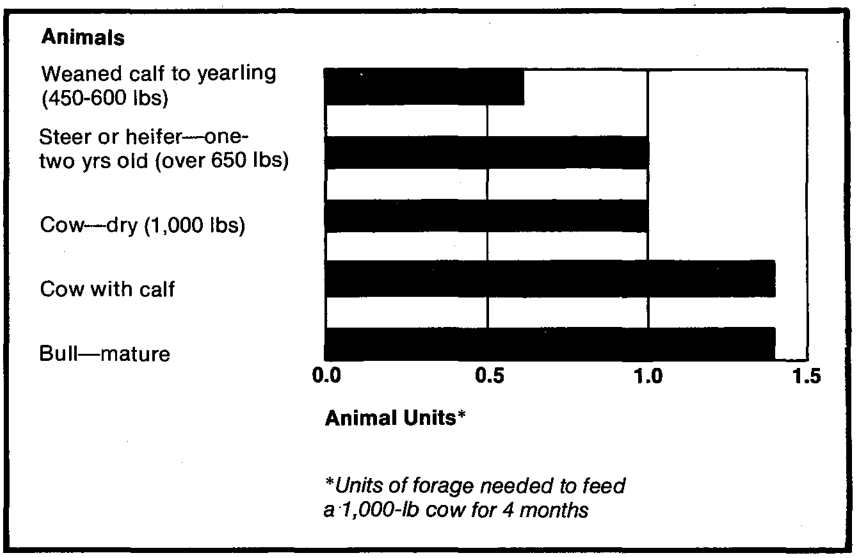
At the Lovewell Project (Kansas), livestock were excluded from the impoundment area by 13 miles of fencing to prevent damage to plantings and existing vegetation. At the Angostura Project (South Dakota), fencing protects the food and cover plantings and grazing by livestock is controlled along the reservoir shoreline where the habitat has reverted to a native condition. The South Dakota

Department of Game, Fish and Parks administers all grazing on project lands. A regular inspection is made by the Land Manager to see that grazing regulations are adhered to. Exhibits 1 and 2 present animal units and stocking rates for a grazing control program implemented at the Canton Project in Oklahoma. The program was prepared by the Oklahoma Department of Wildlife Conservation and the U.S. Soil Conservation Service.

Limitation

If the grazing terms are fixed for more than one year for an established number of animal units, overgrazing probably will occur. Overgrazing reduces or destroys escape and nesting cover and may cause a severe long–term loss of grassland productivity by destroying or reducing climax grasses and legumes. Even if the animal units are not exceeded, overgrazing will occur in drought years. The optimum rate of grazing cannot be predicted several years in advance. Grazing control is further limited by noncompliance with lease conditions. In 1970 the U.S. Soil Conservation Service conducted an extensive range survey at the Fort Gibson Project in Oklahoma and found that among 39 leased sites only seven were properly grazed while three were severely abused. Another major constraint is the cost of fencing. Sometimes relatively few acres are protected as compared to the length of fence required. Boundary surveys to locate the fence may be extensive, and annual maintenance usually is required.

Exhibit 1. Animal units for the Canton Project in Oklahoma.



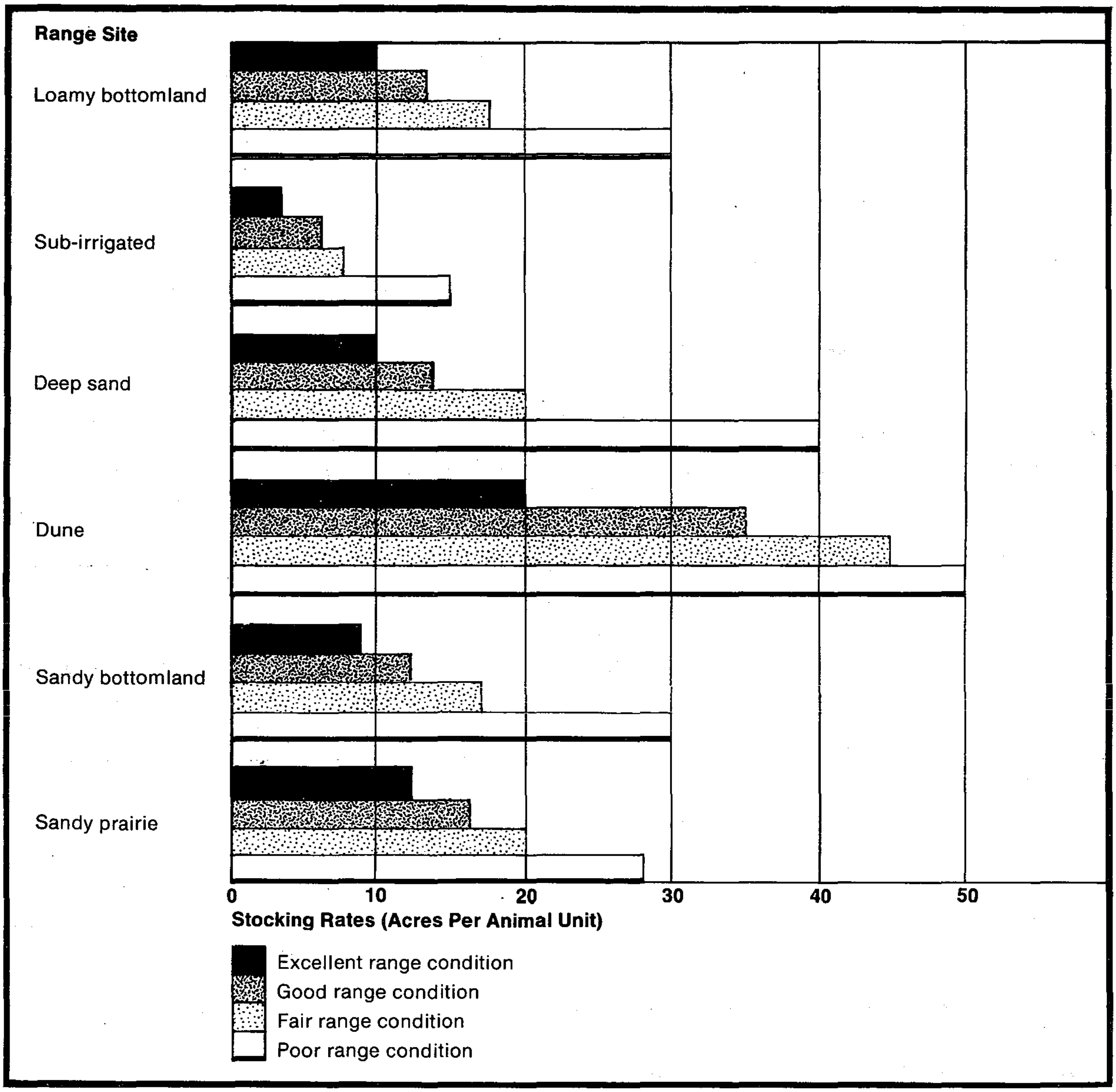


Exhibit 2. Stocking rates for the Canton Project in Oklahoma.

Performance

Most applications of this improvement measure were judged to be successful; no cases were assessed as unsuccessful (Exhibit 3). Successful cases generally were associated with a high degree of implementation and high degree of predictive accuracy or soundness.

Exhibit 3. Success and confidence matrix for grazing control.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high			medium			low		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	7	6	3	2	1	2	4	0	2	1
	Population	4	4	2	2	0	1	2	0	1	0
Marginally Successful	Habitat	3	1	0	1	1	3	0	1	0	2
	Population	2	1	0	1	0	2	0	1	0	1
Unsuccessful	Habitat	0									
	Population	0									

The primary monetary cost of grazing control is the cost of fencing which includes the boundary survey and construction as well as operation and maintenance. The per–mile construction costs of fencing for the three reservoir projects having cost data are presented in Exhibit 4 (1977 dollars). However, Latham and Verzuh (1971) estimated fence construction costs to be $6,700 and $10,000 per mile for barbed wire and woven wire stock fences, respectively (1977 dollars). They reported operation and maintenance costs for stock fences at $70 per mile (1977 dollars). Another cost associated with grazing control is equivalent to the loss of revenue to the lessee resulting from grazing restrictions to benefit wildlife as well as the loss to the lessor resulting from lower fees due to such restrictions.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Beaver Creek	$1,800	–	Curtailment	Maintenance	2
Baldhill	$1,500	–	Curtailment	Maintenance	2
Lovewell	$1,400	$36	Curtailment	Maintenance	2

Exhibit 4. Cost per mile and associated biological output for grazing control.

Grazing Control H6.3

Project Review

IDAHO: Cascade

KANSAS: Lovewell, Wilson

MONTANA: Beaver Creek

NEW MEXICO: Navajo

NORTH DAKOTA: Baldhill

OKLAHOMA: Brushy—Peaceable Creek

SOUTH DAKOTA: Angostura (2 cases)

WYOMING: Boysen

The projects underlined had successful applications of this improvement measure.

Reference

Latham, H. S., and J. M. Verzuh, "Reducing Hazards to People and Animals on Reclamation Canals," U.S. Bureau of Reclamation, Report No. REC–ERC–71–36, September 1971.

White, R. J., and O. M. Brynildson, "Guidelines for Management of Trout Stream Habitat in Wisconsin," State of Wisconsin, Division of Conservation, Technical Bulletin No. 39, 1967.

Fish and Waterfowl Ponds H6.4

Description

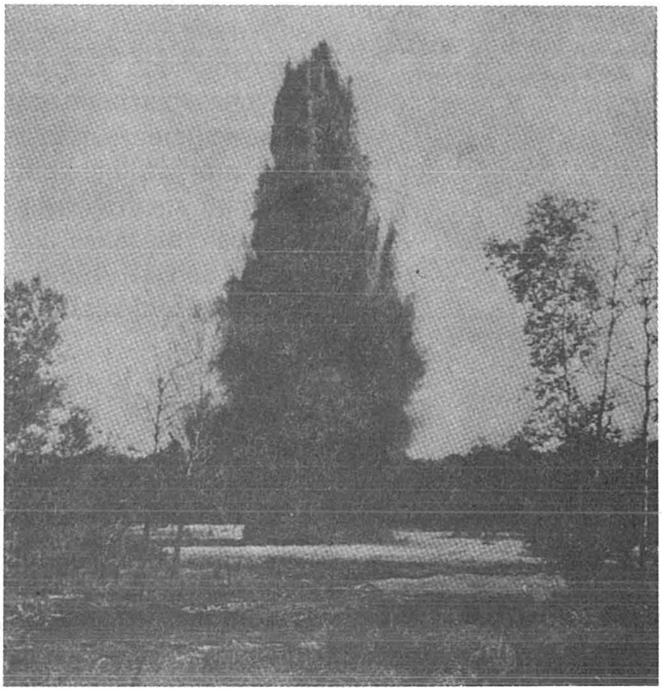
Ponds are developed to provide increased or better habitats for fish and waterfowl. They may be created by excavation, blasting, or impoundment. For example, below the TAT Momolikot Dam in Arizona, four ponds totaling 50 surface acres were to be excavated to a maximum depth of 15 feet. The excavation of borrow pits also may provide the pothole or pond habitat. Blasting is the most common method employed in producing most small potholes, although draglines and bulldozers have been used as well (U.S. Forest Service, 1969). Exhibit 1 shows the use of a blasting agent and the resulting pothole.

An approach to providing pond habitat using an impoundment is exemplified by Joe's Valley project in Utah. In this instance, the construction of a new irrigation reservoir freed the use of four ponds for fish and wildlife purposes. Historically, the ponds were used to meet irrigation needs. When the new reservoir was filled, 100 acre–feet of storage was made available to the irrigators who held rights to the water in the ponds. By substituting reservoir storage the surface levels in the ponds could be stabilized to make them suitable for fish habitat.

The depth and surface area of the pond will depend on the site and the management objectives. Waterfowl thrive best where the average water depth is 18 to 24 inches (U.S. Forest Service), whereas fish generally require a depth of at least 8 to 10 feet for protection during the winter as well as to prevent the intrusion of cattails and other emersed plants (Dillard, 1975). Fish in shallow ponds are especially vulnerable to winterkill due to the high surface–to–volume ratio. The pond site should be chosen on the basis of topography, soil type, drainage area, and suitability of existing food and cover.

Evaluation

The conversion of irrigation ponds at Joe's Valley Dam (Utah) was judged successful. On the other hand, excavated ponds at TAT Momolikot Dam (Arizona) were considered unsuccessful, primarily because the pond bottoms were too porous and the water supply insufficient. This problem may be prevented by sampling the clay content of the sub–soil. A leaking pond sometimes can be sealed by the application of bentonite, a volcanic clay that swells when wet. It is most effective on sandy soil in ponds that do not have widely fluctuating water levels (Dillard, 1975). The availability of water rights for pond supply can be a limiting factor. Besides water rights required for filling, other rights may have to be acquired to replace evaporation which can be quite severe in arid regions.



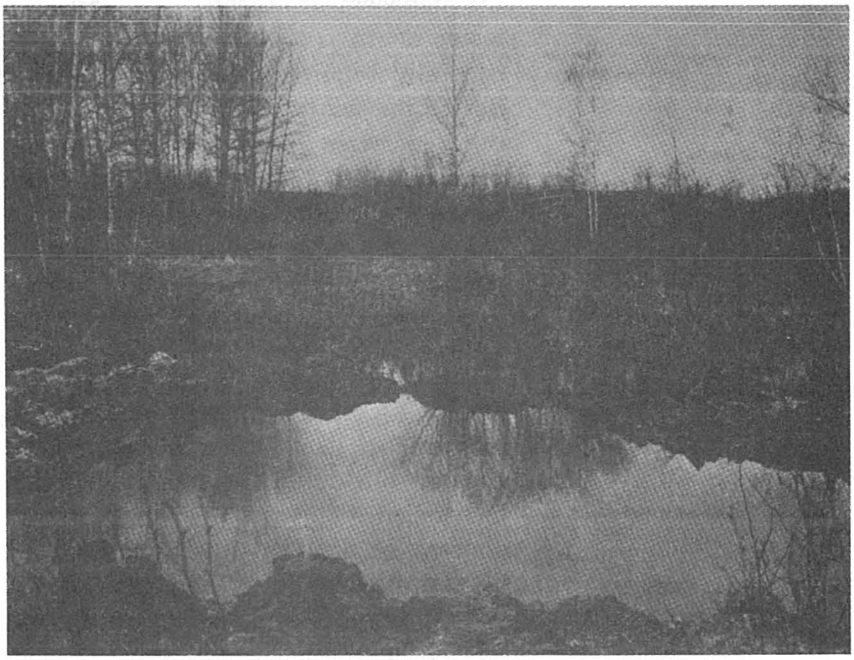


Exhibit 1. Blasting to produce a pothole for waterfowl habitat.

Fish and Waterfowl Ponds H6.4

Another problem with ponds is shoreline erosion from wind and waves, which may be prevented by establishing aquatic plants. These plants also promote fish food organisms and furnish wildlife food and cover, including nesting habitat. However, such plants can multiply excessively and interfere with fish production (see Section 6.6, Macrophyte and Algae Control). Under severe conditions, submerged vegetation may over–supply cover for small fishes which increases the chances for over–population and slow growth (Dillard).

If optimum production of particular species is the objective of the pond, it is important that their environmental needs be understood and fulfilled. For example, wild ducks and domestic livestock directly compete for grass around a pond. The duck needs it for cover; the cow for food. This conflict can be resolved by fencing out portions of the pond shoreline for waterfowl use (see Section H6.3 concerning grazing control). On the other hand, where ponds are enclosed by dense stands of brush or trees there is a need to create openings supporting herbaceous vegetation to encourage waterfowl breeding.

Overall, it has been reported that small impoundments for the express purpose of providing additional fish and waterfowl habitats have been highly successful (U.S. Forest Service and Dillard). Costs for these ponds vary widely, depending on the surface area, depth, type of construction, and outlet works. At Joe's Valley Dam the cost for acquiring the four existing irrigation ponds was $614,000 (1977 dollars), whereas at the TAT Momolikot Dam the cost for constructing four ponds was $58,000 (1977 dollars), with an annual operation and maintenance cost of $1,000.

Reference

Dillard, J. G., Missouri Pond Handbook, Missouri Department of Conservation, April 1975.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

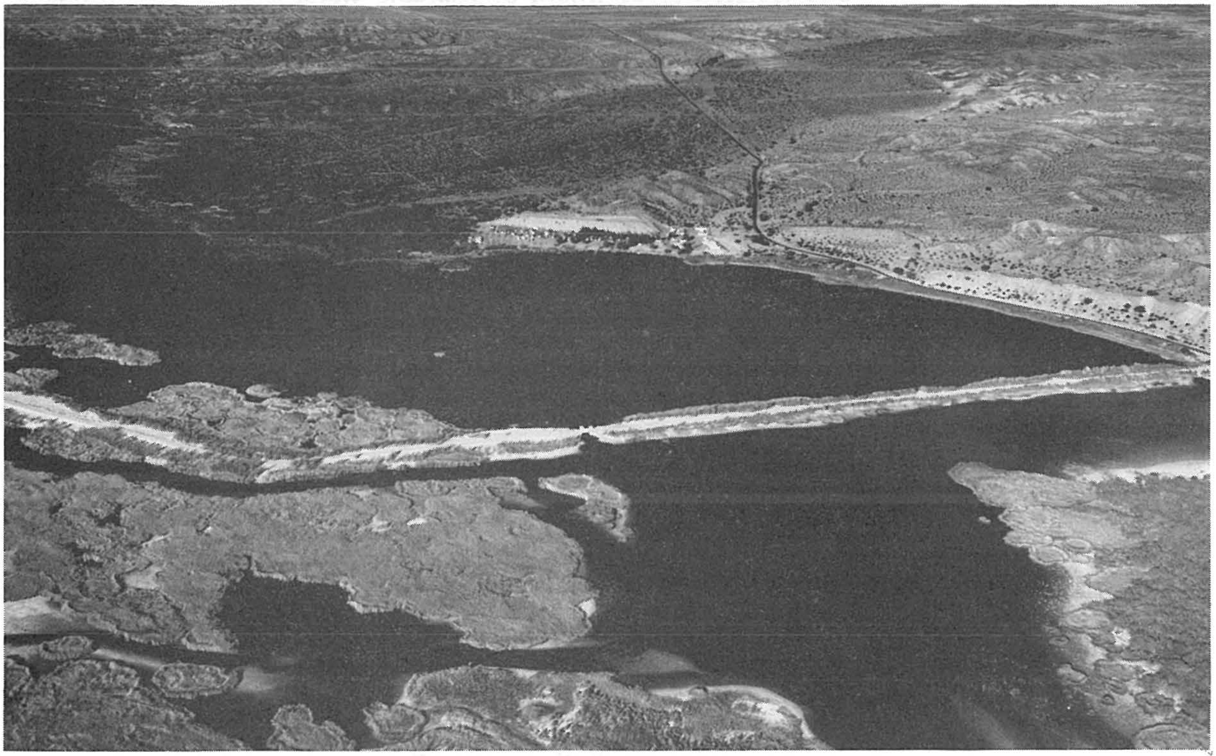
Wetland Dredging and Diking H6.5

Description

Wetland dredging and diking are undertaken to increase the water level and manageability of wetlands as well as to create additional wetlands. Water control structures usually are installed in dikes to allow for water level manipulation (see Section H2.3 on seasonal manipulation). Exhibit 1 indicates a retention dike at the Topock Marsh Unit in Arizona that contains an outlet structure to control the surface elevation of the marsh. Open water interspersed with marshland and interlaced with ditches and high spoil banks can create habitats favorable to ducks, geese, beaver, muskrat, mink, otter, and warmwater fishes. Many birds, such as herons, cranes, and sandpipers, also inhabit this environment.

Dikes may be constructed along a river or reservoir shoreline to create a wetland subimpoundment. Water levels can be maintained within the subimpoundments even though the river or reservoir is drawn down. Subimpoundments can be effective in reducing windblown dust that may result from drawing down a reservoir (Eng and Childress, 1977). At Canyon Ferry Reservoir in Montana, 1,900 acres of marsh lands within subimpoundments were designed to alleviate this problem and to create a habitat for Canada geese. A push–up berm was built to impound the water.

Exhibit 1. Wetland diking and control structure at Topock Marsh, Arizona (from U.S. Bureau of Reclamation).



Often draglines and bulldozers are used to dredge bottom material for building a dike. Also, dredging is done to form ditches that increase habitat variety for furbearers and waterfowl. Water in deep ditches helps animals by furnishing food and cover during dry periods. In addition, the spoil banks offer dry resting and feeding sites and shelter during periods of flooding (see Section P4.2, Nesting Islands).

Evaluation

Wetland dredging and diking have been used primarily in western States where management of water levels is particularly critical. At the Garrison Project (North Dakota), subimpoundments have been credited with significant increases in waterfowl use (Enyeart, 1973). Pheasant, whitetailed deer, and other wildlife have been found in the vegetation along the banks.

At the Topock Marsh Unit (Arizona), wetland diking has successfully produced habitats for fish, waterfowl, and marsh birds such as the endangered Yuma clapper rail (Deason and Sharpe, 1978). In fact, the increase in the Yuma clapper rail population has been greater than expected. Dredging and diking also has improved water circulation; reduced water temperatures, pH levels, and turbidity; and isolated areas where undesirable water quality conditions are extreme. Exhibit 2 depicts in cross–section a dredged ditch and a dike formed from the spoil material at the Topock Marsh Unit. Exhibit 3 shows the Bureau of Reclamation dredge, "Little Colorado", in operation in Topock Marsh. The dredge is deepening existing channels to improve water flow within the marsh as well as creating an island habitat tor the Yuma clapper rail. The islands shown have since become vegetated.

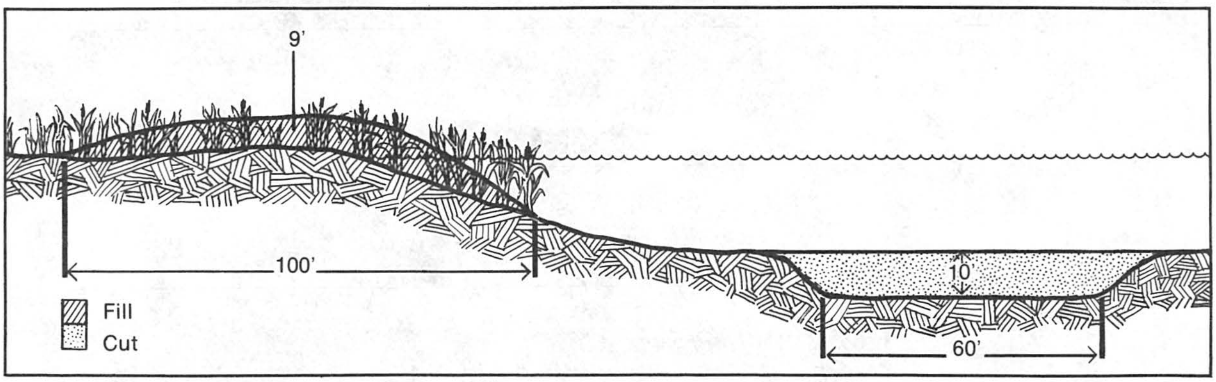


Exhibit 2. Typical cross-section of dredging and diking at Topock Marsh Unit, Arizona.

Exhibit 3. Channel dredging and island building at Topock Marsh Unit, Arizona (from U.S. Bureau of Reclamation).

An important consideration when diking is the possession of adequate water rights to fill the impoundment and replace annual evaporation losses. This was a limiting factor for the Topock Marsh Unit development. However, if surface water rights are unavailable, pumping from wells may be used to fill impoundments. The U.S. Forest Service (1969) reports that dredging is often superior to blasting as a method of ditch construction. Blasted ditches are shallower, and loosened muck along the edges of the ditch is highly susceptible to wind and wave erosion. The absence of high spoil banks so desirable for waterfowl nesting sites and muskrat dens further limits the value of blasting. When constructing improvements in shallow marshes the Forest Service recommends the use of scoops, draglines, bulldozers or a combination of the three so that displaced material may be piled along the edges to create a high riparian habitat.

The costs of this habitat improvement measure can vary depending on the height of dike or depth of dredging and the type and number of outlet controls installed in the dike. For the Topock Marsh Unit (Arizona), the costs of dredging and diking were approximately

$600,000 (1977 dollars). This development involved 6.2 miles of diking with five control structures, 7.4 miles of channels, 2.1 miles of artificial islands, and the evacuation of a silt basin at the entrance of the inlet channel.

Reference

Deason, W. O., and F. P. Sharpe, "Development of Hydraulic Structures for Improvement in Habitat of the Endangered Yuma Clapper Rail," in Proceedings of the International Symposium on Environmental Effects of Hydraulic Engineering Work, September 1978.

Eng, R. L., and D. A. Childress, "Ecological Study on Canyon Ferry Dust Abatement Program," Montana State University and Montana Fish and Game Department, Quarterly Progress Report, 1977.

Enyeart, G. W., "Summary Report on Garrison and Snake Creek Reservoirs 1955–1972 –– A Sixteen Year Resume of Research, Management, and Development Work Done on Garrison and Snake Creek Reservoirs," Report No. A–954, North Dakota State Game and Fish Department, January 1973.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Macrophyte and Algae Control H6.6

Description

Aquatic plants are essential elements in providing food and cover for fish and many forms of wildlife. They are beneficial until they begin to interfere with the intended use of the body of water. Control measures may be necessary when plants reduce flows in canals and drainage ditches; produce objectionable taste and odor in domestic water supplies; and prevent access and recreational use of lakes and reservoirs. Aquatic plants may be placed into four basic categories:

- Algae, such as filamentous and bluegreen types
- Floating, such as duckweed and water lilies
- Submergent, such as pondweed
- Emergent, such as cattail.

The implementation of a plant control procedure should follow several basic steps. The cause of the overabundance of aquatic plants should be determined and corrected, if possible. For instance, inflows of sewage or agricultural runoff should be diverted to minimize the influx of nutrients to the body of water. The species of plants causing the problem should be identified. Guides such as Otto and Bartley (1972) or others listed by Meyer (1966) are valuable sources. The uses of the water should be considered, whether for irrigation, domestic or industrial supply, recreation, or a combination of these. Considering these factors, the basic method of plant control should be chosen –– biological, mechanical, or chemical.

Biological controls include plant–eating animals such as ducks and grass carp; mechanical methods include raking, dragging chains or cables to dislodge weed beds, and specialized aquatic plant harvesting equipment; chemical controls include a number of herbicides. Excellent lists providing names of chemicals and the plant species affected are reported in Meyer and Lueschow (1972). No all–purpose herbicide has been developed so the best control chemical for the dominant aquatic plants should be selected. Also, dosage rates and the needed application equipment should be determined.

Evaluation

Biological and mechanical control measures are generally limited in their scope of application because of the relatively small area they can treat effectively. Mechanical measures incur high operating costs. Chemical treatments can be effective in many instances, though the effects are usually temporary. The chemicals are limited mainly by their toxicity to fish, fish food organisms, and other plants and animals which may come in contact with the treated water. Meyer discusses the toxicity of several herbicides to various fish species and other animals. Many of the chemicals or their decomposed products are long–lived in the environment and may concentrate as they progress upward in the food chain. Consequently, they may be banned or otherwise regulated by Federal and State laws.

Timing of chemical application may be important as was the case for the Tehama–Colusa fish spawning channel along the Sacramento River, California (see Section P1.2). The channel is incorporated into an irrigation canal that must be treated periodically to reduce algae growth. The treatments are scheduled so as not to coincide with adult salmon spawning or with the hatching and rearing of fry in the channel. Other constraints on the use of chemical controls include the danger to workers who must apply the material and the possibility of causing a fish kill through depletion of dissolved oxygen by decomposing vegetation. Alternatives for some aquatic plant control problems include seasonal water level manipulation (Section H2.3) and deepening the edges of smaller lakes and ponds to discourage emergent vegetation.

Reference

Lueschow, L. A., "Biology and Control of Selected Aquatic Nuisances in Recreational Waters," Wisconsin Department of Natural Resources, Technical Bulletin No. 57, 1972.

Meyer, F. A., "Aquatic Plant Control," in Inland Fisheries Management, A. Calhoun (ed.), State of California, The Resources Agency, Department of Fish and Game, April 1966.

Otto, N. E., and T. R. Bartley, Aquatic Pests in Irrigation Systems, U.S. Bureau of Reclamation, 1972.

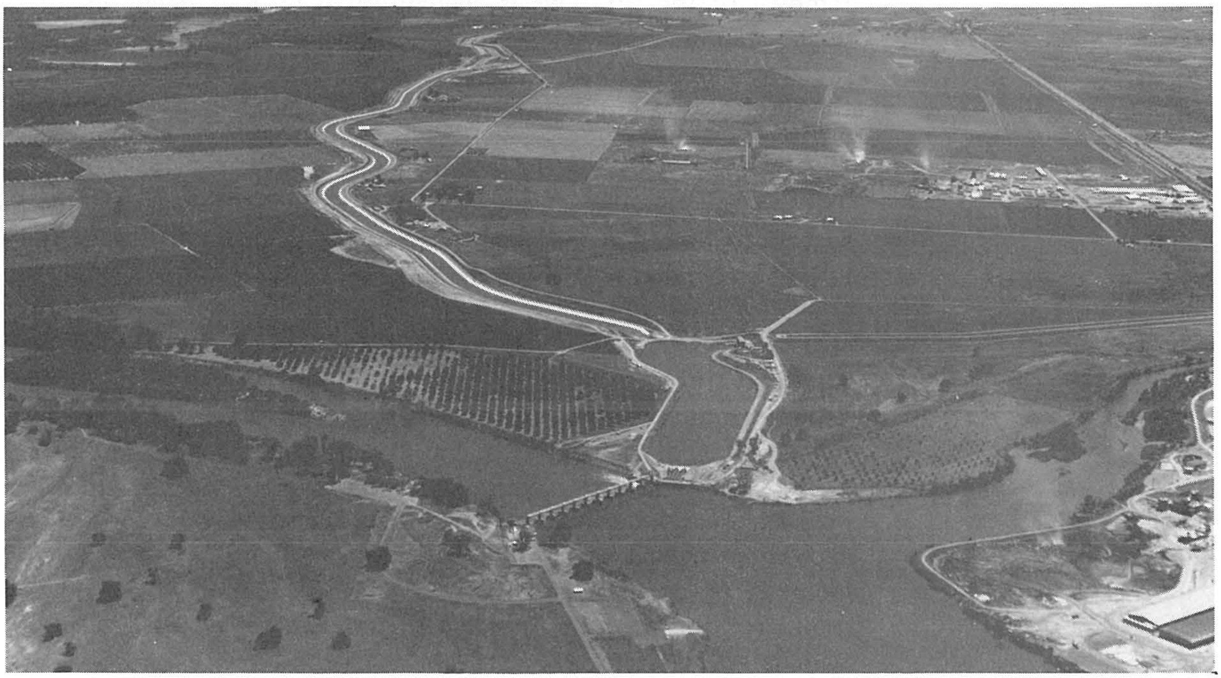
Settling and Retention Basins H6.7

Purpose

Settling and retention basins are constructed to reduce turbidity and streambed load. Turbidity is a measure of the suspended solids present in water, usually expressed in parts per million. The ability of light to penetrate water has a pronounced effect on growth and survival of bottom fauna which affects fish growth. Bed load refers to material moving on or near the streambed; it consists of materials rolled or slid along the bed. Bed load can kill buried eggs and newly hatched fry by blocking water interchange as well as smothering food organisms. Also, the silt carried by a stream may have adverse effects on aquatic life through direct damage to breathing organs such as gills. For a discussion of the effects of turbidity and bed load on fish and other aquatic organisms, see Bell (1973). For a discussion of methods to determine sediment transport, see Grenney, Porcella, and Cleave (1976).

Settling and retention basins are constructed so that the velocity of stream inflow is decreased enough to settle out the silt on the basin bottom. Settling and retention basins are used in conjunction with hatcheries (Section P1.1), artificial spawning channels (Section P1.2), spawning riffles (Section P1.3), fish and waterfowl ponds (Section H6.4), and wetland dredging and diking (Section H6.5). The basins may be permanent or temporary, depending on the cause and severity of the problem they are designed to correct.

Exhibit 1. Sediment basin at the entrance to Tehama-Colusa Canal, Sacramento River, California (from U.S. Bureau of Reclamation).



Illustration

For the three projects reviewed while preparing this handbook, stream siltation was controlled during construction. At Ruedi Dam (Colorado), the temporary installation of off–stream settling basins prevented siltation damage to aquatic habitats along 30 stream miles. At Sugarloaf Dam in Colorado, the on–stream basins protected 8 to 10 miles of stream habitats. Settling basins also are used to improve the quality of water entering hatcheries, spawning channels, and wetlands. Exhibit 1 shows an off–channel settling basin at the entrance to the Tehama–Colusa Canal (Sacramento River, California). The canal is a dual–purpose structure used for conveying irrigation water as well as for spawning (see Section P1.2). At the Topock Marsh Unit in Arizona, a settling basin has been excavated at the entrance of the inlet canal to trap sand and prevent it from being carried into the marsh (see Section H6.5 on wetland dredging and diking). The basin is approximately 100 feet wide, 800 feet long, and 20 feet deep. When required, silt will be removed by dragline equipment and placed on upland areas near the basin.

Limitation

Because the magnitude or extent of adverse effects of siltation often are difficult to predict, the benefits of settling and retention basins are highly uncertain. Therefore, recommending and implementing this improvement measure may be difficult to justify. Operation of a settling and retention basin necessitates periodic removal of the silt. This is accomplished by a dredging operation which can be quite expensive. Furthermore, the disposal of the dredged material may require land purchase and revegetation of the spoil.

Performance

Two of the three applications of this measure were judged to be successful; one was marginally successful (Exhibit 2). Confidence ratings associated with these findings were mixed.

Cost/Output

The construction costs of a settling and retention basin vary depending on whether the structure is permanent or temporary, the amount of surface area and depth, and the inlet and outlet works required. Also, maintenance costs will vary depending on how frequently the accumulated silt in the basin must be removed and which technique for removal is used. Sometimes costs may be incurred to acquire land for spoil disposal and to revegetate the spoil. For the projects investigated, these costs could not be disaggregated.

Settling and Retention Basins H6.7

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	high: Degree of implementation	high: Soundness of predictions	high: Reliability of reports	medium: Degree of implementation	medium: Soundness of predictions	medium: Reliability of reports	low: Degree of implementation	low: Soundness of predictions	low: Reliability of reports
Successful	Habitat	2	1	1	0	1	1	1	0	0	1
	Population	2	1	1	0	1	1	1	0	0	1
Marginally Successful	Habitat	1	1	0	0	0	1	1	0	0	0
	Population	1	1	0	0	0	1	1	0	0	0
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 2. Success and confidence matrix for settling and retention basins.

Project Review

CALIFORNIA: Oroville

COLORADO: Ruedi, Sugarloaf

The projects underlined had successful applications of this improvement measure.

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Grenney, W. J., D. B. Porcella, and M. L. Cleave, "Water Quality Relationships to Flow –– Streams and Estuaries," in Methodologies For The Determination Of Stream Resource Flow Requirements: An Assessment, Stalnaker, C. B., and J. L. Arnette (eds.), U.S. Fish and Wildlife Service, Office of Biological Services, Western Water Allocation, 1976.

Land Acquisition H6.8

Purpose

Acquisitions of land are made primarily to facilitate fish and wildlife management on project—associated sites. Land may be acquired by purchase, easement, or lease. If land is purchased in fee title, fish and wildlife interests have a "free hand" to develop and manage the land in perpetuity. Purchase of an easement entitles limited use of private land in perpetuity or for a finite period. Leases or licenses which are granted by the construction agency to a fish and wildlife agency to manage project land for a period of 25 to 50 years usually exclude uses of land that would significantly conflict with the preservation and improvement of wildlife habitats. Also, leases generally are renewable.

After acquisition, land is made available to the State fish and game agency or the U.S. Fish and Wildlife Service for administration and management in accordance with the terms of a General Plan and supplemental agreements under the Fish and Wildlife Coordination Act. The agreements are signed by the head of the State fish and wildlife agency, the Secretary of the Interior, and, for a Corps of Engineers reservoir, by the Secretary of the Army. Land is acquired to provide habitats for big game, upland game, waterfowl, and fish. A refuge or game preserve may be established to manage the acquired habitat.

Illustration

Size of land acquired and intended purposes were quite varied for the dam and reservoir projects reviewed. Areas varied upward from 27 leased acres at Angostura Dam (South Dakota) to 35,000 leased acres at Oklahoma's Eufaula Reservoir. At Eufaula, a General Plan made available 35,000 acres of land and water to the Oklahoma Department of Wildlife Conservation for fish and wildlife management. Management plans included fencing of wildlife areas, fire breaks, and habitat development. At Nimbus Dam in California, 50 acres were purchased in fee title for a fish hatchery site; whereas, 7,585 acres at Flaming Gorge (Utah) were purchased in fee title for big game protection and for goose nesting.

Limitation

To meet the needs of some species of wildlife, land areas must be extensive, thus increasing the difficulty of acquisition when faced with highly competitive, conflicting uses such as agriculture, recreation, and residential or industrial development. Fencing to exclude grazing of livestock or browsing by big game (see Sections H6.3 and P5.2) during establishment of wildlife food and cover plantings (Section H6.1) may incur a significant corollary expense with land acquisition. However, the costs of such improvements may be offset by allowing sharecropping under State or Federal fish and wildlife agency control, or by granting grazing leases incorporating conditions desired by fish and wildlife interests for effective wildlife management.

Lags in the acquisition of project lands for fish and wildlife purposes can be particularly damaging because of two factors. One of these is inflation which erodes the purchasing power of the funds allocated to land acquisition; ultimately, the targeted amount of land may not be acquired. The second factor is that the longer land acquisition is postponed, the greater will be the difficulties associated with finding willing sellers, and the more necessary it may become to resort to condemnation proceedings. These are likely to involve complicated political issues which reduce the chances that acquisition targets will be met. Moreover, because the Federal government already has vast holdings in most of the western States, State and local interests may object to further Federal acquisition which removes land from State and local tax rolls.

Performance

Examination of 17 cases of this improvement measure showed 13 instances of successful population improvement; successful habitat improvement was achieved in 14 cases (Exhibit 1). High ratings for all three confidence factors were linked with cases classified as successful.

Exhibit 1. Success and confidence matrix for land acquisition.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high — Degree of implementation	high — Soundness of predictions	high — Reliability of reports	medium — Degree of implementation	medium — Soundness of predictions	medium — Reliability of reports	low — Degree of implementation	low — Soundness of predictions	low — Reliability of reports
Successful	Habitat	13	12	11	8	1	2	5	0	0	0
	Population	14	12	12	8	1	2	6	0	0	0
Marginally Successful	Habitat	3	0	0	0	0	2	4	3	0	0
	Population	2	0	0	0	0	1	3	2	0	0
Unsuccessful	Habitat	1	0	1	0	0	0	1	1	0	0
	Population	0									

Cost/Output

Exhibit 2 lists the fee title acquisition cost per acre of land in 1977

Exhibit 2. Per acre cost and associated biological output for land acquisition.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Wynoochee	$620	––	Curtailment	Improvement	3
Arbuckle	$190	––	Curtailment	Reduced Curtailment	1
Broken Bow	$140	––	Curtailment	Reduced Curtailment	1
Flaming Gorge	$ 80	––	Curtailment	Maintenance	2

dollars for the four projects with available data. Although easements were not acquired for the projects reviewed, their costs are figured as a percentage of purchase cost according to the degree the easement would restrict private land use. Frequently, these costs are close to the full purchase value. For a proposed easement purchase along the James River in South Dakota, these costs would range up to 90 percent of fee title values. Leases are usually obtained from construction agencies where actual expenditure of funds is not involved. Besides direct costs associated with each form of acquisition, legal fees and administrative expenses are incurred for each parcel acquired.

Project Review

ARIZONA: Alamo, Yuma

CALIFORNIA: Nimbus

IDAHO: Lucky Peak, Minidoka

IOWA: Rathbun (3 cases)

OKLAHOMA: Arbuckle, Broken Bow, Mountain Park, Optima, Pat Mayse

UTAH: Flaming Gorge, Joe's Valley (2 cases)

WASHINGTON: Wynoochee

The projects underlined had successful applications of this improvement measure.

Reservoir and Flood Plain Zoning H6.9

Purpose

Zoning the reservoir water surface and associated land ensures that conflicts among project purposes will be minimized. For example, recreational activity such as use of four–wheel–drive vehicles that is in opposition to wildlife habitats and production can be prohibited on designated project land. This land usually is fenced and posted to effectuate the zoning. On the reservoir itself, zoning may be applied to protect fish spawning or waterfowl and raptor resting, nesting, and feeding areas from disturbances of water recreation. The restrictions may be implemented through the use of natural or passive restraints. For instance, timber left standing in the reservoir would be a natural restraint to recreational boating and water skiing. Signs posted in the reservoir specifying a no–wake zone would be a passive restraint.

Zoning may comprise a combination of use and temporal (hourly or seasonal) restrictions. A document such as a reservoir management plan or master plan specifies the areas to be zoned. Zoning of non–Federal land or water relies on State and local police powers since the Federal government can zone only the property it owns.

Another type of zoning is for flood plains. Flood plain or greenbelt zoning may occur either in conjunction with dam and reservoir projects or in lieu of one. This type of zoning protects riparian habitats along a stream by prohibiting development in the floodway –– the zone likely to be inundated by flood waters. Only those uses which are compatible with this hazard, such as agriculture, open space, recreation, and ecological preservation, are allowed there. Flood plain zoning may be effectuated by outright purchase, purchase of development rights only, or zoning of private property under the police power.

Illustration

The Glen Elder reservoir exemplifies a project where the reservoir water surface and associated land have been zoned. In some of the reservoir coves, recreational boating and water skiing are prohibited. This is accomplished by a sign on a buoy at the mouth of each cove. The entire perimeter of the Glen Elder reservoir site is fenced to enforce a prohibition of livestock grazing on project land. Among several purposes, this fencing protects food and cover plantings (see Section H6.1) and established wildlife habitats from destruction by livestock. If grazing is permitted at a project site, then such plantings and habitats would have to be fenced separately to exclude livestock.

Limitation

Monitoring and enforcement of zoning compliance may be quite difficult and expensive. In most cases, preservation of fish and wildlife habitats by zoning depends on voluntary public compliance with the zoning designations.

Performance

Reservoir zoning was judged to be successful in terms of habitat improvement in two out of three applications, and in terms of population improvement in three out of four.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high — Degree of implementation	high — Soundness of predictions	high — Reliability of reports	medium — Degree of implementation	medium — Soundness of predictions	medium — Reliability of reports	low — Degree of implementation	low — Soundness of predictions	low — Reliability of reports
Successful	Habitat	2	2	2	0	0	0	2	0	0	0
	Population	3	2	2	0	1	1	3	0	0	0
Marginally Successful	Habitat	1	0	0	0	1	1	0	0	0	1
	Population	1	0	0	0	1	1	0	0	0	1
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 1. Success and confidence matrix for reservoir zoning.

Cost/Output

Direct monetary costs for reservoir zoning include the value of personnel and materials necessary to post or fence designated areas as well as the value of personnel required to monitor compliance and enforce the regulations. Also, some land or water uses are precluded or limited when portions of a reservoir site are zoned in favor of fish and wildlife habitat preservation. Therefore, the forfeited benefits from these foregone uses constitute surrogate value for the costs of reservoir zoning. However, for the projects evaluated, data were not available to estimate these costs.

Project Review

CALIFORNIA: Stampede

IOWA: <u>Rathbun</u> (2 cases)

KANSAS: <u>Glen Elder</u>

The projects underlined had successful applications of this improvement measure.

P1.0

Fish Propagation

Fish Hatcheries P1.1

Purpose

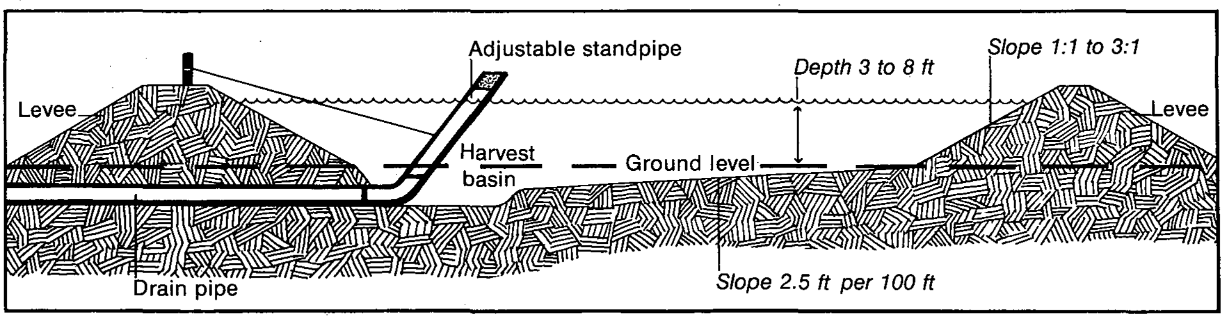
Fish hatcheries generally are intended to compensate for losses due to habitat disruption such as blockage of spawning migration routes, supplement populations subject to over–exploitation from sport or commercial harvest, and stock new or rehabilitated habitats. Most hatcheries raise game fish, primarily trout, salmon, bass, bluegill, and catfish. In some instances, hatcheries have been used to raise non–game or rare and endangered fish such as the Colorado River squawfish.

Illustration

Hatchery facilities vary considerably, depending on the fish species to be raised, the size desired for release, and site–specific factors such as the water supply and the area available for construction. Eggs usually are hatched in vertical incubators having stacks of trays, each supplied with reaerated flow from the tray above. Various types of jars and other containers also are being used. Newly–hatched fry may be reared in indoor troughs until they are large enough to move outside to ponds or raceways. Ponds are normally used for warmwater fish rearing while raceways are used for coldwater species. Bell (1973) discusses water requirements of various raceways and ponds and their associated fish carrying capacities.

Ponds should be rectangular in shape with a gentle bottom slope (about 2.5 ft per 100 ft) to allow complete drainage to a harvest basin (see Exhibit 1). Slope of the levees should range between 1:1 and 3:1, depending on the soil type (20% clay is preferable). Grass or wheat should be planted on the exposed levees to control erosion. Minimum depth of the ponds should be 3 feet to discourage rooted aquatic weeds; maximum depth can be 6 to 8 feet. An adjustable standpipe, as shown in Exhibit 1, can be used to control water depth. Small ponds (less than 10 acres) are preferable though more expensive than large ponds. Small ponds permit easier feeding,

Exhibit 1. Typical hatchery rearing pond in cross-section.



treating, and harvesting of the fish and also reduce the chances of a single catastrophy destroying the fish crop (Giudice, 1978).

Raceways have a continuous through movement of water and can be rectangular or circular, preferably with a concrete lining. Rectangular raceways (Exhibit 2) can be 50 to 200 feet long and should be built in pairs sharing a center wall. By providing a roadway between each pair, mechanical feeders can be used. Depending on water quality and quantity, fish size and stocking density, and the area available, raceways can be built in a series, usually of 3 or 4 pairs. Each pair is higher than the succeeding pair so that water tumbles into the next and becomes aerated. The longer a series of raceways is made, the greater will be the accumulation of waste products toward the lower end and the greater will be the loss from any fish disease developed at the upper end.

Circular raceways should be between 15 and 25 feet in diameter. Water enters through an angled jet at the side of the pool to produce circulation. Less water is needed than for a rectangular raceway because the inflow produces turbulence in the oxygen—depleted water, causing reaeration besides adding a fresh supply. The circular raceways are designed to be self—cleaning through a center standpipe. Flushing for disease control and mechanical capture of the fish for loading are relatively difficult (Leitritz, 1972). Another circular type of rearing facility was developed by the Pennsylvania Fish Commission. Trout were raised in silos 5 meters tall and 2.3 meters in diameter. Water exchange is five times per hour as compared to standard raceways that exchange once or twice in two hours. Trout production is excellent and the silos can be located where space is limited or site restrictions preclude construction of raceways or ponds. Construction and maintenance costs are much lower than for conventional facilities.

Hatchery capacity varies depending primarily on the water supply and the fish raised. For the hatcheries reviewed while developing this handbook, capacities ranged from 70,000 lbs of salmon and steelhead trout released annually from the Nimbus Dam hatchery in California to approximately 480,000 lbs of trout and kokanee salmon released annually from the Dworshak Fish Hatchery in Idaho. Water supplies are about 23 mgd at Nimbus and 86 mgd at Dworshak. Current trends are to locate large hatcheries near dams, utilizing a discharge conduit to convey water supply from the reservoir. For a discussion of basic hatchery requirements and designs, see Bell or Leitritz.

Fish Hatcheries P1.1

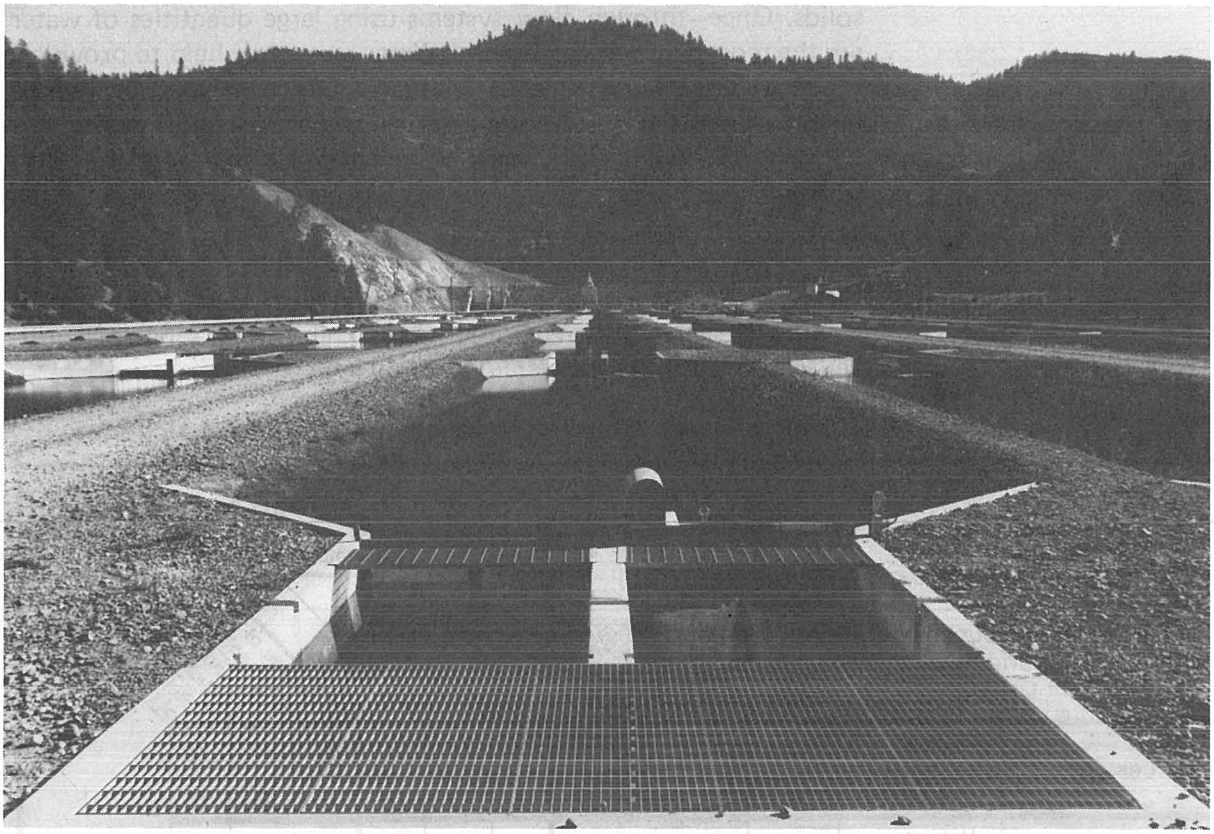


Exhibit 2. Raceways at the Trinity River Fish Hatchery, California (from U.S. Bureau of Reclamation).

Limitation

The dominant limiting factor for both size and siting of fish hatcheries is the water supply. A firm, year–round supply of the proper temperature for the selected fish species is required. Preferred water temperatures for rearing salmonids range from 50 to 60 degrees Fahrenheit (45 to 55°F to hatch eggs). Warmwater species prefer temperatures between 65 and 80 degrees Fahrenheit (50 to 70°F for their eggs). The hatchery water supply should be free from disease and pollution in addition to being protected from deterioration in quality or shortage in quantity. Some hatcheries have water reuse systems where an adequate fresh supply is unavailable. Generally, these systems incorporate filtration and sterilization equipment and may have temperature–control capability, but at present they are experimental and expensive.

Another major limiting factor in hatchery design is meeting current wastewater effluent standards. Some of the critical quality factors include biological oxygen demand, dissolved oxygen, and suspended solids. Once—through flow systems using large quantities of water are the most difficult to improve. Water reuse may help to provide a solution to effluent quality control. Other design limitations include the difficulty of obtaining roadway access and the problems inherent in stocking fish from the hatchery (see Section P3.1, Fish Stocking).

Performance

Most of the hatcheries assessed were judged to be successful in maintaining or improving fish stocks (Exhibit 3). Ratings of confidence in the assessment were uniformly high.

Exhibit 3. Success and confidence matrix for fish hatcheries.

Classification of Success Using Habitat and Population Improvement Criteria		*number of cases*	Confidence Factors and Ratings: *high* – Degree of implementation	*high* – Soundness of predictions	*high* – Reliability of reports	*medium* – Degree of implementation	*medium* – Soundness of predictions	*medium* – Reliability of reports	*low* – Degree of implementation	*low* – Soundness of predictions	*low* – Reliability of reports
Successful	Habitat	4	3	3	3	1	1	1	0	0	0
	Population	10	9	8	7	1	2	3	0	0	0
Marginally Successful	Habitat	1	0	1	1	1	0	0	0	0	0
	Population	3	1	1	3	2	2	0	0	0	0
Unsuccessful	Habitat	0									
	Population	0									

Cost/Output

Exhibit 4 presents the amortized capital costs and operation and maintenance costs to release a pound of fish from the hatchery. Capital costs varied between \$20 and \$27 (1977 dollars) per pound of fish. This is comparable to the estimates in Bell which would be \$12 to \$23 per pound if adjusted to 1977. Besides the very substantial capital outlay, fish production costs varied between \$0.40 and \$1.90 per pound; Bell stated that these costs may vary between \$0.75 and \$1.25 per pound (adjusted to 1977).

Project Review

ARIZONA: <u>Glen Canyon</u> (2 cases)

CALIFORNIA: <u>Iron Gate</u>, <u>Nimbus</u>, Oroville, <u>Shasta</u>, Trinity River

Fish Hatcheries P1.1

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Dworshak	$27	$1.90	Curtailment	Reduced Curtailment	1
Glen Canyon (Hotchkiss)	$20	$0.60	Maintenance	Improvement	1
Glen Canyon (Jones Hole)	$20	$0.40	Maintenance	Improvement	1
Scoggins	––	$1.20	Curtailment	Maintenance	2
Shasta	$0.007 (per egg/fry)	$0.002 (per egg/fry)	Curtailment	Maintenance	2
Nimbus	––	$0.01 (per egg)	Curtailment	Maintenance	2

Exhibit 4. Costs per pound and associated biological output for fish hatcheries.

COLORADO: Pueblo

IDAHO: Dworshak

OREGON: Fall Creek, Foster, Scoggins

UTAH: Flaming Gorge

The underlined projects had successful applications of this measure.

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Giudice, J., "Proper Construction of Fish Ponds Is One Key to Profitable Operations," Commercial Fish Farmer, 4(2): 25–27, January 1978.

Leitritz, E., Trout and Salmon Culture (Hatchery Methods), California Department of Fish and Game, Fish Bulletin No. 107, 1972.

Nursery and Rearing Ponds P1.2

Description

Nursery ponds and rearing ponds apart from hatcheries are used to supplement hatchery programs and natural recruitment. The primary benefits are that the young fish can be protected from predators and raised to a size desirable for stocking. Nursery ponds usually are constructed adjacent to the reservoirs to be stocked, though existing ponds in the vicinity also may be used. Adult fish of the desired species are stocked in the ponds and allowed to spawn. The adults are then removed to suppress cannibalism and the fry are raised. If the pond is adjacent to the reservoir, the fry can be stocked by direct release through water outlets. Rearing ponds normally are part of hatchery facilities but they can be used separately as well. The main difference between nursery and rearing ponds is that the latter are stocked with fry from an outside source, usually a hatchery. The stocking density is a function of the quality and quantity of water available and the age of the fish. Young fish need more room per pound because of their rapid metabolism and growth.

Leitritz (1972) discusses factors affecting the carrying capacity of ponds for trout and salmon culture. Both nursery and rearing ponds should drain rapidly, either directly releasing the fish for stocking or drawing down to a small basin or "kettle" from which the fish can be easily removed. Any water flow in the ponds should be uniform for the best distribution of food and more even growth. Food may be supplied from natural sources or supplemented with prepared feed. Many species of fish have been raised using these pond techniques, including black bass, sunfish, trout, and salmon. Oregon has experimented with rearing ponds to supplement the production of fall chinook salmon fry (Hansen and Sams, 1970). Another application is with existing ponds in soon–to–be–filled reservoir basins. Fry are hatched or stocked in ponds that eventually will be flooded by the reservoir pool. By removing other fish species and using supplemental feed, the fry can be given a headstart in the reservoir stocking program.

Evaluation

Rearing ponds have been an established and successful hatchery feature for many years. The research in Oregon used two water–filled gravel pits of approximately 3 acres and 6 acres. Nearly five million fry had a five–fold increase in size over the five–week experiment using prepared feed. Of the fish originally stocked, 84 percent were recovered and later released despite the use of traps when the ponds could not be completely drained. Nursery ponds also have been successful. They have been used to establish populations of some fish species in reservoirs where stocking fry of those species has failed (Smith, 1976). However, costs for construction of ponds are high.

Reference

Hansen, H. L., and R. E. Sams, "Rearing Fall Chinook Salmon in Upper and Lower Aumsville Ponds," Progress Report to Fish Commission of Oregon, Research Division, July 1970.

Leitritz, E., Trout and Salmon Culture (Hatchery Methods), California Department of Fish and Game, Fish Bulletin No. 107, 1972.

Smith, S. F., "Development of Nursery Cove Techniques," Texas Parks and Wildlife Department, Federal Aid Project No. F—31—R—2, Completion Report, December 1976.

Nursery Cove Barriers P1.3

Description

Nursery cove barriers isolate a cove from the remainder of a lake or reservoir for the purpose of raising fish in the protected water prior to release into the impoundment. The barriers were developed as an alternative to costly nursery and rearing ponds (Section P1.2). Exhibit 1 is a drawing of a nursery cove barrier constructed as part of a study by the Texas Parks and Wildlife Department (Smith, 1976). The nylon netting is 1/16-inch mesh and is designed to restrain largemouth bass fry. The galvanized wire protects the netting from floating debris and animals.

Evaluation

The barrier as tested by Smith was capable of containing largemouth bass fry without suffering serious damage over seven months of observation. It was noted at one barrier site that stumps and logs had to be cleared from the reservoir bottom to provide complete enclosure. Also, sediment had to be removed from the netting to prevent clogging. Additional anchoring may be necessary in areas subject to strong wind and wave action.

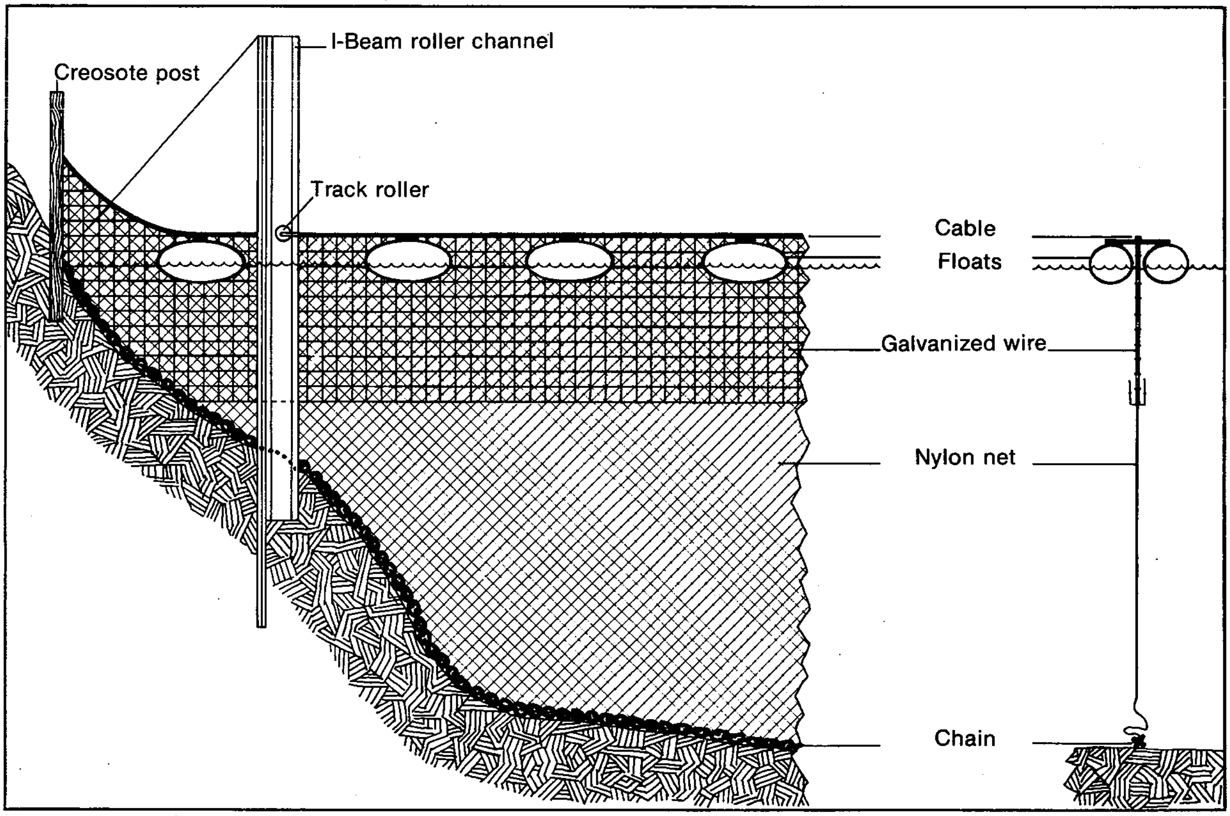


Exhibit 1. Nursery cove barrier used on Lakes Jacksonville and Tyler East, Texas.

Reference

Smith, S. F., "Development of Nursery Cove Techniques," Texas Parks and Wildlife Department, Federal Aid Project No. F–31–R–2, Completion Report, December 1976.

Spawning Bottom and Marsh P1.4

Description

Spawning beds can be installed on a lake bottom to supplement natural spawning areas. Reservoirs having a heavily silted bottom and muddy banks may need additional spawning beds to help provide a self–sustaining fish population. Species normally benefitting from this improvement measure are those requiring a firm substrate for spawning such as walleye, trout, and black bass.

Spawning beds for walleye should consist of rock and gravel 6 inches deep, ½ inch to 2 inches in diameter, and placed in 12 to 30 inches of water. Weber and Imler (1974) constructed such walleye beds while the water level was low in Lonetree Reservoir, a 500–acre irrigation reservoir in Colorado. The Forest Service (1969) reports on development of walleye beds by strategically placing rubble on the ice–covered surface of a lake during the winter. Spawning beds for various species of trout can be established in an impoundment by placing gravel in the mouths of inlet streams. Excess rock and rubble from dam construction is a good source of material.

Spawning marshes have been constructed to supplement natural spawning grounds for northern pike. Pike spawn in shallow weedy marshes adjacent to lakes and reservoirs. The constructed marshes are built near the impoundment; adult pike are attracted to them by artificial flows or are caught and stocked in the marsh. Dikes, controlled outlets, and pumps are sometimes incorporated to allow management of water levels. Once the adults have spawned, they are removed to prevent cannibalizing the fry. The marsh is drained into the impoundment when the fish are the desired size.

Evaluation

Weber and Imler reported a two to tenfold increase in young–of–the–year walleye in Lonetree Reservoir where installed spawning beds increased the available spawning grounds by an estimated 17 percent. Construction costs for two 5,000–square–foot spawning beds were approximately $5,000 (in 1977 dollars). The Forest Service reported on successful lake trout spawning following the introduction of gravel. Obviously, such significant results will be seen only where natural spawning beds are scarce or non–existent. One alternative is a water level management plan (see Section H2.3 on seasonal manipulation) whereby water levels are dropped during the winter to allow cleaning of silt and algae from available spawning gravel such as dam riprap. Water levels are raised and maintained during spring and early summer, if at all possible, to protect the spawning and rearing habitats.

A managed spawning marsh on Bluestem Lake in eastern Nebraska produced suitable numbers of northern pike whose survival appeared to be equal to that of hatchery–reared fish (Morris, 1972). Some problems identified by the study included high mortality during a three–day draining process made necessary by reduced dissolved oxygen levels. Also, some fish were stranded in grass when the marsh was drained. The problems were at least partially resolved in later experiments by controlled burning of the grass prior to filling. A reservoir water level manipulation plan (Section H2.3) in combination with exposed area planting (Section H1.5) might be an alternative to marsh management. These measures have been successful in Kansas reservoirs in providing pike with weedy shallows for spawning.

Reference

Morris, J. W., "Monitor Survival of Northern Pike Produced in an Experimental Artificial Spawning Marsh," Nebraska Game and Parks Commission, Job Progress Report, Project No. F–4–R–17, February 1972.

U. S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Weber, D. T., and R. L. Imler, "An Evaluation of Artificial Spawning Beds for Walleye," Colorado Division of Wildlife, Special Report No. 34, July 1974.

Spawning Riffles P1.5

Description

Spawning riffles occur over gravel beds in shallows of flowing streams and rivers. Trout and salmon deposit their eggs in depressions they carve out in the spawning beds. Gravel should be ¼ to 2 inches in diameter for trout, ½ to 6 inches for salmon. The eggs and newly hatched fry survive in the spaces between the gravel, making them dependent on water percolation through the gravel bed for their oxygen supply and waste removal. A major factor affecting the survival rate of the eggs and fry is the amount of silt and fine gravel in the spaces or interstices of the spawning bed. As the amount of sediment increases, the percolation rate declines and so does survival. Often less than 10 percent of the eggs deposited survive to emerge as free–swimming fry.

With increasing demands on the fisheries and decreasing usable habitats, methods have been sought to revitalize natural stream spawning beds. Several approaches have been experimented with as indicated in the literature search and preliminary studies of Mih (1976). Probably the most obvious solution is to reduce the source of sediment by using settling basins (see Section H6.7), soil conservation measures, and restrictions on development. The Forest Service (1969) discusses methods to trap and hold existing stream gravel and to add graded gravel to form new spawning beds. Mih discusses the use of mechanical agitation such as that caused by tractor–powered forks, rakes, and blades to stir sediment into suspension or separate it from usable gravel. These techniques, including the gravel traps, work best in fast–flowing streams.

The Forest Service developed a machine called a riffle sifter which uses water jets to flush sediment and fines from the gravel and a suction system to remove them from the streamflow. The riffle sifter was used on the Trinity River in California below Lewiston Dam. Another solution becoming possible with the advent of pumped storage reservoirs is the establishment of spawning riffles in the flow transition zones. These could be used by reservoir fish such as brown and cutthroat trout which normally spawn in streams feeding the reservoirs.

Evaluation

Rehabilitation of spawning riffles on the Trinity River (California) was rated marginally successful even though fully implemented. The benefits of riffle cleaning were shortlived because of decreased average flows and elimination of annual flushing flows. Also, mechanical problems plagued the riffle sifter. The sediment flushing system of the sifter uses bars with jet nozzles to penetrate the streambed to a depth of 12 to 14 inches. The sifter is then pulled along the stream by a cable winch and high–pressure water jets clean the gravel. However, the force exerted to pull the flushing system through the gravel causes the flushing bars to break and the anchors for the cable to pull out. In addition, the vacuum system tended to plug with gravel and vegetation. For these reasons, the original riffle sifter is no longer in use, although Mih (1977, 1978) has conducted research for design of a new model (Exhibit 1 is a conceptual drawing of a new design). He has proposed to use a different vehicle and jet nozzles that spray just above the level of the streambed.

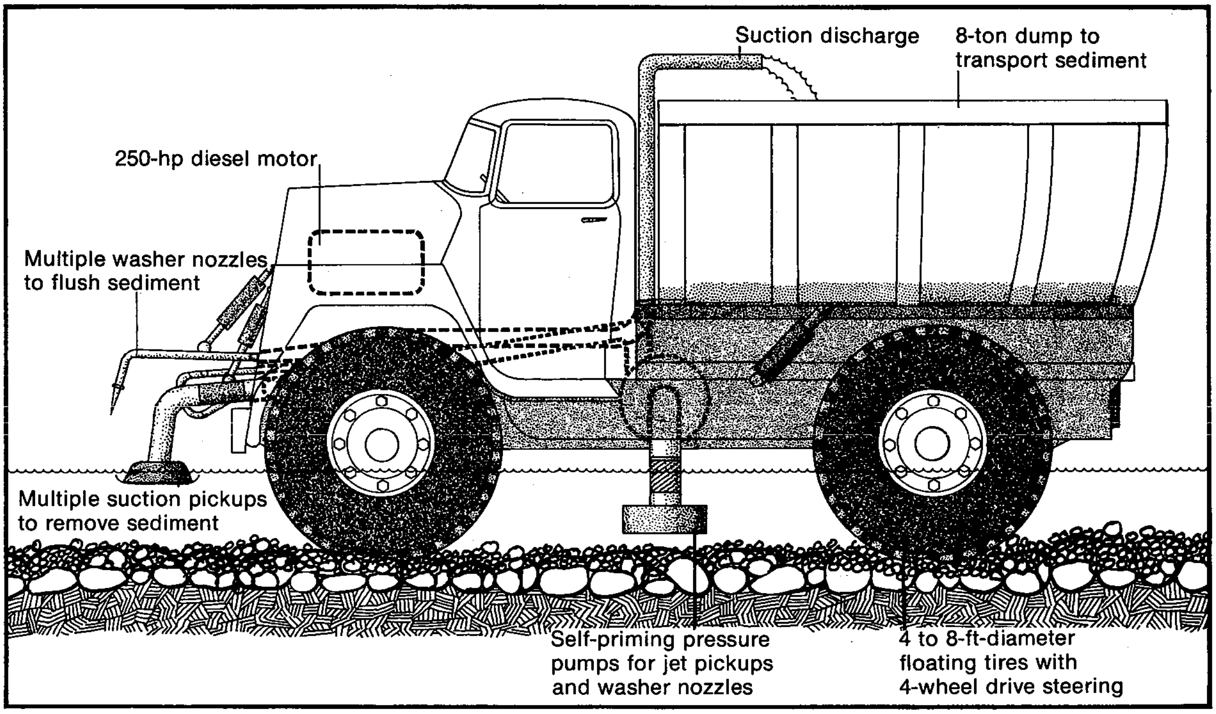


Exhibit 1. Concept for a new spawning riffle sifter to clean spawning gravel (from California Department of Water Resources).

Despite the problems with the first mechanical sifter, riffle cleaning still appears to hold promise. Experimentation has shown that salmon survival improves 40 to 60 percent in cleaned riffles. Also, agitation of stream gravel apparently does not discourage fish spawning nor does it permanently affect populations of bottom fauna. Care must be taken, however, to avoid destruction of streambanks by mechanical equipment and to avoid excessive siltation downstream from cleaning operations.

Reference

Mih, W. C., "Development of Spawning Gravel Cleaning Machine,"

Spawning Riffles P1.5

Quarterly Reports to Washington State Department of Fisheries, 1977 and 1978.

Mih, W. C., "Literature Search on Restoration of Stream Gravel for Spawning and Rearing of Salmon Species," Washington State Department of Fisheries, Progress Report No. 3815–1460, November 30, 1976.

Artificial Spawning Channels P1.6

Exhibit 1. Artificial spawning channels along the Tehama-Colusa Canal, part of the Central Valley Project in California (from U.S. Bureau of Reclamation).

Description

Artificial spawning channels are constructed as an alternative to fish hatcheries for coldwater anadromous fish, primarily salmon. Their purposes are to supplement the natural spawning habitat or to replace habitats lost from construction of dams or other structures. The project investigations covered the spawning channels incorporated into the Tehama–Colusa Canal along the Sacramento River in California. These facilities, constructed by the U.S. Bureau of Reclamation as part of the Central Valley Project, consist of three separate channels. Portions of the channels can be seen in Exhibit 1 which is a view looking upstream. The uppermost section of the canal in the picture is the dual–purpose channel. It functions both as a spawning channel and irrigation canal, and is approximately 3.2 miles long with a normal water depth between 6 and 8 feet; the gravel bed is 100 feet wide and 2.5 to 3 feet thick. A photograph of this spawning gravel is presented as Exhibit 2.

In the lower center section of Exhibit 1 are the two single–purpose spawning channels. These twin channels are approximately 1 mile long with a water depth of 1.5 feet; each gravel bed is 30.5 feet wide and 2.5 to 3 feet thick. The combined spawning area provided by all three channels exceeds 2 million square feet. The twin channels join downstream to form an access channel that empties into a tributary of the Sacramento River. At the mouth of the access channel is an electric barrier to direct upstream–migrating adult salmon into the spawning facilities; also there is a release site for the fry hatched in the channels. Structures shown in the center of Exhibit 1 include:

- A short fish ladder to permit upstream passage of adults from the twin channels to the dual–purpose channel
- A pipe apparatus to deflect spawned–out salmon carcasses to a collection site
- A drum screen complex that prevents downstream–migrating fry from entering the irrigation canal below the dual–purpose channel.

Fry are collected and later released at the mouth of the access channel.

Structures not shown in Exhibit 1 include a louver screen at the headworks of the dual–purpose channel that inhibits the entrance of fish from the Sacramento River; a settling basin just below the louver screen to remove silt and clay particles from the flow; and various holding ponds and counting facilities along the channels. An additional feature is a baffle gate used to clean sediments and fine gravel from the spawning gravel, thus ensuring interstitial water flow to the fish eggs. The gate is suspended across the channel between two moveable carriages. By lowering the baffle gate into the water just above the gravel, a high–velocity scouring flow is produced beneath it. The sediment is washed out of the gravel bed and into the downstream flow. The carriages move the gate slowly downstream so the entire channel is cleaned.

A variety of other sites have been utilized for spawning channels. For example, the State of Washington and the Corps of Engineers have converted sections of existing streams and rivers into spawning channels by screening off oxbows. One channel was constructed at Indian Creek in Alaska using the flood plain. Clay (1961), the

U.S. Forest Service (1969), and Bell (1973) provide further discussion and specifications.

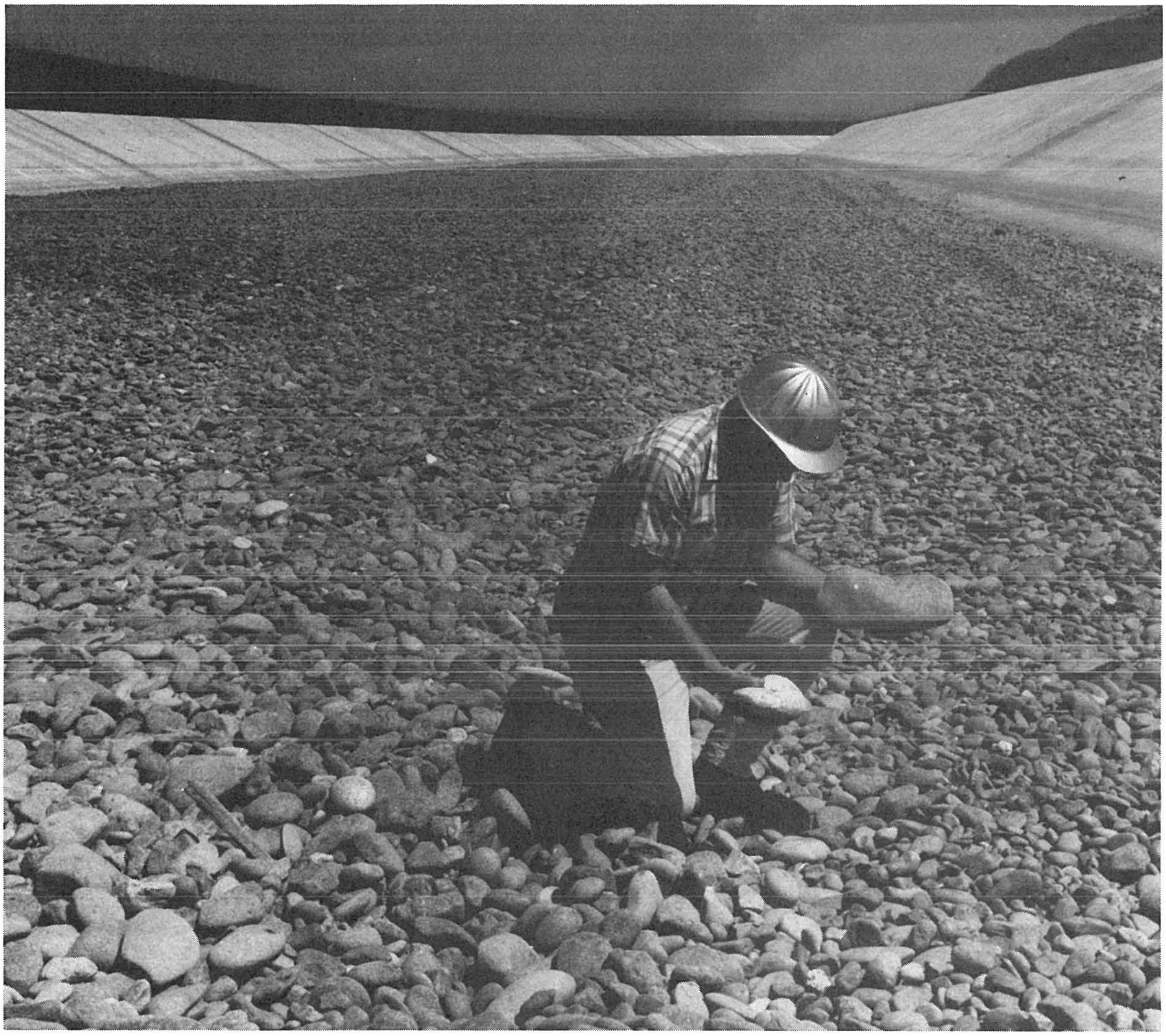


Exhibit 2. Gravel bed of the dual-purpose irrigation and artificial spawning channel along the Tehama-Colusa Canal, California (from U.S. Bureau of Reclamation).

Evaluation

The Tehama–Colusa fish spawning facilities were judged successful; the number of salmon using the channels varies from year to year but the annual average is approximately 5,000. Bell's discussion of spawning channels indicates that successful operations are probably due to increased water percolation through the channel beds as compared to natural stream beds. A controlled flow of good–quality water and high permeability in the gravel bed are the critical factors in producing more rapid hatching and greater survival of the fry.

While costs for artificial spawning channels are substantial, they may be significantly less than for a hatchery of equal production capacity. Maintenance and personnel requirements also may be less for the spawning channels (Clay). Another advantage is that, in situations such as the Tehama–Colusa, some of the needed facilities already exist and a spawning channel could be incorporated with less new construction. In some applications, spawning channels may serve secondary functions such as carrying flood flows. Disadvantages of the channels include the need for gravel cleaning and the compromising effects on hydrologic characteristics of canals or streams.

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Clay, C. H., Design of Fishways and Other Fish Facilities, The Department of Fisheries of Canada, Catalog No. FS 31–1961/a January 1961.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Fish Passage

Trap and Haul Systems P2.1

Purpose

The purpose of this improvement measure is to facilitate the passage of migrating fish, primarily salmon and some trout species, around natural or man–made obstructions. Trap and haul systems most often are used to pass small runs of fish around high dams or past construction sites. The usual operation is to trap upstream–migrating adults below an obstruction and transport them above it to a release site or a hatchery. However, one of the largest fish trapping and hauling operations ever done, termed "Fish Haul 1977", involved transporting approximately 2.8 million chinook salmon and steelhead trout smolts from the Snake River drainage (Washington and Oregon) downstream to the mouth of the Columbia River (Committee on Fishery Operations, 1977).

Illustration

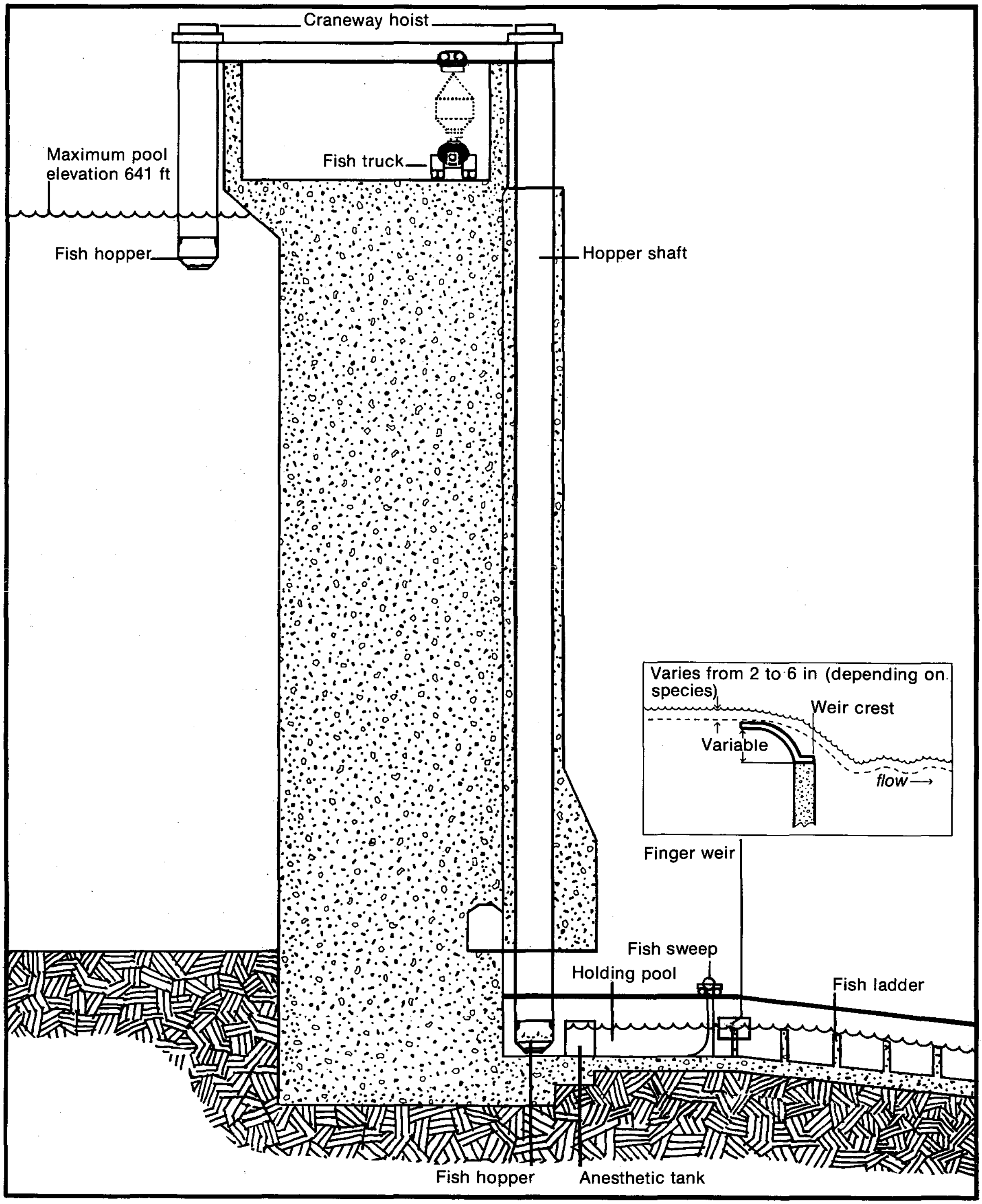
Many types of facilities have been devised to trap and haul fish. The design in use at Foster Dam in Oregon, which was evaluated as part of the project review in preparing this handbook, is presented in Exhibit 1. Supplemental flows are used to attract fish to the entrances of a short fish ladder which leads the fish to the trapping facilities. The last weir on the ladder is a finger weir (see inset, Exhibit 1) that traps the fish in the holding pool by allowing them to pass over the weir, then resisting their escape. The holding pool is equipped with a fish sweep that crowds the fish into an anesthetic tank from which the desired species are sorted into the fish hopper. The hopper has a 1,000–gallon capacity and, when full, is raised by the craneway hoist to the top of the dam. From the top, the fish can be loaded into a fish truck for transport upstream or they can be released directly into the forebay of the reservoir. These facilities have been used to pass approximately 13,000 adult fish per year.

Clay (1961) describes several other trap and haul designs or "elevators" and also presents plans and diagrams to illustrate their operation. The aforementioned "Fish Haul '77" utilized turbine bypass systems (see Section P2.4) to collect the smolts at Lower Granite and Little Goose Dams in Washington. Eight tanker trucks, two barges, and one tank–equipped airplane were used to transport the trapped fish in addition to fish raised in hatcheries. In all, over 5.3 million fish were transported downstream during the spring of 1977.

Limitation

Constraints on the application of these passage systems include high operation and maintenance costs and possible injury to the transported fish due to intensive handling and processing (Calhoun, 1966). Costs may not be as critical when trap and haul systems are used

Exhibit 1. Trap and haul system at Foster Dam, Oregon.



temporarily during project construction. Clay presents some cost comparisons and discusses factors influencing the capacities of these systems. Maximum transport capacity for facilities similar to those at Foster Dam (Oregon) is generally less than 20,000 adult fish per year.

Performance

The success and confidence matrix, shown in Exhibit 2, indicates that nearly all trap and haul systems have been successful where they are fully implemented and reports of their actual effects are reliable. All of the facilities studied were permanent except for those used on the Trinity River in California.

Classification of Success Using Habitat and Population Improvement Criteria		*number of cases*	Confidence Factors and Ratings: *high* — Degree of implementation	*high* — Soundness of predictions	*high* — Reliability of reports	*medium* — Degree of implementation	*medium* — Soundness of predictions	*medium* — Reliability of reports	*low* — Degree of implementation	*low* — Soundness of predictions	*low* — Reliability of reports
Successful	Habitat	2	2	0	1	0	2	1	0	0	0
	Population	6	6	1	4	0	4	2	0	1	0
Marginally Successful	Habitat	1	1	0	1	0	1	0	0	0	0
	Population	0									
Unsuccessful	Habitat	0									
	Population	0									

Exhibit 2. Success and confidence matrix for trap and haul systems.

Cost/Output

The construction costs for trap and haul systems ranged from $1.2 million to $2.7 million with dollars adjusted to 1977. Annual operation and maintenance costs varied from $9,000 to $40,000. Their costs and the associated biological output are presented in Exhibit 3.

While "Fish Haul 1977" was highly atypical, the associated costs may be of interest. The operation and maintenance for "Fish Haul 1977" cost a total of $960,000 (1977 dollars). Of this, $300,000 was for trucking expenses and $600,000 for barging.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Wynoochee	$ 2,690,000	$ 20,000	Curtailment	Improvement	2.5
Foster	$ 2,453,000	$ 30,000	Curtailment	Maintenance	1.5
Fall Creek	$ 1,227,000	$ 40,000	Curtailment	Maintenance	2
Stampede	––	$ 9,000	Curtailment	Improvement	3

Exhibit 3. Cost and associated biological output for trap and haul systems.

Project Review

CALIFORNIA: Shasta, Stampede, Trinity River

OREGON: Fall Creek, Foster

WASHINGTON: Wynoochee

The projects underlined had successful applications of this improvement measure.

Reference

Calhoun, A. (ed.), Inland Fisheries Management, California Department of Fish and Game, 1966.

Clay, C. H., Design of Fishways and Other Fish Facilities, The Department of Fisheries of Canada, Catalog No. FS 31–1961/1, 1961.

Committee on Fishery Operations, "Special Drought Year Operation for Downstream Fish Migrants," Columbia River Water Management Group, October 1977.

Fishways P2.2

Purpose

The purpose of a fishway is to provide for the upstream passage of migrating fish past natural or man–made obstructions such as dams or waterfalls. Fishways are designed to create flow conditions enabling the fish to swim through the facility using their own effort as opposed to trap and haul facilities (Section P2.1) that transport the fish mechanically. Other terms used for fishways include fish passes and fish ladders.

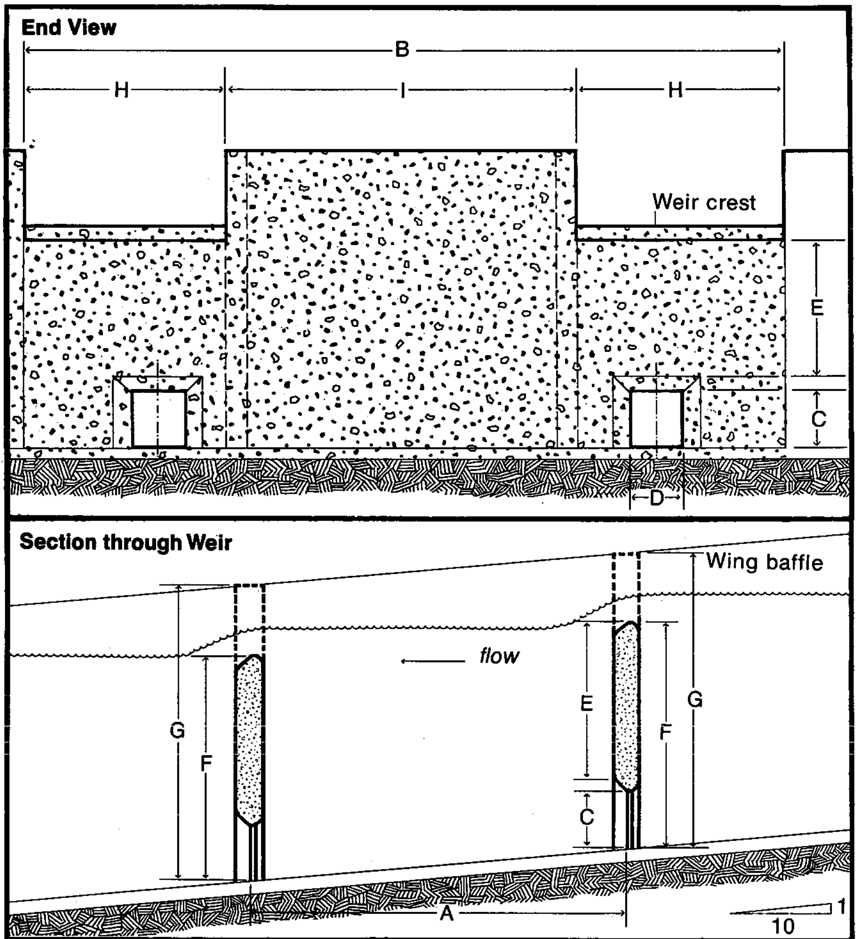
Fishway designs generally have followed a few basic patterns with modifications devised to improve performance or solve site–specific problems. The fishway easiest to describe in terms of function and operation is the pool and weir ladder. It is essentially a sloping chute divided by overflow weirs that create a step–wise series of descending pools. With water flowing over each weir, fish ascend the fishway by jumping into successively higher pools.

A variation on the pool and weir ladder is the pool and orifice ladder. This fishway has an orifice (or two) in each of the weirs (see Exhibit 1) and the fish primarily use these openings to ascend the ladder. The water normally passes from pool to pool through the orifices, but in periods of high flow it passes over the weirs also. The drop between pools should be 12 inches or less and the orifices should not exceed 4 square feet. The maximum practical vertical height for this ladder as well as for the pool and weir type is approximately 100 feet. The pool and orifice ladder is the only type of fishway covered in the selected project investigations and, therefore, the only type which has applications directly evaluated in this text.

Another type of fishway is the vertical slot or pool and jet fishway. It is also termed the Hell's Gate fishway because of its initial application at this site on the Fraser River in British Columbia. Exhibit 2 shows a section of this fishway. The center baffle and the sidewall projections cause the water to flow in paired jets that meet on the upstream side of the next center baffle. Some of the energy of the flow is dissipated because the water jets meet at an angle. Additional dissipation results from the small component of flow directed back upstream by the center baffle. The principal advantage of this fishway is that it can function effectively even with extreme fluctuations in water surface elevations.

Clay (1961) states that the vertical slot fishway at Hell's Gate has operated successfully with water levels varying as much as 45 feet compared to limits of just a few feet for other types of fishways.

Exhibit 1. Weir design for a pool and orifice fish ladder (from Bell, 1973).



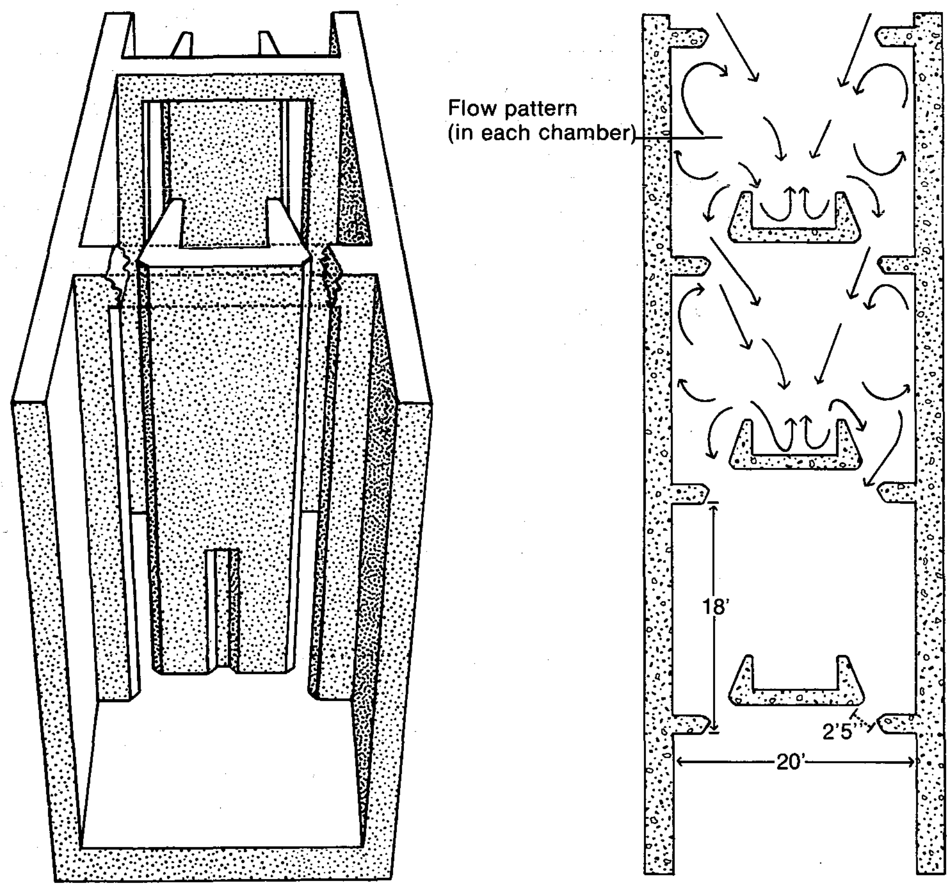
A	Pool length	8 to 20 ft
B	Pool width	6 to 20 ft
C	Orifice height	18 in
D	Orifice width	15 in
E	Position of orifice vertically	4.25 ft
F	Weir height	6 ft
G	Wing baffle height	8 ft
H	Position of wing baffle	1.5 to 5 ft
I	Width	½ of B

Other advantages of the vertical slot are that the fish can choose their swimming depth, and the path the fish must take is not tortuous and apparently lessens the difficulty of passage. Smaller versions of the Hell's Gate fishway have been constructed (see Clay for additional information).

Fishways P2.2

The Denil—type fishway is an energy dissipator that uses lateral vanes in the sides and bottom of a chute to turn part of the flow back on itself. The result is a reduced overall velocity in the chute through which the fish can ascend. Advantages of the Denil include a choice of swimming depth and a straight path in addition to excellent characteristics for fish attraction because of the large volume of water this fishway is able to pass. An improved version, the Alaskan Steep Pass, is smaller and can be made portable (see Exhibit 3).

The selection of a particular fishway type is dependent on many factors, including the water supply and the fish species involved. Bell (1973) and Clay discuss selection criteria and other critical points in the design and installation of fishways.



Segment of Baffle

Section Through Baffle

Exhibit 2. Vertical slot fishway used at Hell's Gate on the Fraser River, British Columbia.

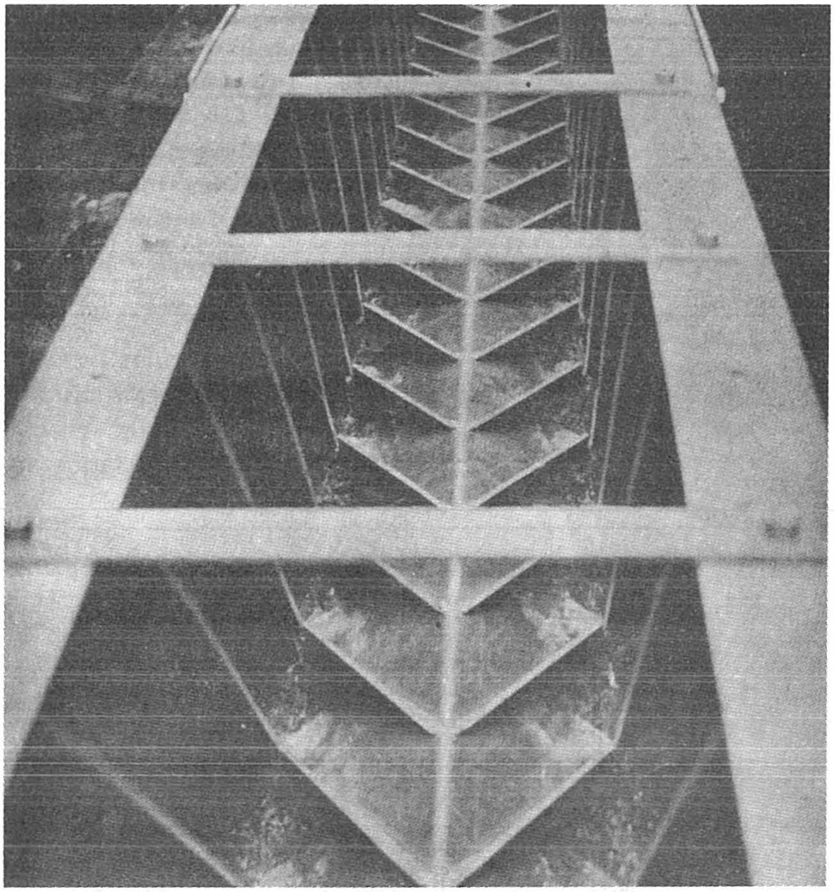


Exhibit 3. Alaska Steep Pass fishway, showing inside detail.

Limitation

Each type of fishway has constraints particular to it. The pool and weir ladder tends to collect debris in the pools and also does not work well with highly—variable water levels. The pool and orifice ladder functions well with some head fluctuation but the orifices tend to plug with debris, particularly during high flows. The vertical slot fishway works most efficiently when variations in water level are reasonably equal above and below it. The Denil has had limited application because of its intricate design which is critical if flow velocities are to be controlled. Also, the vanes are difficult to make rugged enough to withstand heavy bedload movement which has resulted in higher maintenance requirements for this ladder.

In general, the entrance to a fishway is the single most important element; it must be designed to attract fish effectively to avoid delay in passage. Thus, the entrance cannot be too far downstream from the barrier, too far from the main streamflow, in a back eddy, or too high. Also, sufficient flow from the entrance must be provided to attract the fish. Again, Clay provides discussion of these and other critical factors.

Costs for fishways are often substantial. Clay states that annual maintenance costs alone may be as high as 5 percent of the initial construction costs. Consequently, the need for fishways and the benefits to be derived from them must be firmly established.

Performance

Since only pool and orifice ladders were found at the projects reviewed, Exhibit 4 reports results for the four fishways of this type only. Two were judged to be applied successfully and two were considered unsuccessful. The unsuccessful ladders were both at the same project and apparently failed to pass fish because of poor entrances. The exact cause could not be determined.

Classification of Success Using Habitat and Population Improvement Criteria		*number of cases*	Confidence Factors and Ratings: *high*			*medium*			*low*		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	1	0	1	1	1	0	0	0	0	0
	Population	2	1	2	1	1	0	1	0	0	0
Marginally Successful	Habitat	0									
	Population	0									
Unsuccessful	Habitat	2	2	0	2	0	2	0	0	0	0
	Population	2	2	0	2	0	2	0	0	0	0

Exhibit 4. Success and confidence matrix for fishways.

All of the fishways discussed under <u>Illustration</u> have been successful in some cases. Structurally, these fishways are capable of passing fish but their installation and operation as well as outside factors can influence their effectiveness. For instance, the operation of a hydroelectric power plant at a dam can cause large water level fluctuations in a small reservoir. These fluctuations may adversely affect a fishway flow and the entrance and exit functions. At diversion dams, fish facilities may be dewatered after the irrigation season.

Cost/Output

Exhibit 5 presents the available cost data adjusted to 1977 for two of the fishways and their associated biological output. Cost information for other fishways is provided by Clay.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Ice Harbor (south ladder)	$10,268,000	––	Curtailment	Curtailment	0
Ice Harbor (north ladder)	$ 4,775,000	––	Curtailment	Curtailment	0

Exhibit 5. Cost and associated biological output for fishways.

Project Review

CALIFORNIA: Red Bank (Bluff), Stampede

WASHINGTON: Ice Harbor (2 fishways)

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Clay, C. H., Design of Fishways and Other Fish Facilities, The Department of Fisheries of Canada, Catalog No. FS 31–1961/1, January 1961.

Conduits and Culverts P2.3

Description

Conduits and culverts are water conveyance structures that also can be used for fish passage. Conduits have had some use at dams in the Pacific Northwest for fish collection and bypass systems, particularly for migrating smolts. In addition, conduits have been used with low–head dams in Texas to provide passage for striped bass and with diversion structures for canals to bypass fish from fish screens back to the stream channel. Slatick (1971) reports on the effectiveness of an inclined pipe for fish passage with different flow velocities and fish species.

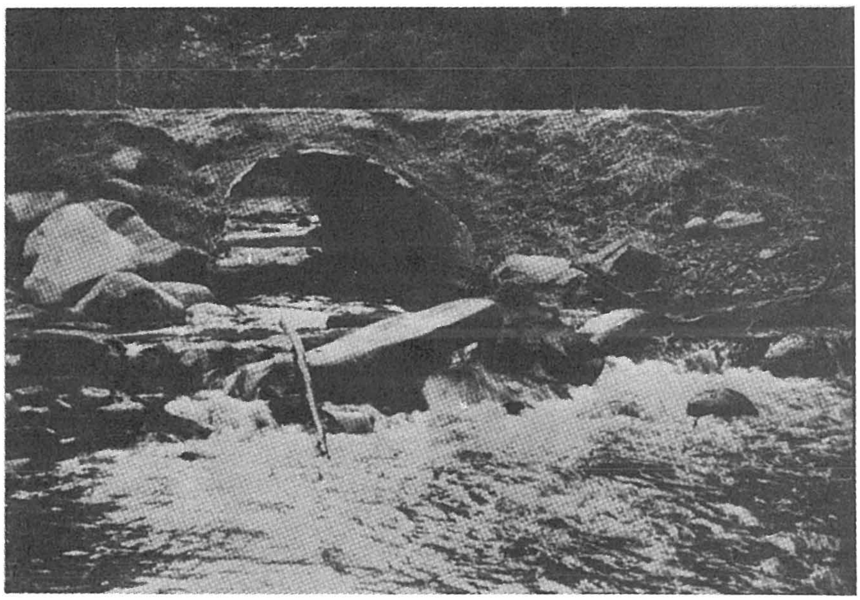
Culverts commonly provide a roadway crossing over a small stream. Unfortunately, many installations also block fish migration. Outlets that are too far above streambed elevations, flows that are too fast and too thin, and blockage from debris above and within culverts all are common problems that affect fish passage adversely.

Evaluation

Conduits can be effective for fish passage. Slatick demonstrated that several species of migratory salmonids would pass through a 24–inch–diameter conduit having both a decline and an incline. Supplying proper flows for the particular fish species and restricting rapid changes in pressure appear to be the most critical factors (Bell, 1973).

Increasing concern has been expressed over the blockage of fish

Exhibit 1. Arch culvert suitable for fish passage.



runs by roadway culverts. The U.S. Forest Service in Region 5 (California) initiated a five—year project in 1973 to correct culvert installations that were unsuitable for fish migration (Evans and Johnston, 1976). Watts (1974) reviews hydrological and biological problems of fish passage and suggests how to design culverts to pass fish. Some of the problems of blockage can be solved by setting a pipe culvert partially below the streambed elevation or by using an arch culvert as shown in Exhibit 1. This allows for a bed of natural stream gravel in the culvert which tends to reduce flow velocity. By keeping the culvert gradient nearly level, the velocity is further reduced.

Using sunken pipe or arch culverts also eliminates problems with culvert outlets that are too high for fish passage. Where existing culverts have high outlets, concrete sills or check dams have been used successfully to form a pool at the level of the lip of the outlet (Evans and Johnston).

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Evans, W. A., and F. B. Johnston, "Fish Migration and Fish Passage — A Practical Guide to Solving Fish Passage Problems," U.S. Forest Service — Region 5, June 1976.

Slatick, E., "Passage of Adult Salmon and Trout Through an Inclined Pipe," Trans. Amer. Fish. Soc., 100(3): 448–455, 1971.

Watts, F. J., "Design of Culvert Fishways," Water Resources Research Institute, University of Idaho, Moscow, Idaho, May 1974.

Turbine Bypasses P2.4

Description

Turbine bypasses are used to divert downstream–migrating juvenile salmon and steelhead trout (smolts) from hydroelectric turbines into bypass channels or collection facilities. Smolt mortality at a dam varies depending on the amount of water discharged over the spillway as compared to the amount passed through the turbines. Fish passed over the spillway are seldom injured while those passing through the turbines suffer significant mortality. Collins (1976) states that conservative estimates place smolt losses at each dam at 15 percent. This toll is expected to worsen as further upstream im-

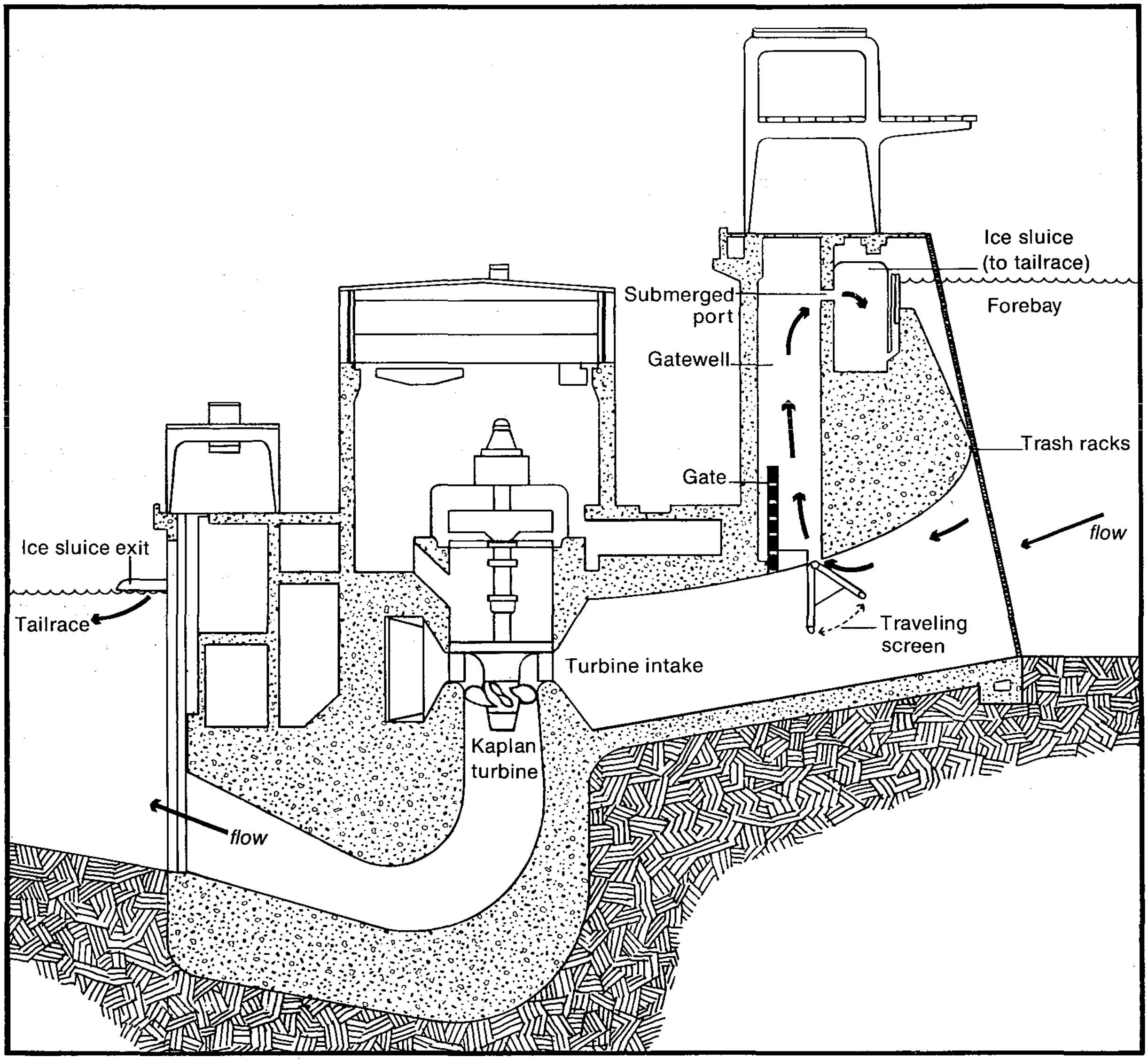


Exhibit 1. Sectional view of turbine bypass system used at Lower Granite and Little Goose Dams, Washington.

poundment and control force a higher proportion of the streamflow and fish to pass through the turbines.

Evidence for increasing mortality is presented in a report by the Committee on Fishery Operations (1977) which indicates that smolt survival over the entire Columbia River system during normal and high flow years is between 30 and 45 percent. However, during low flow years when most of the water must be passed through the turbines, survival is estimated to be only 5 to 10 percent. Ebel, et al (1975) maintain that recent declines in salmon and steelhead populations in the Snake River are due primarily to juvenile mortality during the downstream migration.

Exhibit 1 is a general diagram of a turbine bypass system installed at both the Lower Granite and Little Goose Dams on the Snake River in Washington. Research on the movement of downstream migrants has indicated that most of them collected near the ceiling when they entered a turbine intake. By placing a traveling screen at an angle to the intake flow, the smolts can be diverted into a gatewell and from there through a submerged port into the ice sluice. The ice sluice is a bypass channel normally used to transport ice and other debris around the dam to the tailrace. With this system, the smolts can use the sluice to safely bypass the turbine for release in the tailrace, or they can be trapped from the channel and hauled downstream to the lower Columbia River as was done during "Fish Haul 1977" (see Section P2.1).

Other systems have been devised to intercept downstream migrants before passing through turbines. Clay (1961) describes "skimmers" and "gulpers" that were installed with the Pelton Dam in Oregon and the Baker River Dams in Washington, respectively. A diagram of a skimmer is shown in Exhibit 2. Water is drawn in from the reservoir and is passed over an inclined screen. The bulk of the water is pumped back into the reservoir but the remainder carries the fish across the screen and into a bypass around the dam using the adult fish ladder. The gulper is similar in operation except that it floats on pontoons so that it can adjust to reservoir fluctuations.

Evaluation

Results indicate that approximately 80 percent of the downstream migrants entering a turbine intake can be bypassed using the traveling screen and ice sluice system. Furthermore, when fish were collected at the bypass system of Little Goose Dam (Snake River, Washington) and hauled downstream by trucks and barges to a site below Bonneville Dam, increased survival ranged from 50 to over

Turbine Bypasses P2.4

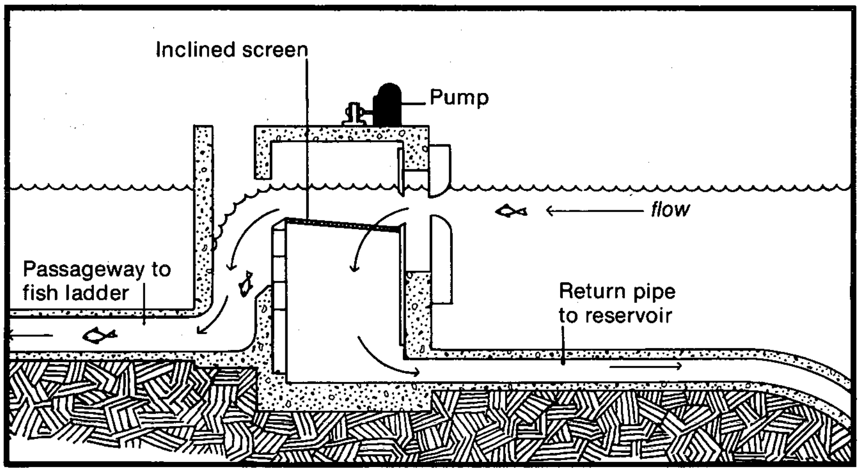


Exhibit 2. Sectional view of skimmer used to bypass smolts at Pelton Dam, Oregon.

2,000 percent as indicated by returns of adult fish to Little Goose Dam (Ebel, et al). Subsequent research has focused on designing turbine intakes with fixed fish deflectors.

Bell (1973) states that skimmers and gulpers have not been universally successful though the floating–type collectors have been successful in some instances. Bell also details a collector that can attract and catch fish at varying levels in a reservoir. This is beneficial because downstream migrants often follow a particular temperature gradient in moving through a reservoir. The device apparently has been successful.

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Clay, C. H., Design of Fishways and Other Fish Facilities, The Department of Fisheries of Canada, Catalog No. FS 31–1961/1, January 1961.

Collins, G. B., "Effects of Dams on Pacific Salmon and Steelhead Trout," Marine Fisheries Review Paper 1222, 38(11): 39–46, November 1976.

Committee on Fishery Operations, "Special Drought Year Operation for Downstream Fish Migrants," Columbia River Water Management Group, October 1977.

P2.4

Ebel, W. J., H. L. Raymond, G. E. Monan, W. E. Farr, and G. K. Tanonaka, "Effect of Atmospheric Gas Supersaturation Caused by Dams on Salmon and Steelhead Trout of the Snake and Columbia Rivers," National Marine Fisheries Service Processed Report, January 1975.

Fish Stocking and Control

P3.0

Fish Stocking P3.1

Purpose

Fish stocking measures have been incorporated in dam and reservoir projects for many purposes, such as to compensate losses in anadromous fish runs resulting principally from dam construction and operation; realize the full potential of small impoundments; introduce desirable fish species in a large new impoundment; and, in some cases, control insect pests that have aquatic stages in their life cycles such as black gnats and mosquitoes. In many instances, fish stocking is requested in conjunction with fish production facilities (see Chapter P1.0, Fish Propagation). Generally, sub–catchable fish such as fry and fingerlings are stocked, though some catchable fish populations are maintained by stocking (Butler and Borgeson, 1966).

Illustration

A considerable variety of stocking requirements exist for the projects examined. Stocking of salmon and steelhead trout is required below Oroville and Trinity–Lewiston Dams in California to compensate for losses of natural spawning and nursery habitats upstream. For the Bear Creek Watershed in Missouri, stocking of bass, bluegill, and channel catfish was requested for all suitable warm-water impoundments. At Foster Dam in Oregon, 18,000 catchable rainbow trout are stocked annually to maintain the reservoir for trout fishing.

Limitation

Non–fishing mortality of stocked fish is often very high, making a stocking program an expensive undertaking in terms of actual benefit to the angler. Furthermore, if stocking densities are increased, the percentage of returns will generally decrease. In some situations, the carrying capacity of a system may be exceeded by stocking which causes high mortality. Stocking of some species of fish may inhibit the growth and reproduction of native species which may be more important to local anglers. Also, a problem increasingly encountered is the lack of enough aquatic habitats suitable for effective stocking to compensate for all of the habitats displaced.

Performance

All applications of this improvement measure were judged to be successful or at least marginally successful; confidence ratings were generally high (Exhibit 1).

Cost/Output

Costs for fish stocking are an aggregate of production, transportation, and personnel costs. For costs of hatchery production of fish, see Section P1.1. Transportation costs depend on the equipment used, the distance of the haul, and the accessibility of the release

Exhibit 1. Success and confidence matrix for fish stocking.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high — Degree of implementation	high — Soundness of predictions	high — Reliability of reports	medium — Degree of implementation	medium — Soundness of predictions	medium — Reliability of reports	low — Degree of implementation	low — Soundness of predictions	low — Reliability of reports
Successful	Habitat	1	1	0	0	0	1	1	0	0	0
	Population	5	3	2	2	2	3	2	0	0	1
Marginally Successful	Habitat	0									
	Population	2	1	0	2	1	2	0	0	0	0
Unsuccessful	Habitat	0									
	Population	0									

site. Some of these costs are reviewed in Section P2.1, Trap and Haul Systems. A modern insulated tank truck with mechanical refrigeration, as shown in Exhibit 2, may cost between $50,000 and $55,000 (1977) and about $1.40 per mile to operate, assuming 20,000 miles annually (Bell, 1973).

Project Review

CALIFORNIA: Iron Gate, Oroville, Trinity

IDAHO: Dworshak

MISSOURI: Bear Creek

OREGON: Foster

UTAH: Flaming Gorge

The projects underlined had successful applications of this improvement measure.

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Butler, R. L., and D. P. Borgeson, "'Catchable' Trout Fisheries,"

Fish Stocking P3.1

in Inland Fisheries Management, A. Calhoun, (ed.), State of California, The Resources Agency, Department of Fish and Game, April 1966.

Exhibit 2. Insulated tank truck with mechanical refrigeration for hauling and stocking fish (from Oregon State Game Commission).

Fish Screens P3.2

Purpose

Fish screens are used to reduce the numbers of fish entering water intakes to irrigation canals and pumps, power generating plants, industrial plants such as pulp and steel mills, drinking water supplies, and similar installations. Many States now require that all water diversion facilities be screened. Screening is particularly important where migratory fish are present and where the mortality of the fish, once in the water intake, is certain, such as in irrigation, industrial, and domestic water supply systems.

Illustration

Burns (1966) states that the design of a fish screen depends upon the amount of water to be screened; the amount of excess water available; the swimming ability, behavior, and size of the fish expected at the screening site; and the quantity and size of debris expected. The maximum allowable approach velocity of the water flow to the screen is determined by the swimming ability of the fish to be screened. Several sources (Haley, 1966; Bell, 1973) provide tables of swimming speeds for various fish species. Clay (1961) asserts that flow approach velocities should be limited to 0.5 feet per second (fps) and 1.0 fps for fry and smolts of Pacific salmon, respectively. Another critical component of a fish screen is the bypass. It must have an attractive and substantial flow and have entrances where the fish will be diverted, usually at one or both ends of the screen.

Exhibits 1, 2 and 3 present several types of fish screens commonly in use. The perforated plate or Model "T" screen (Exhibit 1), so–called because of its T–shaped wiper blade used to keep the plate free of debris, can utilize a paddle wheel (as shown) or an electric motor to actuate its wiper. The plate has about half of its total area perforated and lies at about a 30–degree angle to the flow. This screen is used primarily at irrigation diversions where approach velocities can be relatively low.

The horizontal drum screen (Exhibit 2) has screening or perforated plates on the revolving drum. The drum is fitted into the channel with seals along the bottom and sides and is powered by a paddle wheel or electric motor. With this design, the drum is submerged from two–thirds to three–quarters of its diameter during normal operation to reduce the possibility of fish being carried over the top of the drum. Debris is carried over and washed off as the screen direction is reversed on the downstream side. Another design uses a totally submerged drum with a collection and bypass channel at the top (Mayo, 1974). There is a vertical drum screen similar in operation to the horizontal drum screen except that it uses water jets inside the drum to clean debris from the screen. A screened flow past the drum can be created or water can be drawn through the base of the drum as was done with the original design. This is one of the more efficient screens in use (Burns).

The traveling screen (Exhibit 3), also called a link belt or chain belt screen, uses screened frames to form a continuous belt that travels vertically on an incline through the flow. Water jets wash debris and fish into the collection flume at the top. This type of screen is used primarily for industrial intakes. Approach velocities should be as low as possible to reduce injuries to small fish. Automated controls that monitor head differential are often installed; they allow the screen to be rotated intermittently as dictated by the accumulation of trash. This reduces wear on the mechanism and prevents heavy fish mortality resulting from localized high velocities. A recent modification of the traveling screen is the horizontal type that uses vertical screen panels traversing diagonally across the intake channel toward a bypass. Initial testing showed good

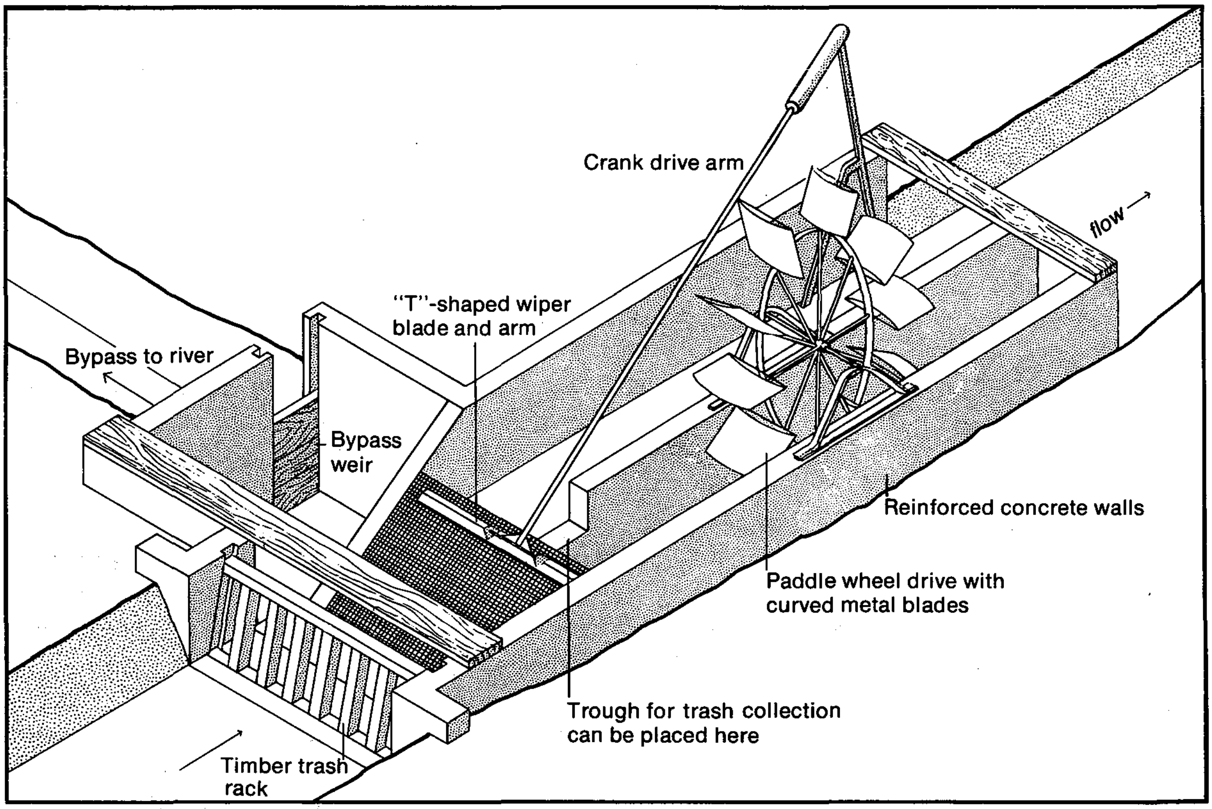
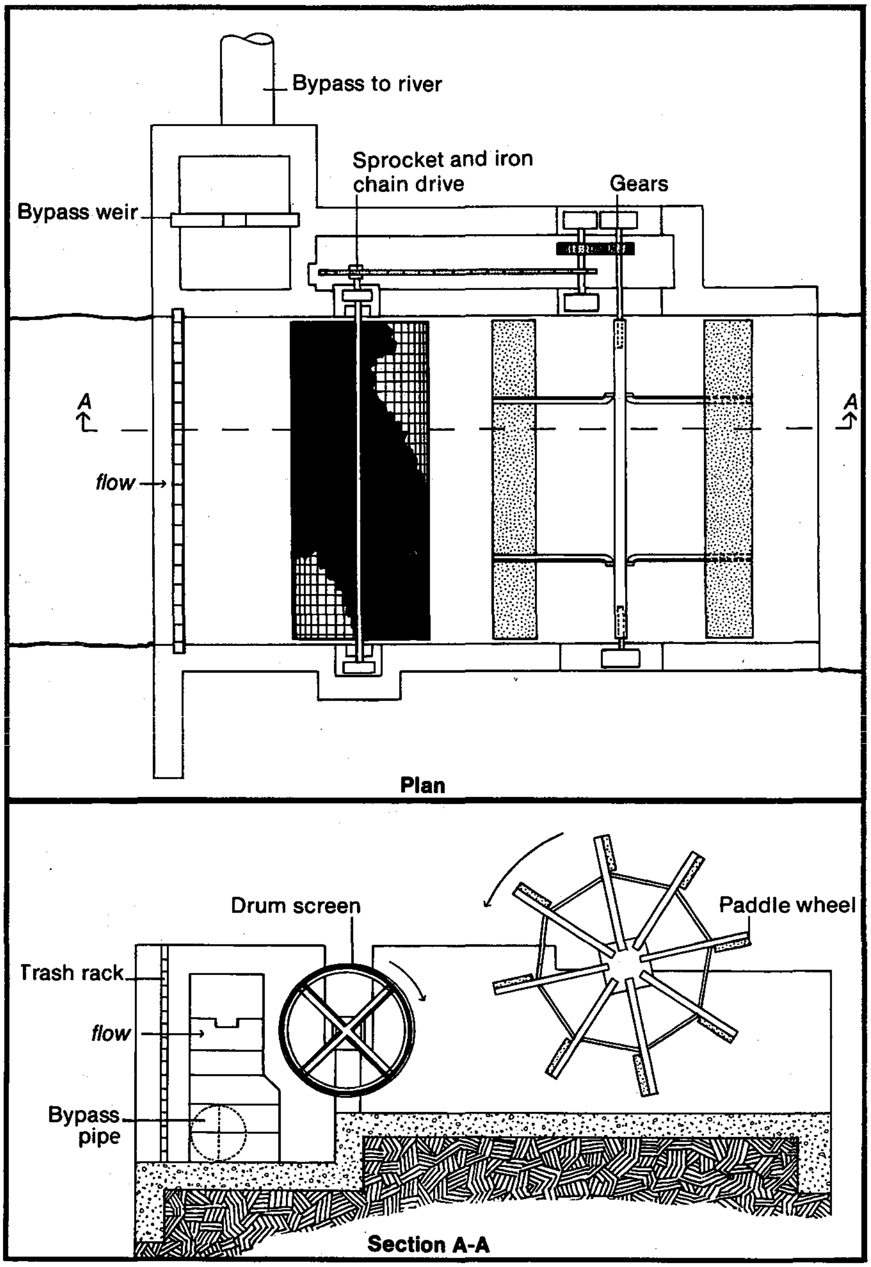


Exhibit 1. Perforated plate or Model "T" fish screen.

Exhibit 2. Horizontal drum screen.



efficiency of diversion and minimal adverse effects on young salmonids (Prentice and Ossiander, 1974). For additional discussion concerning other control and screening devices, see Section P3.4.

Limitation

The primary limitation on fish screens is their tendency to collect debris, resulting in the need for substantial maintenance. Debris, ice, and particularly algae are the most prevalent causes of screen plugging and failure. In addition, making the screening material and seals into fish–proof barriers requires careful construction and maintenance. Head loss due to the screening structure, screens, and any plugging of the screens may be a problem, particularly in gravity–operated irrigation ditches (Clay). Deposition of silt upstream and downstream from the screening structure also may prove to be a problem. Trash racks are necessary to prevent damage by heavy objects.

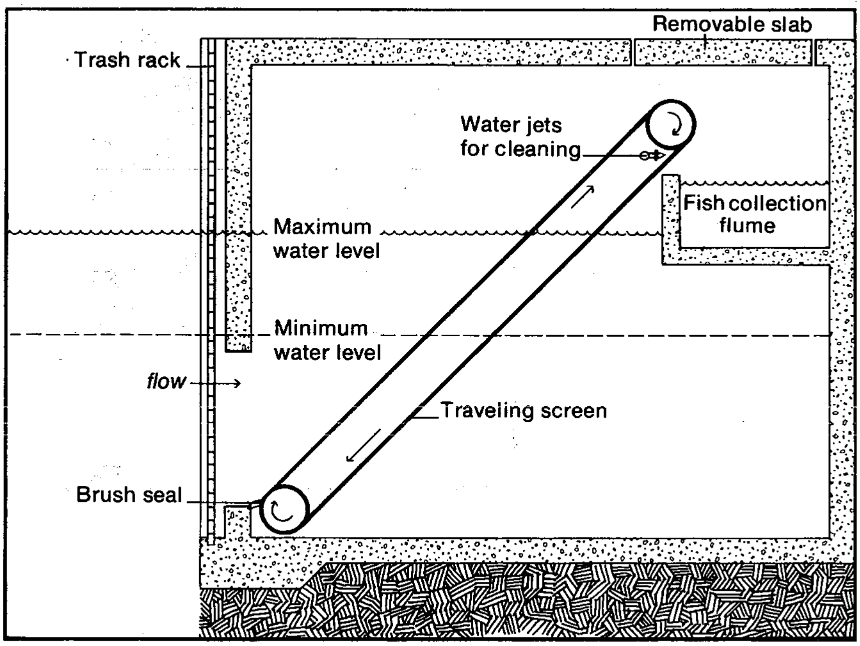


Exhibit 3. Traveling screen.

Performance

Most of the screens judged to be successful (see Exhibit 4) were associated with fully implemented applications. Failure or near–failure of other fish screens resulted most frequently from algae growth clogging the screening material.

Cost/Output

The cost per fish screen in 1977 dollars, ranging from $18,000 to $33,000, and the associated biological output are presented in Exhibit 5 for several projects having data available. For additional cost data comparing different types of screens, see Clay.

Project Review

CALIFORNIA: Tehama–Colusa, Trinity River

Fish Screens P3.2

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high — Degree of implementation	high — Soundness of predictions	high — Reliability of reports	medium — Degree of implementation	medium — Soundness of predictions	medium — Reliability of reports	low — Degree of implementation	low — Soundness of predictions	low — Reliability of reports
Successful	Habitat	5	3	1	0	2	0	2	0	4	3
	Population	7	6	3	1	1	1	3	0	3	3
Marginally Successful	Habitat	2	2	0	0	0	0	0	0	2	2
	Population	4	3	1	0	1	0	1	0	3	3
Unsuccessful	Habitat	1	0	0	0	0	0	0	1	1	1
	Population	2	0	1	1	0	0	0	2	1	1

Exhibit 4. Success and confidence matrix for fish screens.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Lemon	$ 33,000	$300	Curtailment	Curtailment	0
Palmer	$ 23,000	––	Curtailment	Maintenance	2
Roza	$ 18,000	––	Curtailment	Reduced Curtailment	1

Exhibit 5. Cost per screen and associated biological output for fish screens.

COLORADO: Lemon

IDAHO: Minidoka

MONTANA: Clark Canyon

OREGON: Clearwater, Lemolo, Prineville

WASHINGTON: Palmer, Roza

The projects underlined had successful applications of this improvement measure.

Reference

Bell, M. C., Fisheries Handbook of Engineering Requirements and Biological Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, February 1973.

Burns, J. W., "Fish Screens," in Inland Fisheries Management, A. Calhoun (ed.), State of California, The Resources Agency, Department of Fish and Game, April 1966.

Clay, C. H., Design of Fishways and Other Fish Facilities, The Department of Fisheries of Canada, Catalog No. FS 31–1961/1, January 1961.

Haley, R., "Maximum Swimming Speeds of Fishes," in Inland Fisheries Management, A. Calhoun (ed.), State of California, The Resources Agency, Department of Fish and Game, April 1966.

Mayo, R. D., "Conventional Fish Screening Systems and Some Promising Alternatives," in Proceedings of the Second Entrainment and Intake Screening Workshop, L. D. Jensen (ed.), The Johns Hopkins University Cooling Water Research Project, Report No. 15, December 1974.

Prentice, E. F., and F. J. Ossiander, "Fish Diversion Systems and Biological Investigation of Horizontal Traveling Screen Model VII," in Proceedings of the Second Entrainment and Intake Screening Workshop, L. D. Jensen (ed.), The Johns Hopkins University Cooling Water Research Project, Report No. 15, December 1974.

Barrier Dams P3.3

Purpose

Barrier dams primarily serve two purposes: to direct upstream–migrating fish into a fishway or holding pond; and to prevent the upstream movement of undesirable fish into protected habitats. Other uses include the maintenance of populations of desirable species in a reservoir by preventing emigration; restriction of the stream spawning habitat available to undesirable species within a reservoir; prevention of intermingling between fish populations such as native cutthroat and rainbow trout; and, in coastal areas, the suppression of salt water intrusion into an estuary.

Barrier dams restrict movement of fish populations by their height or by the design of the downstream apron so as to produce high velocities and turbulence with shallow water depth.

Illustration

Exhibit 1 displays overhead and cross–sectional views of a typical barrier dam installation. As shown in the overhead view, barrier dams that are used with fishways or fish collection facilities should be placed diagonally across the flow to form a lead toward the entrance. The dam shown in cross–section is a buttress type that is very suitable as a barrier to migrating fish because of the passage channel under the concrete slabs. The head differential of 10 feet between the headwater and tailwater is even sufficient to stop chinook salmon (Clay, 1971). To achieve this, the spillway crest must be high enough to establish a differential with the flows anticipated during the migration season. A head differential of 3 feet normally is sufficient to stop carp and other rough fish, which allows the use of timber crib dams for barriers (Clay).

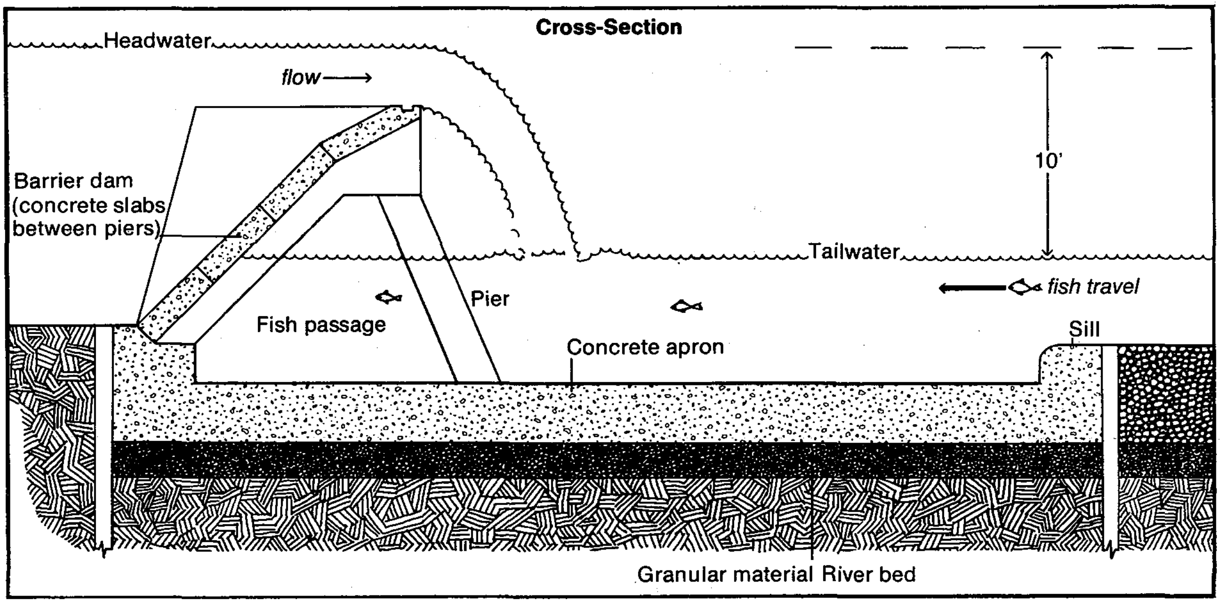
Limitation

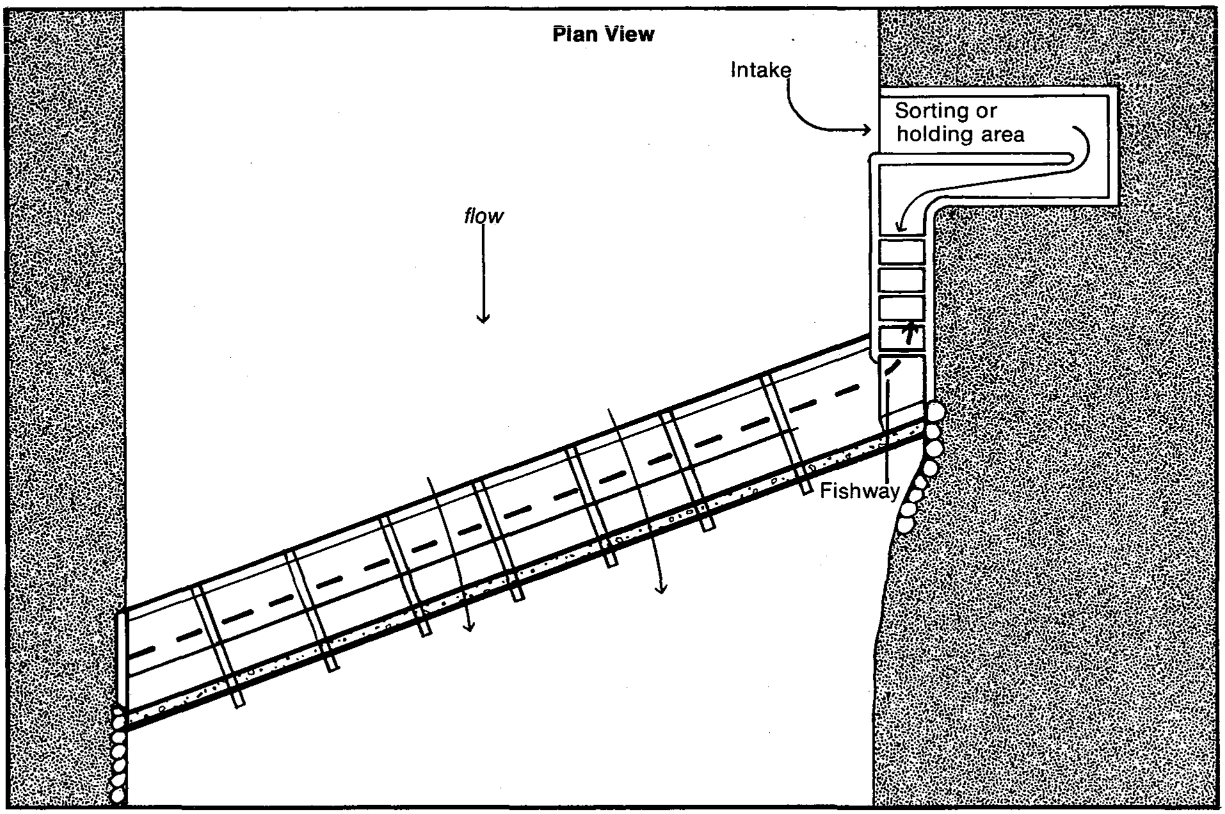
Primary constraints on using barrier dams concern high construction costs and difficult site selection. Ideal, stable site conditions are nearly impossible to find and very expensive to create. The wider the stream or river, the more difficult it becomes to establish the necessary head differential. In addition, many streams where barriers are needed are subject to periodic high water and flooding which can wash out all but very stable structures. Maintenance and replacement costs also may be limiting factors.

Performance

Of the five barrier dams identified in the project review, three were classified as successful with generally high confidence ratings (Exhibit 2). The one unsuccessful dam was subjected to frequent flood waters and was washed out several times. Each time it was installed, however, it was effective until the next flood flow.

Exhibit 1. Typical barrier dam installation.





Barrier Dams P3.3

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	high: Degree of implementation	high: Soundness of predictions	high: Reliability of reports	medium: Degree of implementation	medium: Soundness of predictions	medium: Reliability of reports	low: Degree of implementation	low: Soundness of predictions	low: Reliability of reports
Successful	Habitat	2	1	2	1	1	0	1	0	0	0
	Population	3	2	3	2	1	0	1	0	0	0
Marginally Successful	Habitat	0									
	Population	1	0	0	0	0	1	1	1	0	0
Unsuccessful	Habitat	0									
	Population	1	0	0	1	1	1	0	0	0	0

Exhibit 2. Success and confidence matrix for barrier dams.

Exhibit 3. Cost and associated biological output for barrier dams.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Libby	$ 70,000	$900	Curtailment	Maintenance	2

Cost/Output

Exhibit 3 presents the only project costs available (1977 dollars) and the associated biological output for a single application of a barrier dam. Clay maintains that any cost information for barrier dams is highly site dependent and that making preliminary estimates based on comparisons with other dams is probably unsound.

Project Review

CALIFORNIA: Nimbus, Shasta, Trinity

MONTANA: Libby

TEXAS: Pat Mayse

The projects underlined had successful applications of this improvement measure.

Reference

Clay, C. H., Design of Fishways and Other Fish Facilities, The Department of Fisheries of Canada, Catalog No. FS 31–1961/1, January 1961.

Other Control Devices P3.4

Description

Many other devices besides fish screens (Section P3.2) and barrier dams (Section P3.3) have been used or proposed to control the movement of fish. As with fish screens, these devices generally function to restrict or prevent the entrance of fish into water intakes for facilities such as irrigation canals, power plants, and industrial and domestic water supplies.

One device currently in use is called a fish excluder. It is a concrete and gravel sill 35 feet wide and approximately 300 feet long that essentially surrounds the canal intakes of the East Bench Unit on the Beaverhead River in Montana (Exhibit 1). The sill has a slight upward slope from front to back. Water flowing from the river over the excluder becomes more and more shallow before spilling into the canal headworks. Fish can sense when they are moving into shallower water and generally will turn back. Therefore, the excluder is a behavioral barrier, not an absolute physical barrier to fish movement.

Another control device dependent on fish behavior is the louver diverter. A diagram showing the basic functional components is presented in Exhibit 2. Fish drifting downstream will avoid obstructions in their path and seek a clear passage. When fish enter the diverter channel, they tend to avoid the diagonal line of vertical louver slats and move farther downstream in the direction of the bypass. Even with the slats as much as 4 inches apart, young fish are still diverted to the bypass (Clay, 1961). Flow velocities through

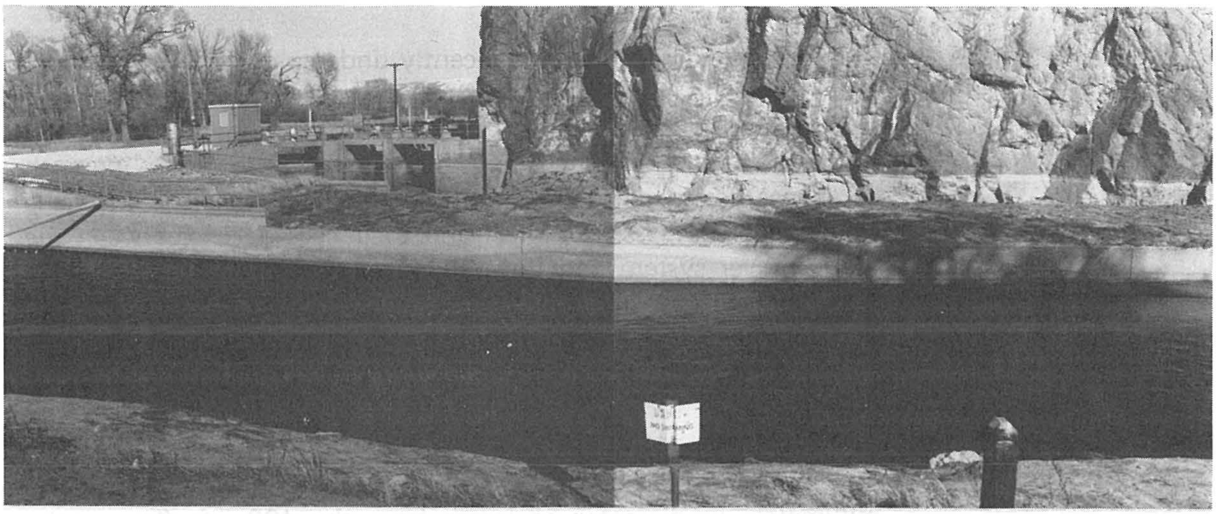
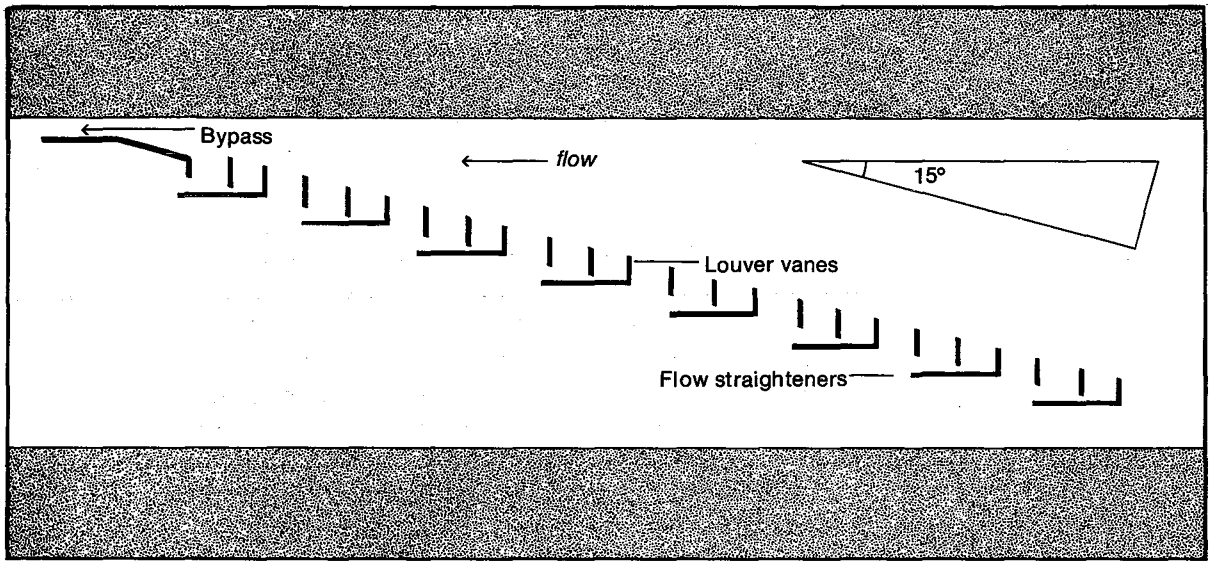


Exhibit 1. Exposed fish excluder, normally submerged, in the Beaverhead River, Montana (from U.S. Fish and Wildlife Service).

Exhibit 2. Functional components of the louver diverter.



the channel must be maintained within a range that allows the fish time to react to the louver line without encouraging them to pass through. The original louver diverter system was installed at the Delta–Mendota Canal intake at Tracy, California and is described fully in a report by the U.S. Department of the Interior (1957). The system was developed because of the need to pass flows of up to 5,000 cfs which contain great quantities of moss and other debris while providing for safe passage of migrating salmon smolts and striped bass fry.

Another fish control device, recently undergoing experimentation, is the sand and gravel filter. These filters have been used extensively with domestic water supplies and are being developed for canal and power plant intakes where large flows must be passed. One such filter was designed for use in the Marias–Milk Canal in Montana to prevent the passage of fish and their eggs or fry between the Marias River system and the Milk River system which flows from Canada. The filter bed was designed with an area of approximately 30,000 square feet and a 5–foot depth, having layers ranging from coarse sand on top to 3 to 6–inch rounded cobblestones in the bottom.

The sand and gravel filter was designed to remove any particle 2 millimeters in diameter or larger from the 400–cfs flow in the canal. Maintenance was anticipated to include annual flushing and replacement of sand every three years. Additional research on high–capacity sand filters for power plant cooling water intakes is reported by Stober, et al (1974).

Another filtering device for use in an interbasin canal is the subject of recent research by the U.S. Bureau of Reclamation (Johnson, 1975). This device features a fixed, downward sloping screen with very fine mesh. Its purpose is to prevent movement of undesirable fish and their eggs and fry from the Missouri River through the McClusky Canal of the Garrison Diversion Unit (North Dakota) into river systems flowing into Canada. The canal will have a maximum flow of 1,950 cfs which must be completely filtered of all material larger than 1 millimeter in diameter. The structure being considered would use 40– to 80–mesh screen mounted on a 5–degree downward slope over which the flow would be passed.

Electric fences or weirs also have been used to control fish movement. They have been most successful in guiding upstream–migrating adult salmon into spawning or counting facilities. A typical fence installation, shown in Exhibit 3, is on Coyote Creek in California and is used to divert adult salmon into the Tehama–Colusa Fish Facilities (see Section P1.6 dealing with artificial spawning channels). Other installations are described by Clay.

Additional control and guidance devices have included the use of sound, light, air bubbles, and combinations of these. For a description of various models and installations, see Eicher (1974), Alevras (1974), or Bibko, et al (1974).

Evaluation

The fish excluder has been effective since its installation in Montana in 1960 by the U.S. Bureau of Reclamation. There have been no significant losses of adult fish in the associated canals since the installation, whereas heavy losses of adult trout were reported every year before. However, this type of device could not be used to prevent downstream–migrating salmon smolts from entering a canal because the fish would be attracted by the flow over the sill.

Louver diverters have been relatively successful though 100 percent screening efficiency is not possible. Also, the facility at Tracy, California has had continuing problems with debris collecting on the louver slats and in the bypass channels despite the use of both a floating trash boom and a trash rack. Cleaning the louvers is a difficult problem. Other constraints inherent with louver diverters involve the flow approach velocities which cannot exceed 4 or 5 feet per second but cannot be much lower because the screening efficiency falls off rapidly. For installations where the flow demand varies greatly, louver systems are not recommended.

Because the anticipated demand for irrigation water has not developed, the Marias—Milk Canal in Montana and the sand and gravel fish filter were not constructed. Strandberg (1974) states that high—capacity sand filters have many attractive attributes for screening water intakes of thermal power plants, including the ability to draw a sufficient quantity of water through the filter while producing a low approach velocity at the intake. This will reduce the impingement of fish, invertebrates, and debris. Also, the filters require relatively little space and should be economically feasible. Clogging due to establishment of plants and microfauna in the filter media appears to be the most serious problem.

In North Dakota, the McClusky Canal screening structure was still in a developmental stage. The results of hydraulic modeling reported by Johnson indicate the screen should function satisfactorily and be

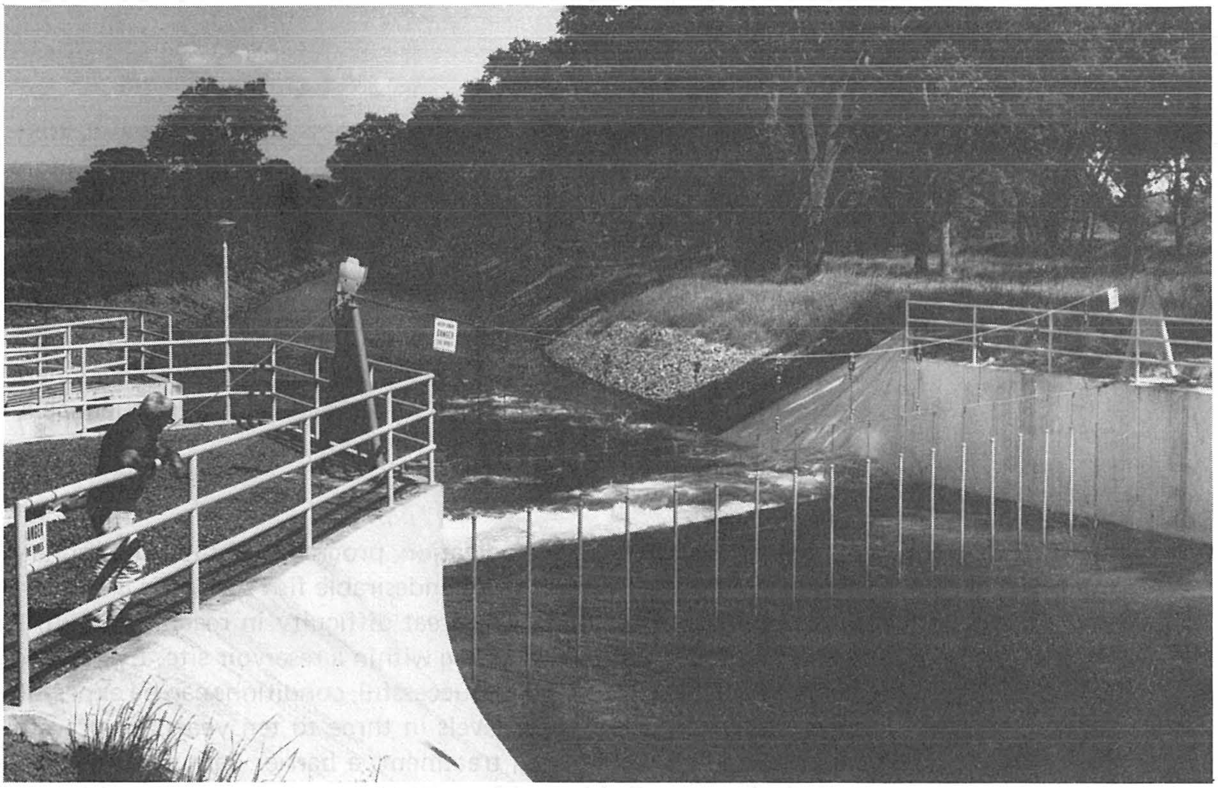


Exhibit 3. Electric fence on Coyote Creek at Tehama-Colusa Fish Facilities, California.

self–cleaning. Recent research focused on testing the screen with fish eggs and larvae to establish the mesh size necessary to prevent any passage. Preliminary findings indicate 50– or 60–mesh screening may be required. Also, field testing at the proposed site was planned to determine the quantity of debris that can be expected at the screen.

Electric fences have not had the extensive use that once had been expected. Their greatest effectiveness is in guiding upstream–migrating adult salmon; fish moving downstream are seldom stopped by the fences because the fish are stunned and then swept past the electrodes. Bell (1973) indicates that fish generally will avoid an electric field, but they also may become disoriented and dart into the field. An additional limitation is the potential danger to people which necessitates tight security measures around the installation.

Research on sound, light, and air bubbles for fish control has produced variable results. Initially, fish seem to be repelled by these systems but later may ignore them. Fish attraction and guidance systems using low–intensity lights have been successful in some cases (Bell).

Reference

Alevras, R. A., "Status of Air Bubbler Fish Protection at Indian Point Station on the Hudson River," in Proceedings of the Second Entrainment and Intake Screening Workshop, L. D. Jensen (ed.), The Johns Hopkins University Cooling Water Research Project, Report No. 15, December 1974.

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Bibko, P. N., L. Wirtenan, and P. E. Kueser, "Preliminary Studies on the Effects of Air Bubbles and Intense Illumination on the Swimming Behavior of the Striped Bass (Morone saxitalis) and the Gizzard Shad (Dorosoma cepedianum)," in Proceedings of the Second Entrainment and Intake Screening Workshop, L. D. Jensen (ed.), The Johns Hopkins University Cooling Water Research Project, Report No. 15, December 1974.

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Strandberg, H. V., "A High Capacity Sand Filter for Thermal Power Plant Cooling Water Intakes — Part II: Design Concept," in Proceedings of the Second Entrainment and Intake Screening Workshop, L. D. Jensen, (ed.), The Johns Hopkins University Cooling Water Research Project, Report No. 15, December 1974.

U.S. Department of the Interior, "Fish Protection of the Tracy Pumping Plant," Bureau of Reclamation, Region 2 and the Fish and Wildlife Service, Region 1, February 1957.

Fish Eradication P3.5

Purpose

Fish eradication is a drastic control measure deemed necessary when too much of the total fish productivity of a stream or impoundment has favored undesirable fish species. This measure is used to provide desirable sport fish with a short–term advantage over competitive rough fish. Generally, a complete elimination of all fish species is sought and sport fish are restocked following treatment. However, in most cases only a partial eradication is obtainable. The most frequent targets of eradication programs include several species of suckers, chubs, and carp. In addition to competing with game fish for food and habitat, some species such as carp can interfere with aquatic plant production and subsequent waterfowl use.

The most common method of fish eradication is the introduction of a toxicant such as rotenone to the water. McKnight (1975) provides an excellent review of this and other fish toxicants. Other methods include the use of explosives (Tate, et al, 1973), drawdown (see Section H2.3 on seasonal manipulation of reservoir pools), introduction of non–native predators such as striped bass and northern pike, and commercial harvest where a market exists or can be established.

Illustration

To improve the economy and effectiveness of this measure, toxicants usually are applied to whole watersheds above dams before final closure as in the case of Rathbun, Navajo, Fontenelle, and Flaming Gorge Dams, or when the reservoirs are depleted as was done at Fall Creek and Sugarloaf Dams. Only the initial eradication was carried out, even though periodic treatments were anticipated for some projects such as Fontenelle. Application of the toxicant was sometimes quite extensive, as for the Fontenelle project where 445 miles of the Green River in Wyoming and Utah were chemically treated (McKnight).

Limitation

A major constraint on eradication programs is their temporary nature. Complete eradication of undesirable fish species is an almost impossible task because of the great difficulty in reaching all unfiltered water and potholes existing within a reservoir site. Even when the initial eradication is highly successful, conditions can be expected to return to pre–treatment levels in three to ten years. To prevent rapid degradation following treatment, a barrier dam or other control device (see Sections P3.3, P3.4) may be necessary although installation may be too costly or technically infeasible.

Eradication programs are seldom selective so any game fish in the treated area can be destroyed. Other organisms, particularly invertebrates, often are lost during chemical treatment (Anderson, 1970). This circumstance will affect the rate at which fish species can be reestablished. Also, precautions must be taken to protect endangered or threatened species which may be affected adversely. It may be necessary to obtain an Environmental Impact Statement (EIS) for an eradication program because of Federal regulations regarding the release of toxicants into the environment. Also, education of the public concerning the functions and benefits of the program may be needed to prevent adverse reaction.

Performance

Among the nine cases studied, the results in five were judged to be successful, marginally successful in two, and unsuccessful in two (Exhibit 1). In several cases having a successful outcome, it was noted that the results were expected to be temporary and that pre—treatment conditions would return.

Classification of Success Using Habitat and Population Improvement Criteria		number of cases	Confidence Factors and Ratings: high			medium			low		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	4	1	0	2	3	3	2	0	1	0
	Population	5	2	1	3	3	3	2	0	1	0
Marginally Successful	Habitat	2	1	0	0	0	1	2	1	1	0
	Population	2	1	0	0	0	1	2	1	1	0
Unsuccessful	Habitat	2	2	0	0	0	0	1	0	2	1
	Population	2	2	0	0	0	0	1	0	2	1

Exhibit 1. Success and confidence matrix for fish eradication.

Cost/Output

For five of the cases reviewed, fish eradication costs adjusted to 1977 are presented in Exhibit 2 with the associated biological output. It should be noted that, in general, costs are related to the volume of water treated, which tends to explain the extreme variability.

Exhibit 2. Cost and associated biological output for fish eradication.

Project	Capital Cost	Annual Operation and Maintenance Cost	Predicted Condition Without the Measure	Actual Condition With the Measure	Increased Levels of Biological Output
Flaming Gorge	$200,000	––	Maintenance	Maintenance	0
Fontenelle	$ 84,000	––	Curtailment	Improvement	3
Navajo	$ 53,000	––	Curtailment	Improvement	3
Sugarloaf	$ 17,000	––	Maintenance	Maintenance	0
Merritt	$ 9,000	––	Maintenance	Improvement	1

Project Review

COLORADO: Sugarloaf

IOWA: Rathbun

NEBRASKA: Merritt

NEW MEXICO: Navajo

NORTH DAKOTA: Baldhill

OREGON: Fall Creek, Foster

UTAH: Flaming Gorge

WYOMING: Fontenelle

The projects underlined had successful applications of this improvement measure.

Reference

Anderson, R. S., "Effects of Rotenone on Zooplankton Communities and a Study of Their Recovery Patterns in Two Mountain Lakes in Alberta," J. Fish. Res. Bd. Canada, 27: 1335–1356, 1970.

McKnight, R. G., "Fontenelle Reservoir Fishery Investigations," Wyoming Game and Fish Department, Fish Division, June 1975.

Tate, B., G. Davis, L. Wilson, and B. Dabb, "Chemical and Explosive Treatment to Eradicate Undesirable Fish Species in the Drainage to be Inundated by Enlargement of Strawberry Reservoir," Utah Division of Wildlife Resources, Department of Natural Resources, Completion Report, 1973.

Wildlife Propagation and Control

Nesting Structures P4.1

Description

Nesting structures can be used to compensate for a lack of natural nesting sites in habitat which is otherwise capable of supporting a greater wildlife population. Artificial structures have been developed for both game and non–game animals including squirrels, ducks, geese, eagles, ospreys, cormorants, herons, and several songbird species. The U.S. Forest Service (1969) lists a number of general considerations for artificial nesting structures: they should be durable, predator–proof, weather–tight, lightweight, economical to build, convenient to erect and maintain, and they should meet the biological needs of the target species. Placement of nesting structures in proper habitat is important too. For example, goose nesting platforms should be placed near water and feeding pastures for the goslings. At some reservoir sites, it may be necessary to isolate surrounding habitat such as by fencing the shoreline in order to achieve maximum use of nesting structures.

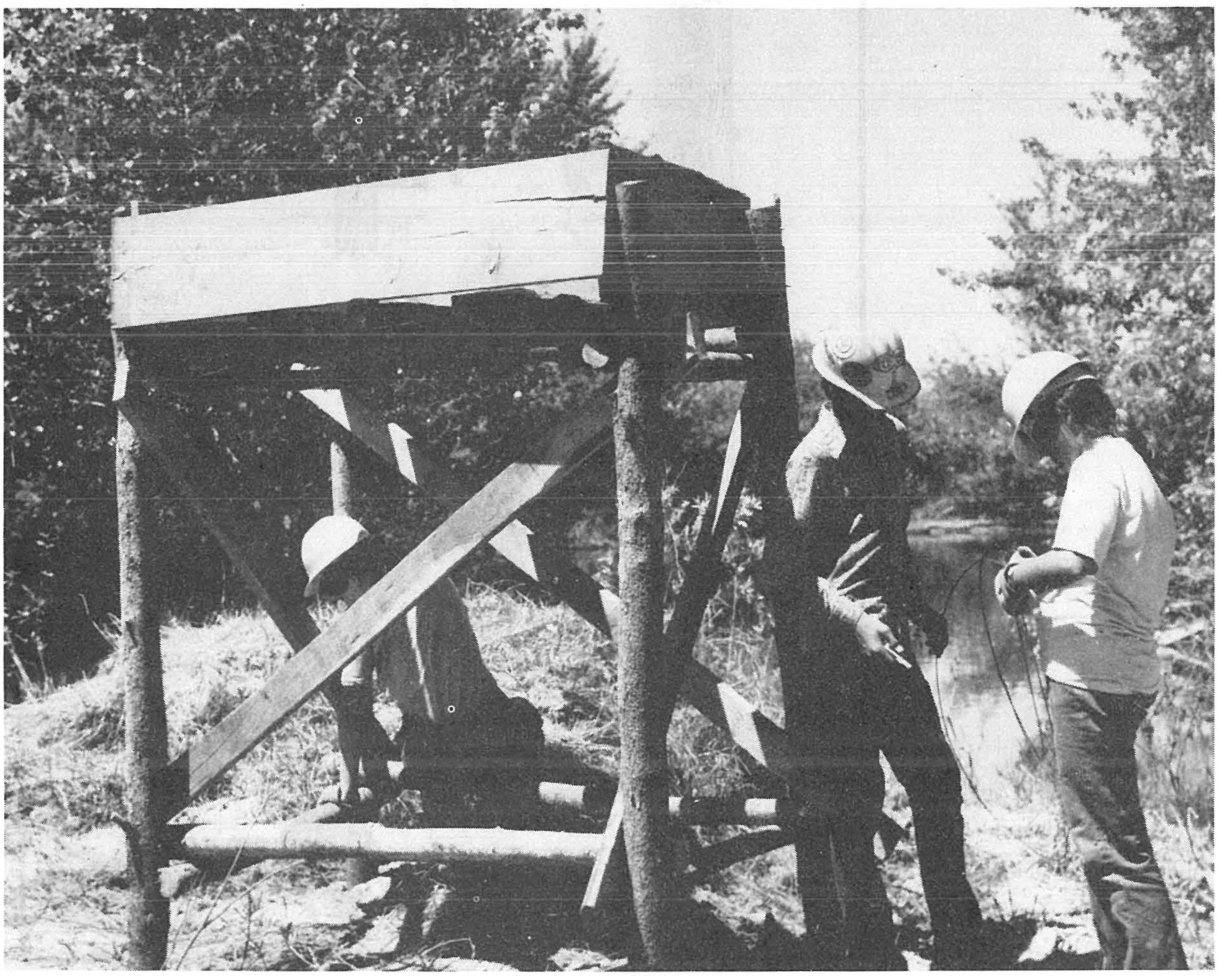


Exhibit 1. Goose nesting platform on the Payette River, Idaho.

Exhibit 1 is a photograph of a goose nesting platform constructed on the Payette River in Idaho. Several types of platforms have been designed; primarily they should be built several feet off the ground to discourage predators and measure up to 4 feet on each side. Nesting materials such as wild hay or straw should be supplied

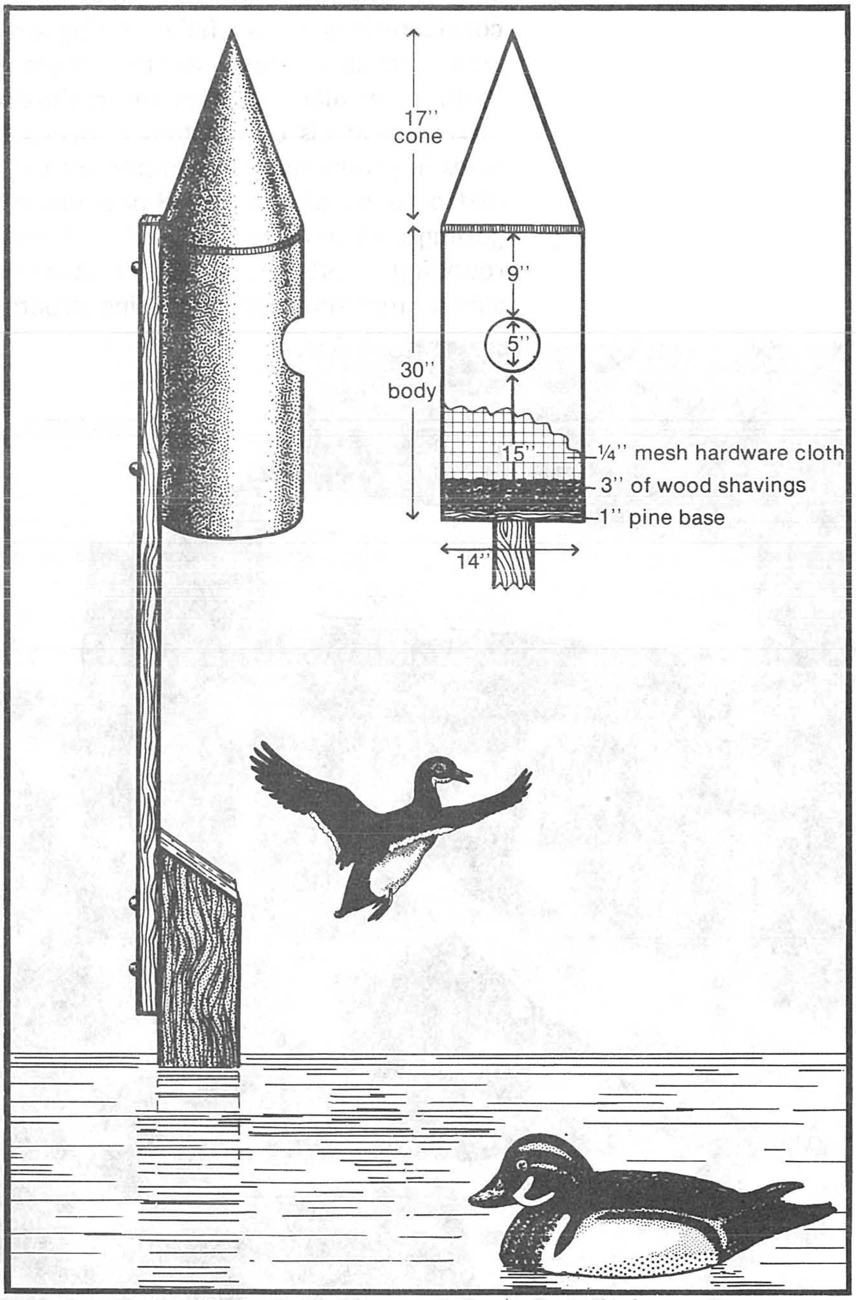


Exhibit 2. Wood duck nesting box made of metal.

annually. Where platforms are built on rivers, high flows should be anticipated and, if possible, controlled during the nesting season (see Section H4.4, Maximum Flows). Other species also may use platforms. For example, on Heron Island in Lake Havasu, Arizona, platforms are being built to protect nesting herons from fishermen and other recreationists.

Exhibit 2 is a drawing of a wood duck nesting box made of metal. The boxes also can be built with wood which may be more acceptable to the ducks. The inner surfaces of the box should be rough or a strip of hardware cloth supplied so the ducklings can climb out. Placement should be near or over water, 10 to 30 feet above ground in trees or above the flood stage if on posts in a reservoir. Annual replacement of nesting materials such as wood shavings is a necessary part of maintenance (U.S. Forest Service).

Evaluation

Nesting structures are readily accepted by many species of wildlife and, consequently, the structures are a valuable management tool. However, they should not be considered a permanent solution to the continuing problem of habitat loss. Fabrication, mounting, and the necessary periodic maintenance all are costly in a large—scale program. Evaluation of the program is necessary, also. Loss due to vandalism should be anticipated. In designing structures, exclusion of predators is a primary concern. The Payette River goose platform inhabitants suffered heavy predation by raccoons soon after construction. Attachment of metal guards to the legs of the platforms reduced their accessibility, and researchers for the Idaho Department of Fish and Game have estimated that the 55 structures should produce 150 to 200 goslings annually.

Reference

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Nesting Islands P4.2

Description

Islands are an important sanctuary for nesting waterfowl and shorebirds and for migrating birds. In some areas, they are important fawning grounds also. Exhibit 1 is a photograph of man—made nesting islands being used by Canada geese at Canyon Ferry Reservoir in Montana. Driftwood nest enclosures, seen in Exhibit 2, have been placed on the islands to provide cover and promote nesting activity on the barren soil. Hay and other nesting material is supplied annually. Many of the Canyon Ferry islands were created using dredge spoil as were several at Topock Marsh in Arizona (see Exhibit 3, Section H6.5). The islands at Topock provide habitat for the endangered Yuma clapper rail in addition to waterfowl and other shorebirds. Nesting islands also may be important features of streams as on the South Fork of the Snake River below Palisades Dam in Idaho. There, approximately 1,000 acres of natural gravel bar islands are prime breeding grounds for Canada geese.

Exhibit 1. Nesting islands at Canyon Ferry Reservoir, Montana.

Evaluation

In most situations, islands have received heavy use and have been responsible for increased production of various wildlife species. At Canyon Ferry Reservoir, gosling production has nearly tripled during 3 years of island construction (Eng and Childress, 1977). The area also serves as a resting ground for several thousand ducks during the fall migration. In general, islands receiving less use are surrounded by shallower water and are closer to the lake shoreline. Topock Marsh has been successful in providing rail habitat, and recent dredging and island construction appear certain to improve conditions further.

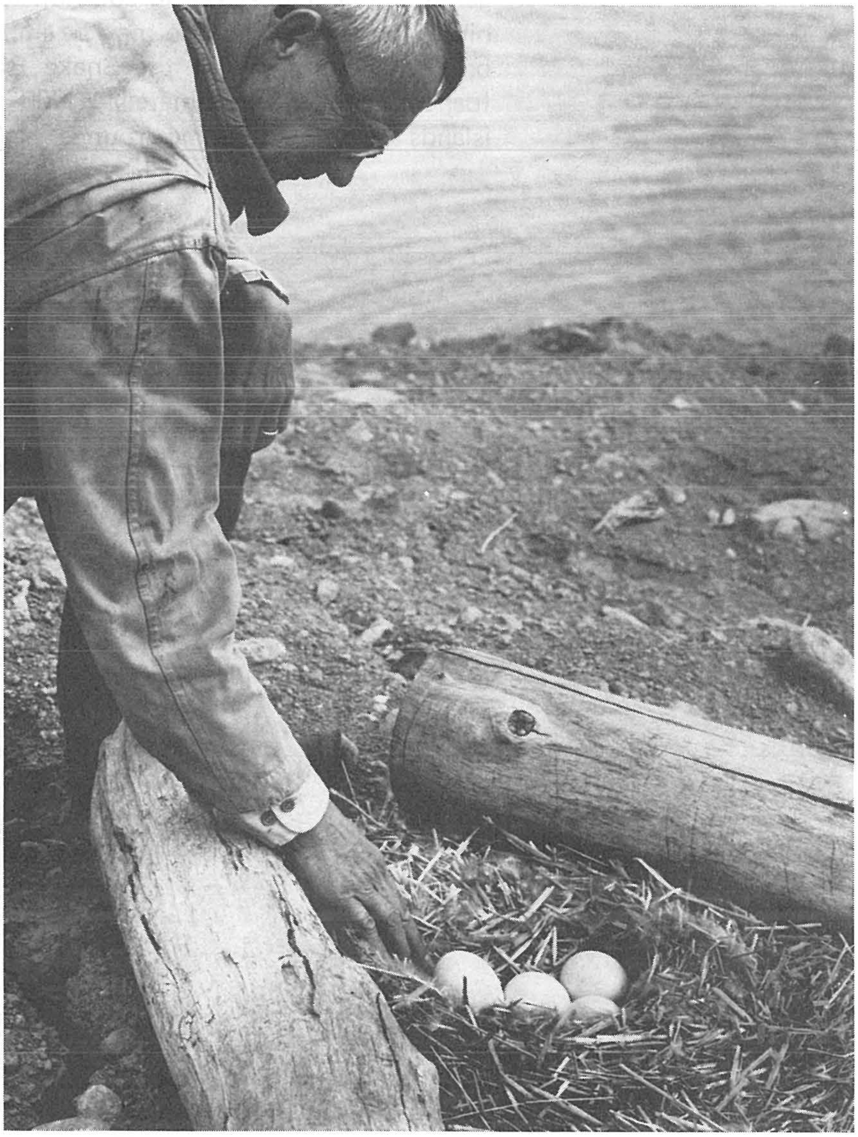


Exhibit 2. Driftwood nest enclosure on a Canyon Ferry nesting island.

Nesting Islands P4.2

The islands below Palisades Dam provide an excellent illustration of a major constraint on the implementation of this measure. For nesting to be successful there, flows in the Snake River must be controlled precisely. Early in the season while geese are selecting nesting sites, flows ideally should be held relatively high to force the geese to nest higher on the islands. This will prevent the flooding of established nests by high flows later in the season. Throughout the nesting period, flows must be maintained at some minimum level or the islands will lose their isolation and heavy predation will result. Similar problems must be considered for islands in reservoirs. Where surface level fluctuations are great, nesting islands may not be an effective measure for habitat and population improvement. Sections H2.2, H2.3, and H4.2 discuss reservoir and stream fluctuation controls.

Reference

Eng, R. L., and D. A. Childress, "Ecological Study on Canyon Ferry Dust Abatement Program," Montana State University and Montana Fish and Game Department, Quarterly Progress Report, 1977.

Passable Fencing P4.3

Description

Livestock fences constructed where they impede movements of wildlife must incorporate features to ensure the least possible hindrance. To fence one herd of wild sheep, for instance, from another can eventually weaken a long–term gene pool by prohibiting young animals from moving out from one range herd to another (Seaman, 1977). The summer and winter ranges of Rocky Mountain sheep are connected with specific migration routes, and barriers such as fences or canals are believed by wildlife biologists to be harmful.

This section discusses fences that are readily passable by antelope, deer, elk, moose, and bighorn sheep; see Section P5.2 for a discussion of impassable fences associated with canals and highways. Passable livestock fences are constructed so the wildlife can jump over, crawl under the bottom strand, through two of the fence strands, or through an opening in the fence. Fencing also may be used to prevent stock, humans, or vehicles from destroying newly planted habitats, nesting areas, and riparian vegetation.

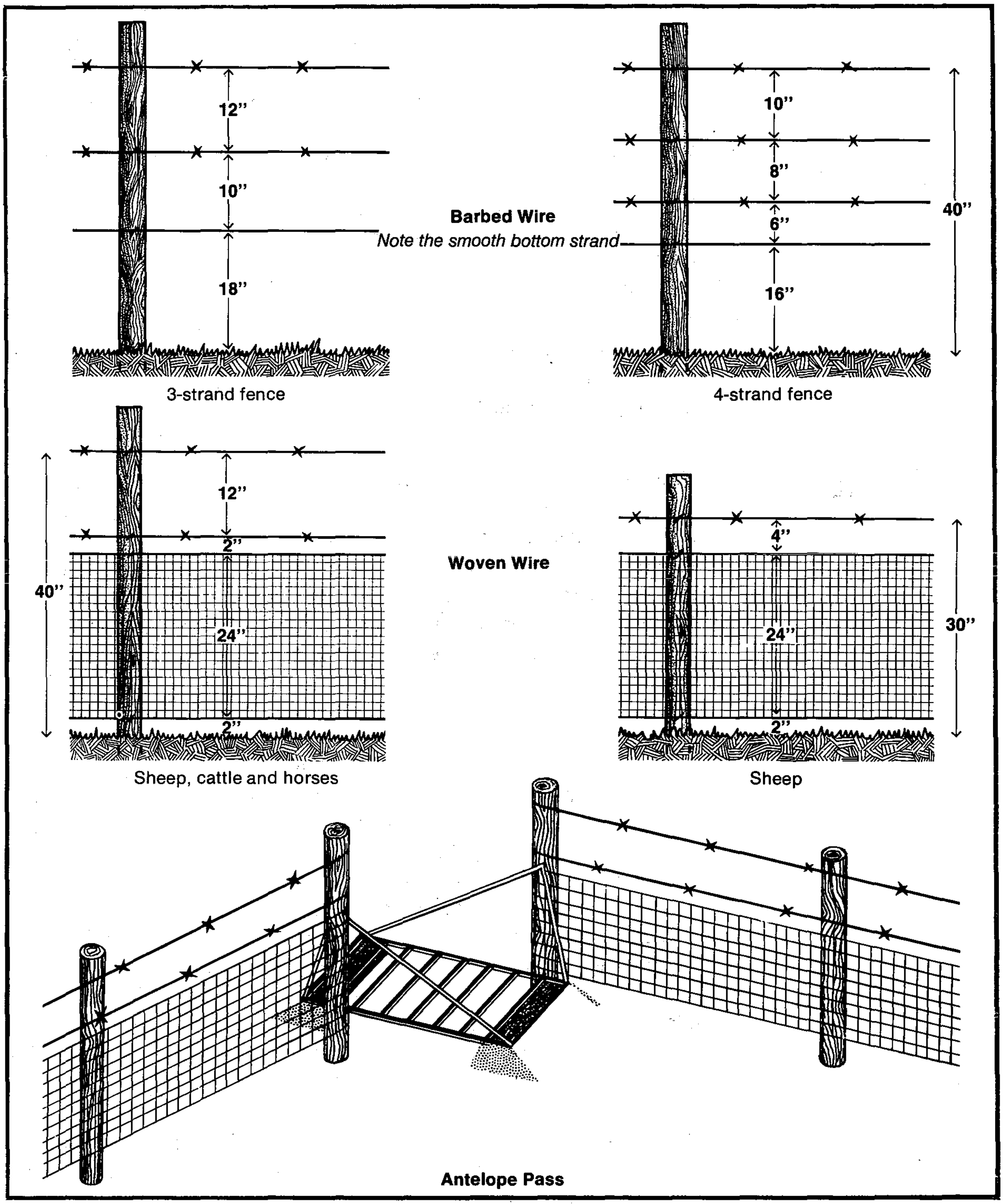
Evaluation

This discussion draws heavily on material presented by the U.S. Forest Service (1969). Where deer, elk, moose, or bighorn sheep are the target species, fences, to be passable, should not be constructed more than 40 inches in height. Also, when poles replace the top wire, they effectively reduce game losses and damage to fences. Because antelope are inclined to go under or through livestock fences, special care must be taken when constructing fences across their range.

Exhibit 1 depicts four types of fencing antelope will go through or jump over, and shows an antelope pass incorporated with a fence. The three–strand fence 40 inches in height allows antelope to pass under or through the fence between the second and top strands. If cattle pressure is great, another wire may be added to control cattle while still allowing antelope to pass under the smooth bottom strand. Woven wire fences present a severe barrier to antelope. A sheep net wire fence constructed with a total height of 30 inches usually will allow antelope to jump over. However, if cattle and horses are present on the range, another strand will have to be added to increase the height of the fence to 40 inches. This top strand should be placed 12 inches above the one below to allow antelope to jump through the fence.

Antelope will jump over a cattleguard. Cattleguards or antelope passes placed along established antelope routes have proved effective in alleviating fencing problems. If the cattleguards are placed

Exhibit 1. Passable fences for antelope and the antelope pass.



in fence corners (Exhibit 1), the fences will tend to direct the antelope to the opening. Cattleguards installed on old railroad ties are raised above the ground; therefore, dirt should be filled in and sloped at the entrance and exit to encourage use by antelope. A 4 x 6—foot cattleguard can be constructed and installed for approximately $140 (1977 dollars). The additional cost to make livestock fencing passable to wildlife is not great (see Section H6.3, Grazing Control). Only a few minor modifications as to the height and spacing of strands are made to the livestock fences. Some cost may be incurred to determine what species the fence is to be modified for, and where cattleguards are to be situated.

Reference

Seaman, E. A., "Wild and Domestic Mammal Control in Concrete—Lined Canals," U.S. Bureau of Reclamation, August 1977.

U.S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Guzzlers, Waterholes and Springs P4.4

Description

Wildlife usually ranges a limited distance from water. Because water is an essential element of wildlife habitats, the carrying capacity for some species can be increased by developing or providing additional sources of drinking water. Measures to supplement the natural supply include the development of guzzlers, water holes, and springs. This section largely draws on material from the U.S. Forest Service (1969) which has an excellent in—depth discussion of the watering methods or devices.

The guzzler is a permanent, self-filling water catchment. Although guzzlers are at times installed for deer, bighorn sheep, or other big game, most often they are provided for upland game birds. Guzzlers commonly are constructed using a water—tight tank made of concrete or plastic, although steel tanks have been employed as well. Rain—collecting aprons which drain into the tanks may be made of concrete sealed with bitumul, galvanized sheet metal roofing, glass mat and bitumul, rubber or plastic sheets, asphalt, and plywood. Generally a guzzler will allow birds and other small animals to enter the covered tank through an open end and descend to the water level down a sloping ramp. For larger game the storage tank may be closed and the water piped by gravity flow to a drinking trough as illustrated in Exhibit 1. This exhibit also shows that the apron has been fenced to prohibit livestock from trampling the catchment area.

Waterholes are small watering ponds available for wildlife use. Larger ponds and small reservoirs are discussed under fish and waterfowl ponds (Section H6.4). A smaller type of waterhole is a dugout. Dugouts or pit tanks are constructed with vertical sides and a 4:1 slope on the ends where conditions permit. Exhibit 2 depicts this type of steep—sided waterhole with no shallow area for small birds and mammals. Floating resting platforms may be anchored in the middle, and the site may be fenced to exclude livestock.

Springs and seeps may be better utilized by wildlife if a protective device such as a spring box to catch and store water is installed; water can be piped from the spring box to a drinking trough. The area around the spring should be fenced to exclude livestock, and devices should be installed inside the trough to allow birds and other small animals that fall into the water to escape. These devices may be floats, ramps, or ladders.

Evaluation

For these wildlife watering methods to be effective, the environ-

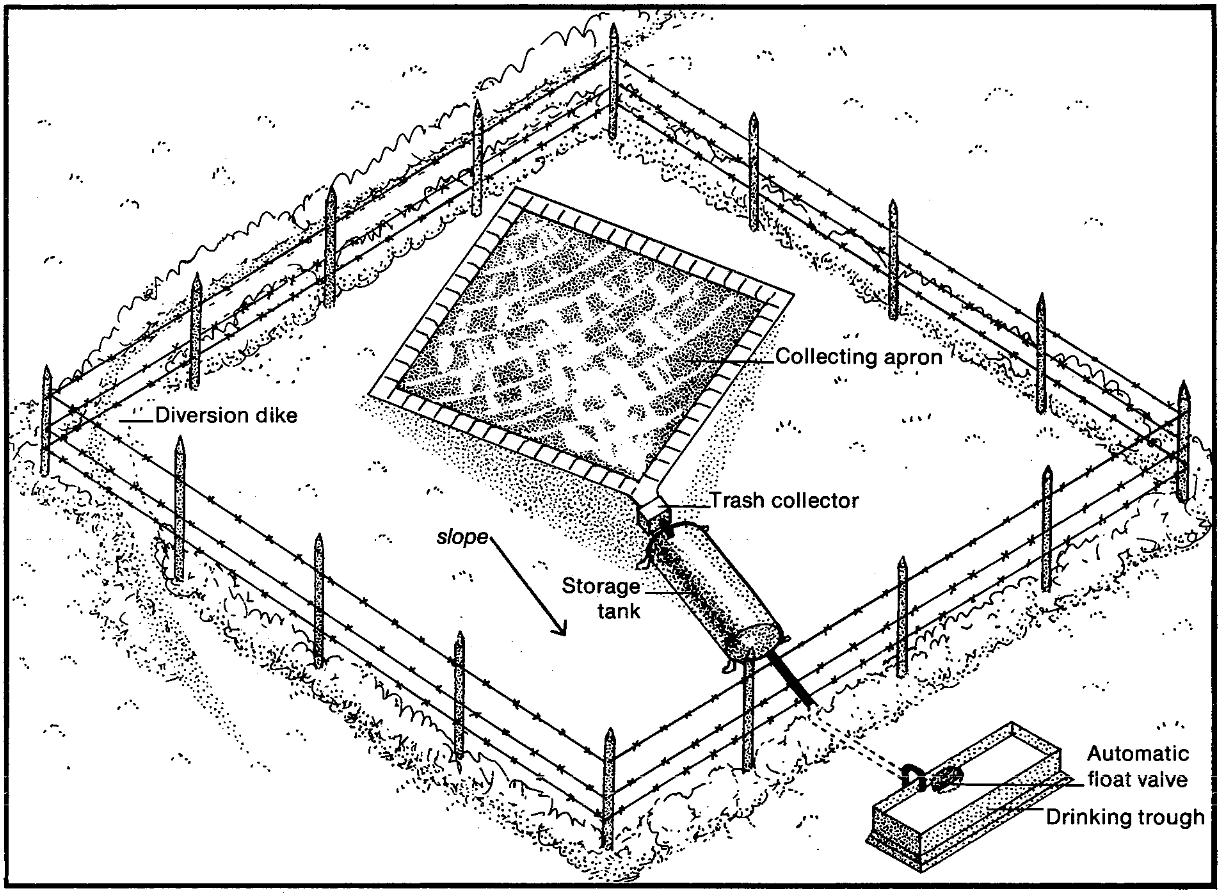


Exhibit 1. Example of a guzzler installation for deer and other large animals.

mental needs of the target species must be known so that an appropriate device can be sized and located properly. To prevent the device from failing during drought years, it should be sized on the basis of the minimum precipitation expected. Sites that provide the food and cover requirements of the target species should be given first priority. All installations should be fenced from livestock. Vegetation planted around the fences will provide habitat for small wildlife. Pointed fence posts should be installed to discourage perching by avian predators. If livestock or human use in the vicinity of an installation is heavy, piping the water outside the enclosure for human or livestock consumption may prevent disruption of wildlife.

The greatest value of guzzlers is in semi–arid regions where natural water is scarce or intermittent. These devices should not be placed in a wash or gully where they will collect silt or sand, or be damaged by floodwaters. Plastic guzzlers may be preferred where labor costs are high. In California the costs for installing plastic guzzlers have ranged from $290 to $370 (1977 dollars). Although many materials have been made into collecting aprons, durable materials such as concrete or metal have proved successful because of low maintenance costs.

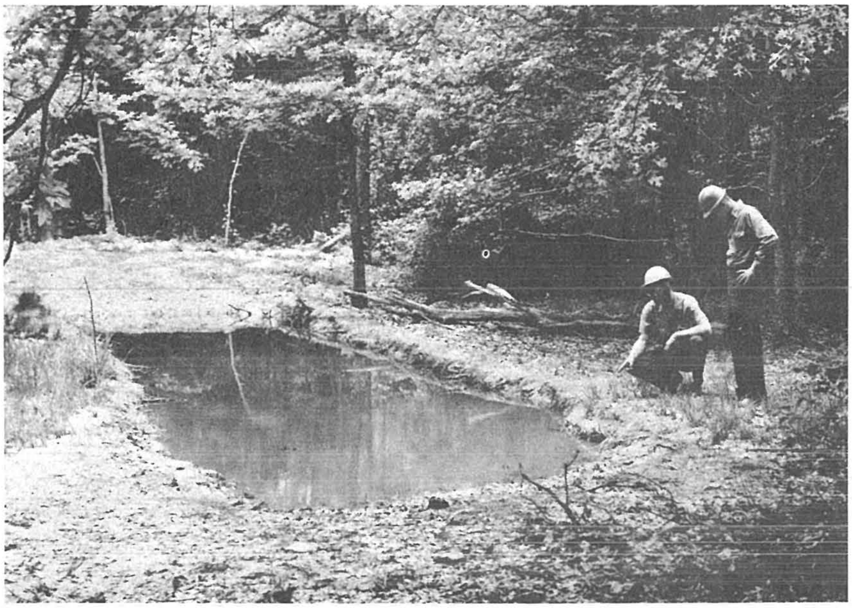


Exhibit 2. Small, steep-sided waterhole or dugout.

Waterhole and spring development should be planned and designed to reduce competitive use at or adjacent to it. Fences should be constructed to protect small game watering and resting areas from livestock and humans. Better habitat will be provided for nesting and resting birds when livestock grazing is excluded around waterholes and springs (see Section H6.3).

Reference

U. S. Forest Service, Wildlife Habitat Improvement Handbook, Catalog No. FSH 2609.11, August 1969.

Wildlife Protection at Canals

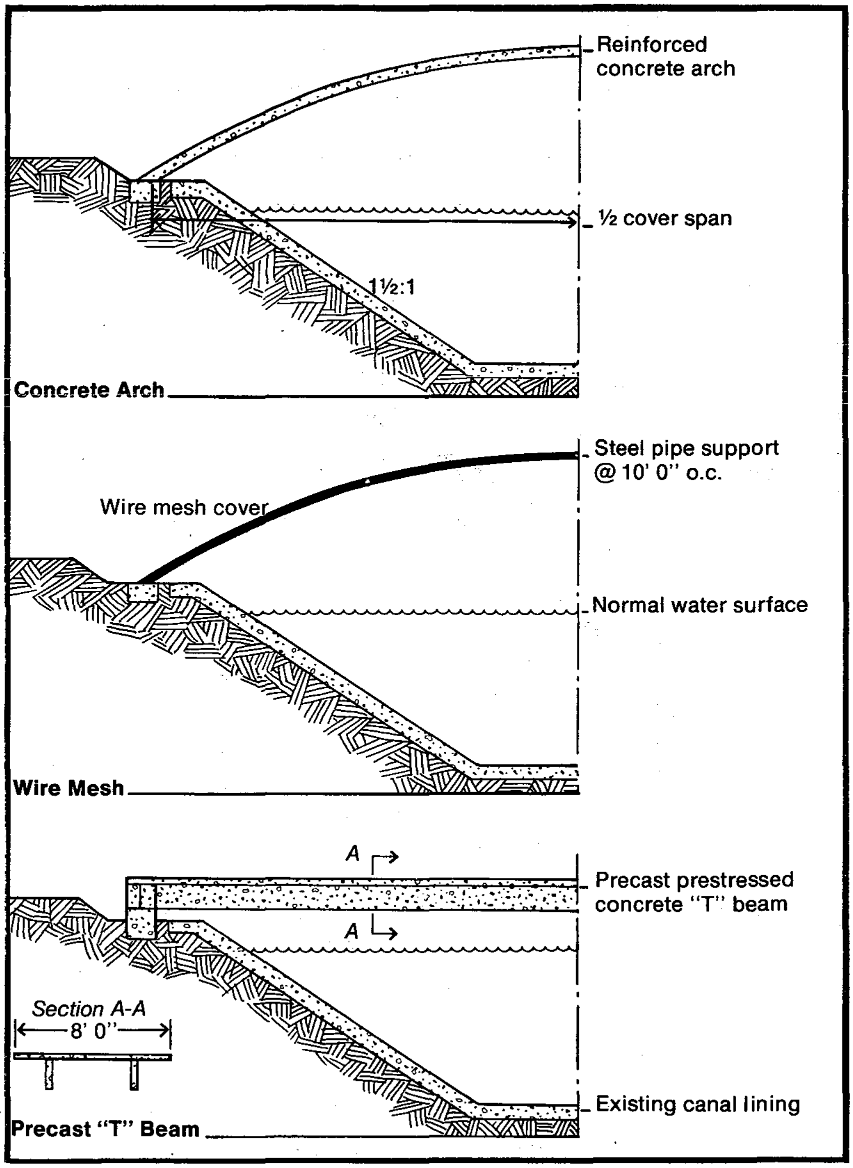
P5.0

Conduits and Canal Covers P5.1

Description

Closed conduits and canal covers are devices proposed to reduce the safety hazards and environmental impacts associated with open, concrete–lined canals. Actual wildlife losses in open canals are difficult to determine and vary with different projects. However, Latham and Verzuh (1971) report that losses of deer, the most frequent big game casualty, are generally one or more per mile of canal per year when the canal crosses suitable deer habitat. In addition to these losses, canals may block migration routes that are

Exhibit 1. Typical canal covers in half cross-section.



critical for daily and seasonal movement. For instance, if migration between herds is prohibited, a weakening of gene pools may result.

Closed conduits would be most usable and practical for initial construction of small—volume conveyance channels. Canal covers could be used on existing open canals, though retrofitting costs could prove to be more than for construction of a conduit. Several types of covers are depicted in Exhibit 1.

Evaluation

The obvious advantage of closed conduits and covered canals is the elimination of the wildlife hazards of open canals, especially the drowning hazard. Other advantages include less maintenance and a reduction of water loss caused by evaporation and seepage.

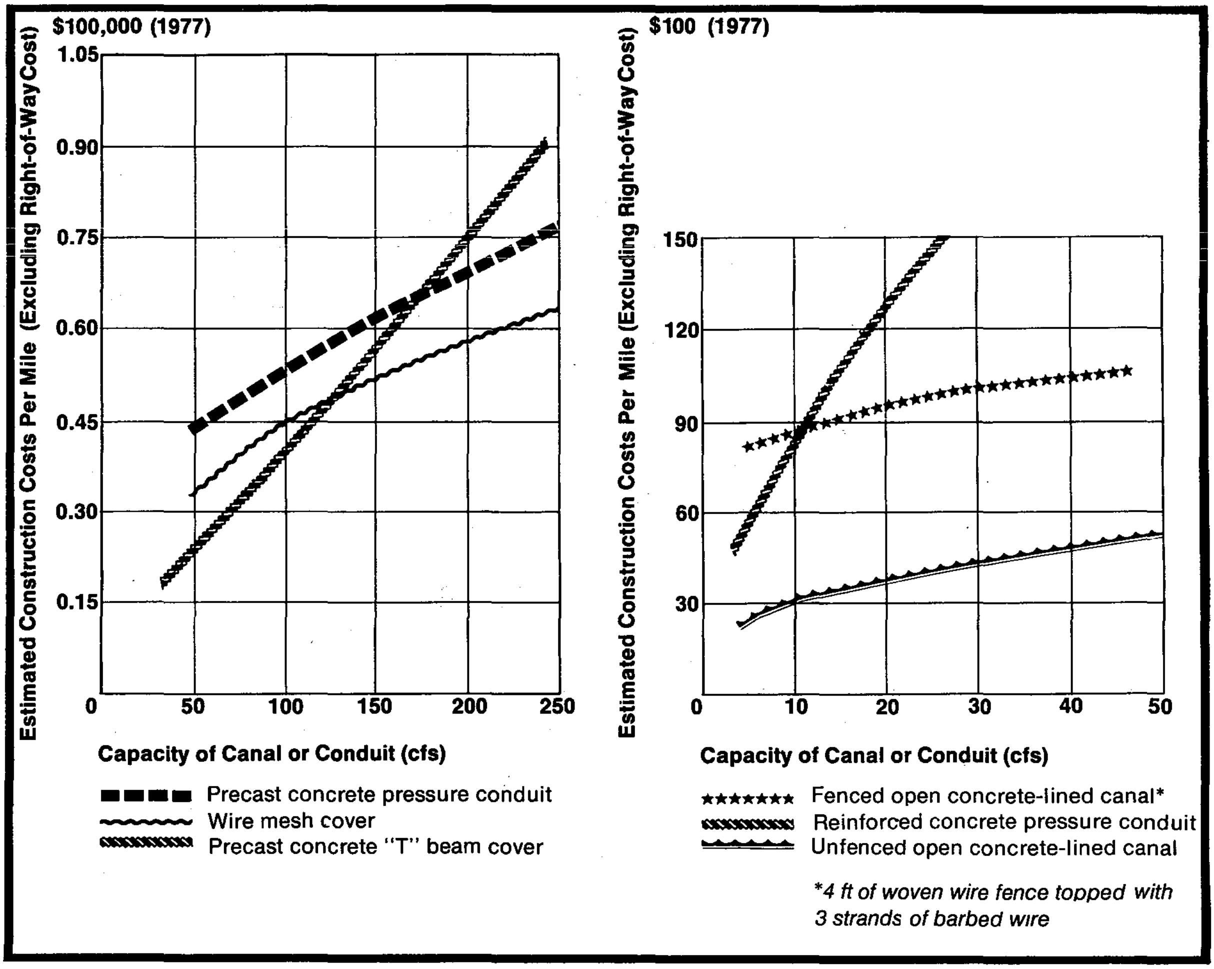


Exhibit 2. Comparison of construction costs for conduits and canal covers.

The obvious disadvantage of these related measures is the construction cost. While costs vary greatly with location and other factors, graphs for general comparison are presented in Exhibit 2 based on figures from Latham and Verzuh. Another disadvantage would be the loss of seepage through embankments that normally is associated with open canals. Bankside seepage supports riparian habitat that can be important to various species of wildlife, particularly small game which usually is not affected by the hazards of an open canal. In addition, closed canals may have a more limited capacity for flood control, and entrances to closed systems must be protected with fencing and safety racks.

Reference

Latham, H. S., and J. M. Verzuh, "Reducing Hazards to People and Animals on Reclamation Canals", U.S. Bureau of Reclamation, Report No. REC—ERC—71—36, September 1971.

Impassable Fencing P5.2

Description

Impassable wildlife fences are installed along concrete–lined canals to prevent the drowning or maiming of deer, elk, antelope, wild sheep, bear, and other mammals as well as humans. Approximately 95 percent of the big game animal losses are deer (Latham and Verzuh, 1971). For example, at the Tiger Creek Canal on the North Fork of Mokelumne River, Amador County, California, records show that from 1960 through 1976 (no data for 1965–66) a total of 356 animals were drowned; 340 deer, 2 mountain lions, 2 bears, 1 bobcat, 1 coyote, and 1 porcupine (Seaman, 1977). Latham and Verzuh report that concrete–lined canals without wildlife fencing and surrounded by suitable deer habitat usually have annual losses of one or more deer per mile.

Fences to prevent wildlife from entering canals range from 6 to 9 feet in height, although 7½ feet is most common. However, deer when pressed can jump an 8–foot fence on level ground; when fences are located on sloping ground, it may be necessary to build them 10 or 11 feet high (Longhurst, et al, 1962). The usual 7½–foot–high fence utilizes 6 feet of wire mesh topped with three strands of wire supported by wooden or metal posts on 8–foot centers. The wire mesh should be secured close to ground level to prevent deer from crawling under. (For an in–depth discussion of deer fence specifications as to construction material, mesh size, and so forth, see Longhurst, et al.) Sometimes impassable fences are constructed in conjunction with crossings to allow the wildlife to migrate, thus preventing herds from being separated (see Section P5.3 on wildlife crossings). A 6–foot–high drift fence may be used to guide animals to these crossings.

Evaluation

A fence 7½ feet high having 6 feet of woven wire under three strands of wire will almost completely eliminate deer access (Latham and Verzuh). Nevertheless, some deer will injure themselves trying to jump this fence. Although livestock fences 4 feet high with four strands of barbed wire have been constructed along canals where cattle graze, generally they have not been effective in reducing deer losses (see Section P4.3 on passable fencing). These fences are simply too low to keep out deer. Moreover, wildlife fencing is required only where significant wildlife populations exist; therefore, a thorough evaluation may be needed to determine if and where wildlife fencing and crossings should be installed.

Of course, the costs of installing and maintaining wildlife fencing can be substantial, as indicated below (Exhibit 1). More effective fencing 8½ or 9 feet high would increase capital cost only by approximately 10 percent and would leave maintenance cost unchanged. Periodic inspection and prompt maintenance is required if wildlife fencing is to be continuously effective.

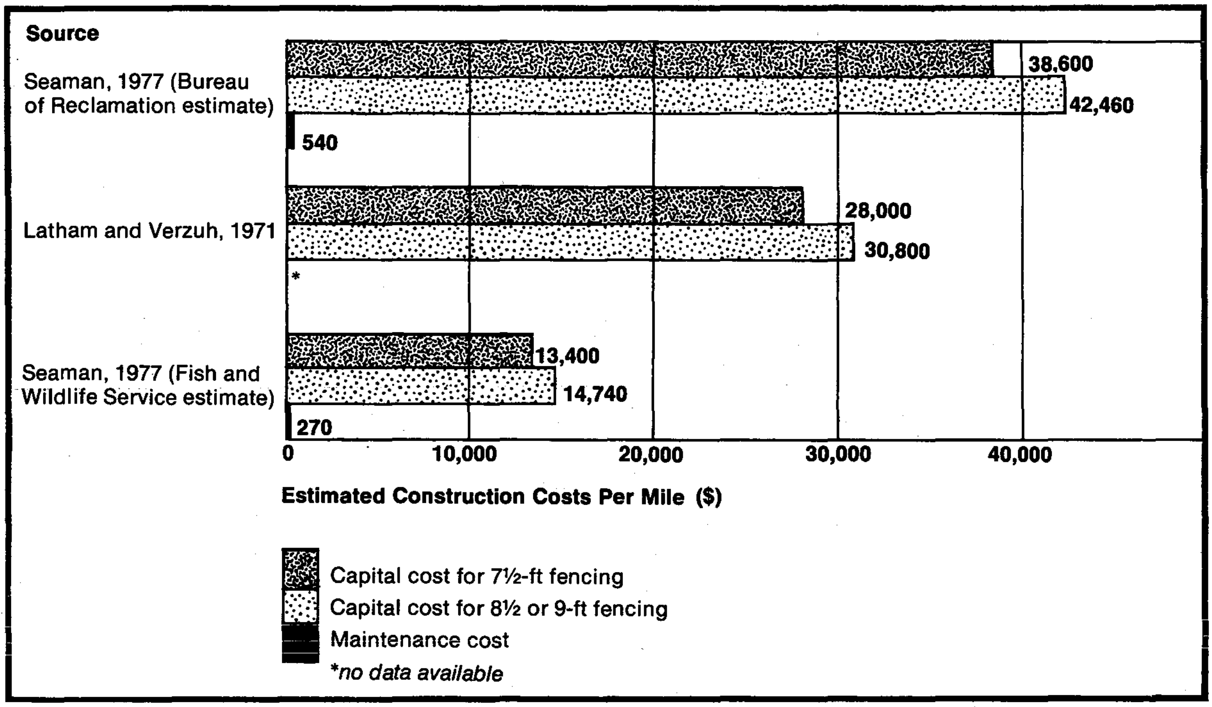


Exhibit 1. Estimated costs per mile for 7½-foot-high wildlife fencing (adjusted to 1977).

Reference

Latham, H. S., and J. M. Verzuh, "Reducing Hazards to People and Animals on Reclamation Canals," U. S. Bureau of Reclamation, Report No. REC–ERC–71–36, September 1971.

Longhurst, W. M., M. B. Jones, R. R. Parks, L. W. Neubauer, and M. W. Cummings, "Fences for Controlling Deer Damage," California Agricultural Experiment Station, Extension Service, CAECAG No. 514,1–20, June 1962.

Seaman, E. A., 'Wild and Domestic Mammal Control in Concrete–Lined Canals, "U. S. Bureau of Reclamation, August 1977.

Wildlife Crossings P5.3

Description

Wildlife crossings are bridges built across canals to provide safe movement from one side to the other. Crossings are particularly necessary where a canal blocks daily or seasonal migration routes. These routes should be located prior to construction, if possible, and bridges should be built where the routes intersect the canal. Snowdrift fencing can be used to guide animals toward the crossing. If the canal itself is fenced, the bridge also should be fenced (Exhibit 1).

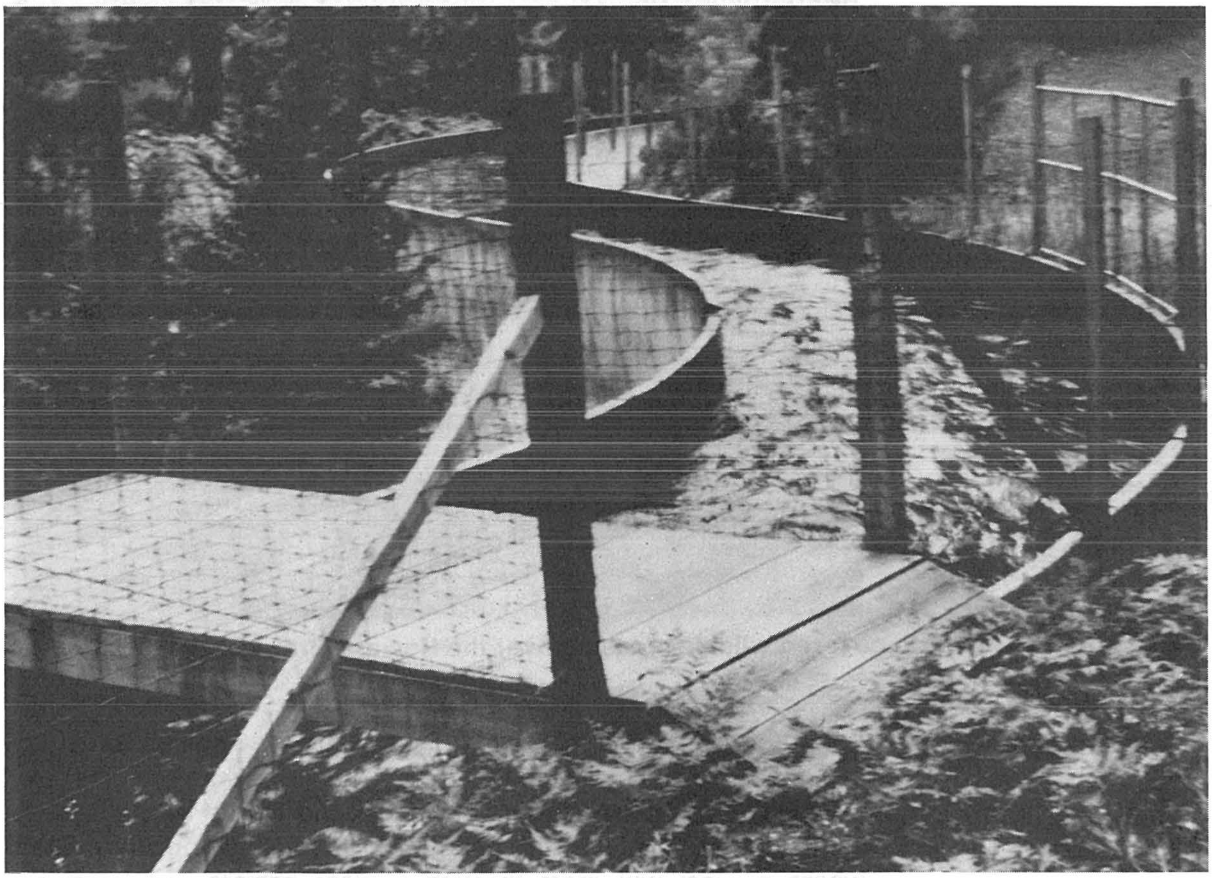


Exhibit 1. Fenced wildlife crossing over the Tiger Creek Canal, California.

Width of the crossings does not appear to be highly critical, though Seaman (1977) states that narrow bridges had less use than bridges at least 4 feet wide. Latham and Verzuh (1971) recommend the crossings be at least 8 feet wide. It does appear that, as the span of the bridge increases or if the bridge has fencing or railings along the sides, the width should be increased. The crossings should be as natural as possible, preferably with an earth covering over a solid structure as illustrated in Exhibit 2. Access to the bridge should be reasonably easy, preferably without steps, although a location at established game trails is more important than an even entrance.

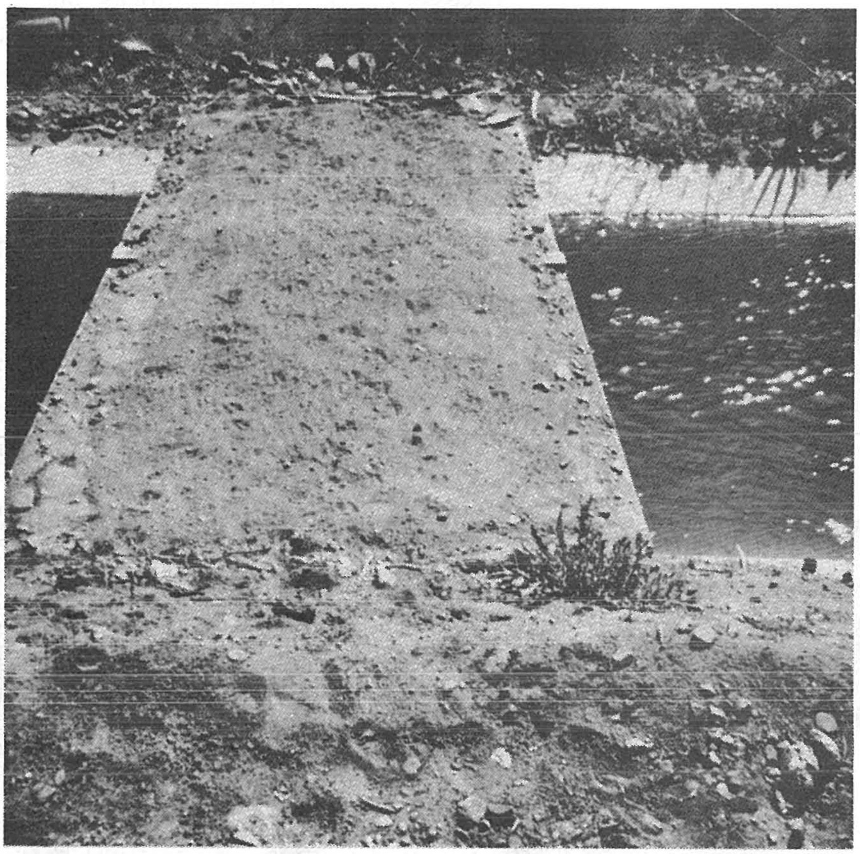


Exhibit 2. An earth-covered wildlife crossing over the Howard Prairie Canal, California.

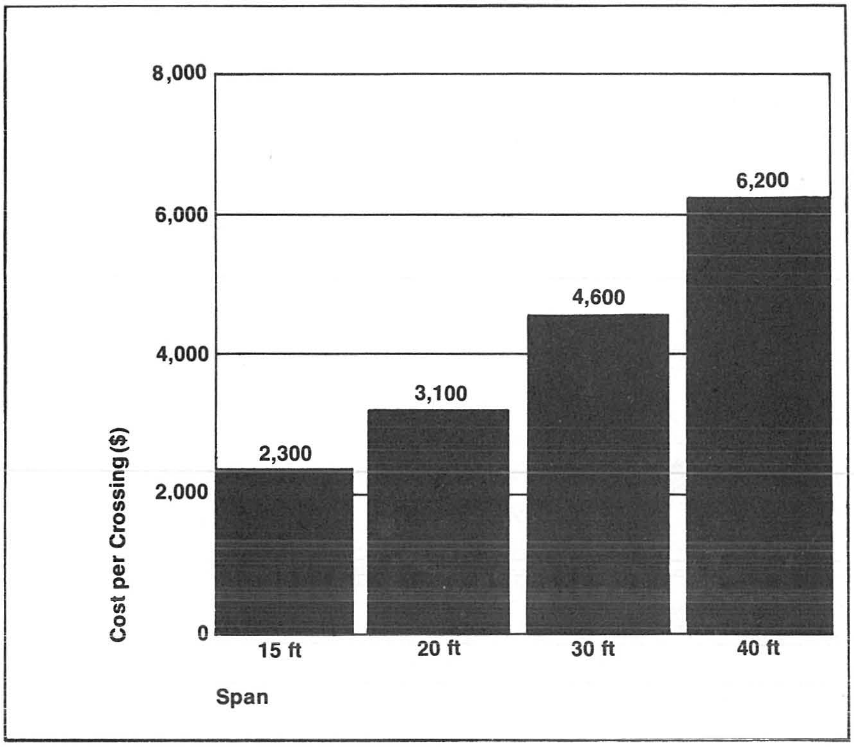
Evaluation

Wildlife crossings have proven to be an effective measure for reducing the number of animals entering canals at several projects, including the Colorado–Big Thompson and Rogue River (Latham and Verzuh). This measure should be considered for any project where a canal will cross through wildlife habitat and losses are anticipated, particularly where migration patterns are established and the canal is to be fenced. Exhibit 3 presents estimated construction costs for timber crossings with various spans (from Latham and Verzuh). In addition, the Engineering and Research Center of the U.S. Bureau of Reclamation has estimated costs for a precast concrete crossing with 6–foot–high drift fencing at $20,000 in 1976 (see Seaman).

Reference

Latham, H. S., and J. M. Verzuh, "Reducing Hazards to People

Exhibit 3. Estimated construction costs for 8-foot-wide timber crossings.



and Animals on Reclamation Canals," U.S. Bureau of Reclamation, Report No. REC–ERC–71–36, September 1971.

Seaman, E. A., "Wild and Domestic Mammal Control in Concrete–Lined Canals," U.S. Bureau of Reclamation, August 1977.

Escape Ramps P5.4

Purpose

The purpose of an escape ramp is to aid wildlife, mainly deer, in escaping from concrete–lined open canals. Ramps are considered an alternative to measures that prevent the entrance of wildlife into the canals such as closed conduits, canal covers, and fencing (Sections P5.1 and P5.2).

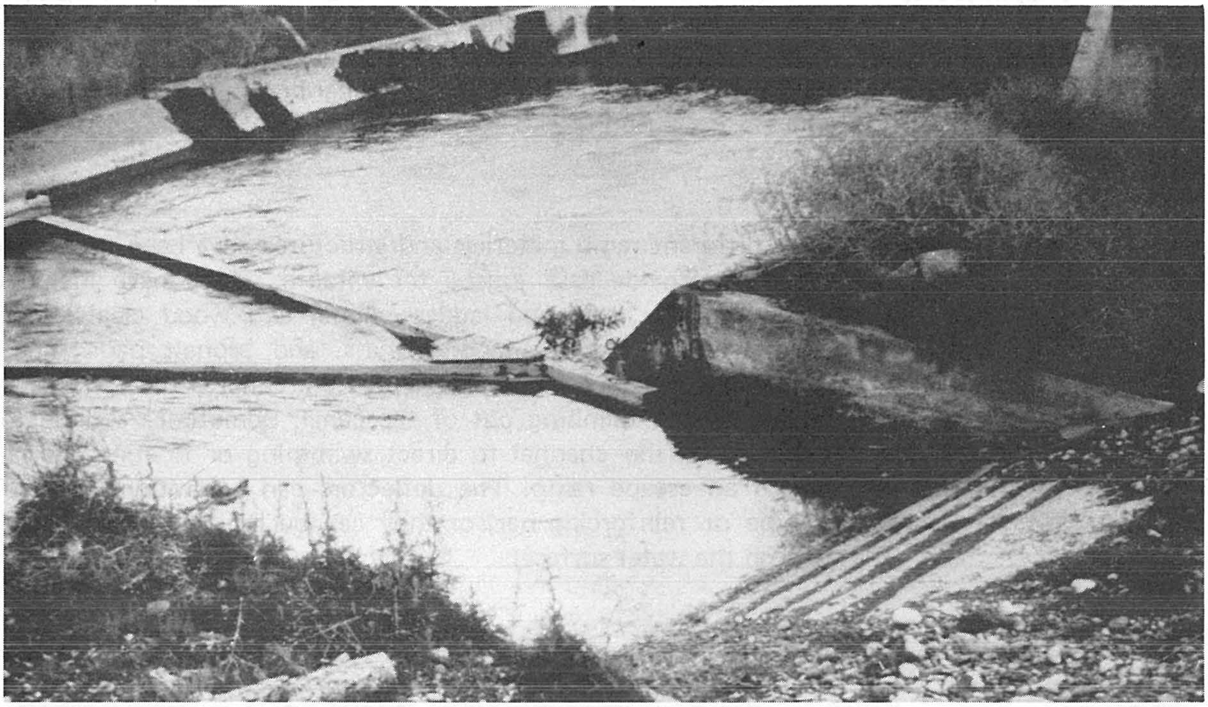
Illustration

Many different ramp materials and structures have been used in an effort to provide easy escape for wildlife. These have included reinforcing–bar mats and ladders, metal and wood cleats, snow fencing, metal airplane landing mats, and asphalt pads. These devices are attached to, or laid upon the canal banks, and assist the animals in climbing out of the canal. Sometimes a deflector is built into the channel to direct swimming or floating animals toward an escape ramp. The deflectors can be stationary, made of pipe or reinforcing bar, or they can be built from wood and float on the water surface.

Another type of escape ramp is discussed by Seaman (1977). The basis of this design, which has taken several forms, is a recessed ramp with a low–gradient (3:1 or 4:1) slope, usually with some type of deflecting or repelling device to help direct animals toward the ramp. The initial design utilizing this approach was the Richmond deer escape built into the Okanagan Canal in British Columbia (Exhibit 1). The floating triangular boom deflects animals toward the low–gradient ramp at the right of the picture. The ramp has grooves to roughen the surface so the animals can obtain a footing. Pacific Gas and Electric incorporated low–gradient deer escape ramps into their Tiger Creek Canal in California. To drive deer toward the ramps, however, they used aluminum strips hanging in the water, held by a cable (Exhibit 2). The moving water causes the strips to flash reflected sunlight, which repels the deer toward the escape ramp at the left of the picture.

Another version of the Richmond deer escape is shown in Exhibit 3. It is built on the outside of a bend in the canal. The eddy current developed by the abrupt widening in the canal tends to draw floating animals into the bay where the ramp is provided. The low gradient of the ramp as well as the reduced flow velocities allow the animal to climb out of the canal. To permit wildlife to exit the ramps but prohibit their entrance, one–way gates (shown in Exhibit 4) can be used. They were originally developed by the Colorado Division of Wildlife for use along highways.

Exhibit 1. Richmond deer deflector and escape ramp, Okanagan Canal, British Columbia.



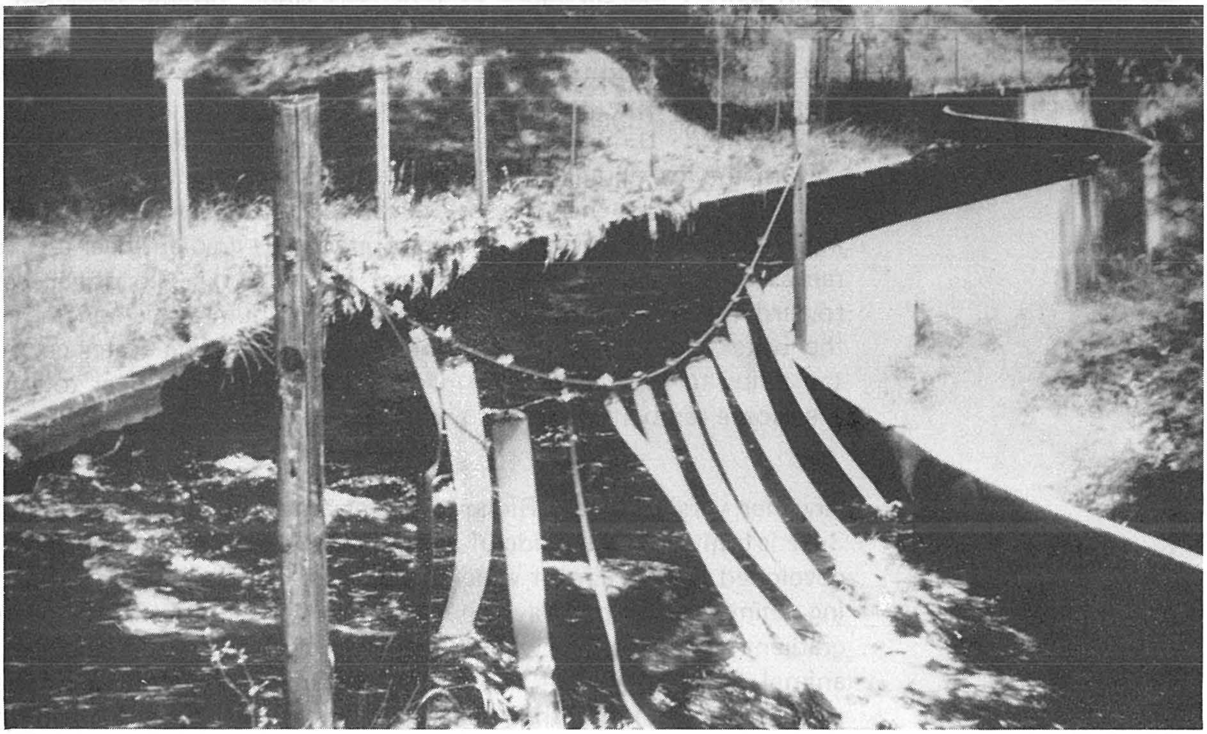
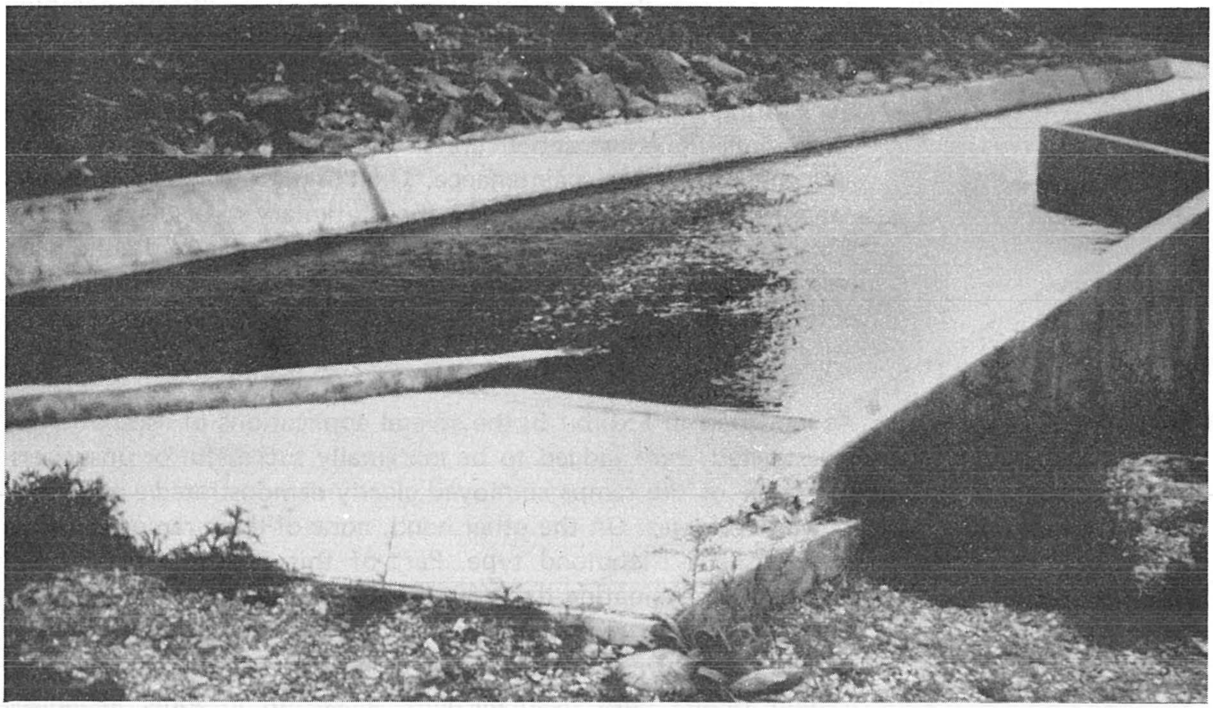


Exhibit 2. Aluminum "flashers" to divert deer toward escape ramp (at left), Tiger Creek Canal, California.

Exhibit 3. Revised Richmond deer escape ramp (water flow is left to right).



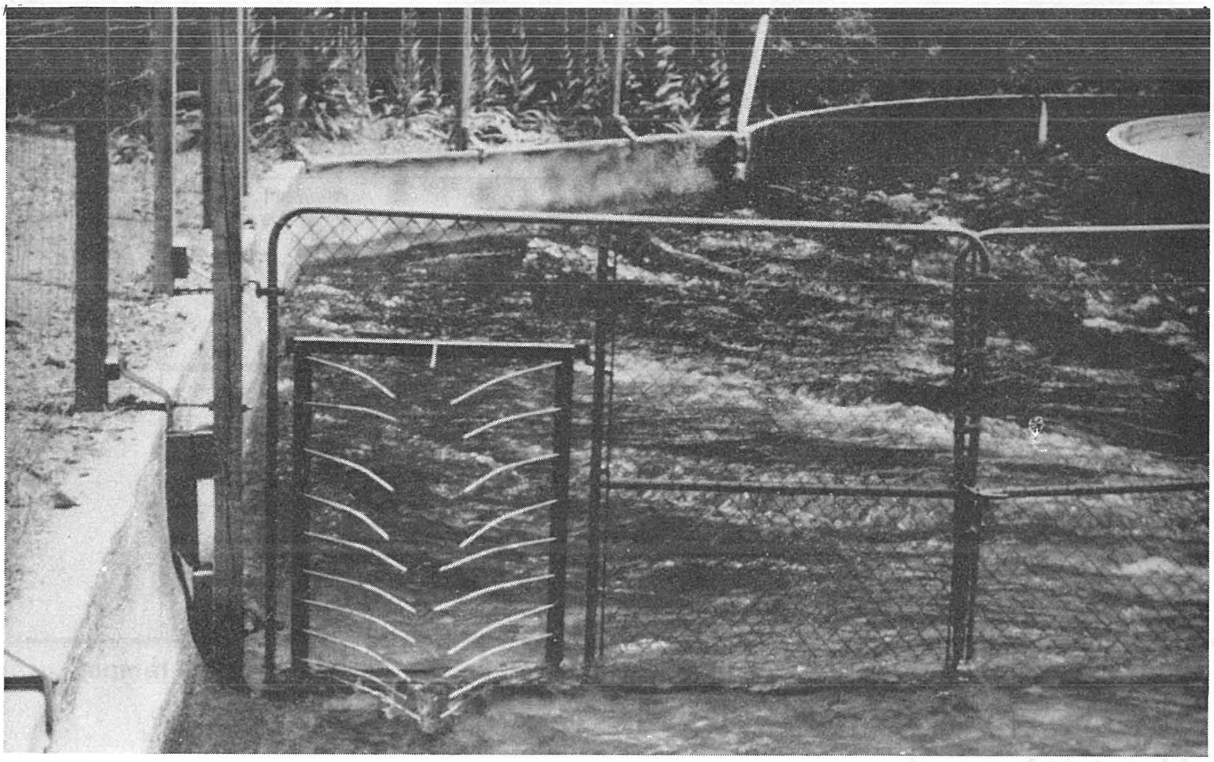


Exhibit 4. One-way exit gate installed with an escape ramp.

Limitation

If the escape device is placed on the original bank of the canal with a 1:1 or 1½:1 slope, an animal will have a difficult time climbing out of the canal, particularly if it is exhausted from fighting the current. Also, algae tend to cover any submerged material, making the footing very slippery. Other considerations for design of escape ramps include construction costs, effectiveness at various flows, and their need for maintenance. One of the problems with in—channel deflectors, particularly the stationary type, is that they collect trash and algae. This can cause considerable hydraulic head loss and possibly overflows and structure collapse, making the deflectors very unpopular with maintenance crews and canal owners.

Performance

As indicated in Exhibit 5, the several applications of escape ramps investigated were judged to be marginally successful or unsuccessful. None of the ramps employed clearly demonstrated a reduction in wildlife losses. On the other hand, none of these ramps were the low—gradient Richmond type. Part of this failure is due to the difficulty in evaluating the effectiveness of these devices; also, part is due to the inherent ineffectiveness of any design which does not reduce the normally steep slope of the canal. While cleats and asphalt ramps have been partially successful in some instances, Seaman feels that the Richmond—type ramp is superior and lists recommendations for its use and testing.

Classification of Success Using Habitat and Population Improvement Criteria		*number of cases*	Confidence Factors and Ratings								
			high			*medium*			*low*		
			Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports	Degree of implementation	Soundness of predictions	Reliability of reports
Successful	Habitat	0									
	Population	0									
Marginally Successful	Habitat	2	1	0	1	1	1	1	0	1	0
	Population	2	1	0	1	1	1	1	0	1	0
Unsuccessful	Habitat	0	0	0	0	1	0	1	0	1	0
	Population	1	0	0	0	1	0	1	0	1	0

Exhibit 5. Success and confidence matrix for escape ramps.

Cost/Output

Costs for the Richmond ramps were unavailable as were the costs for the escape ramps used in the projects reviewed. Generally, the ramps should average $100 to $500 per unit (in 1977), depending on the material used. Construction costs for animal deflectors have been estimated at $2,000 per structure in 1977 (see Seaman).

Project Review

NEBRASKA: Merritt

OREGON: Clearwater, Lemolo

Reference

Seaman, E. A., "Wild and Domestic Mammal Control in Concrete–Lined Canals," U.S. Bureau of Reclamation, August 1977.

Other Protection P5.5

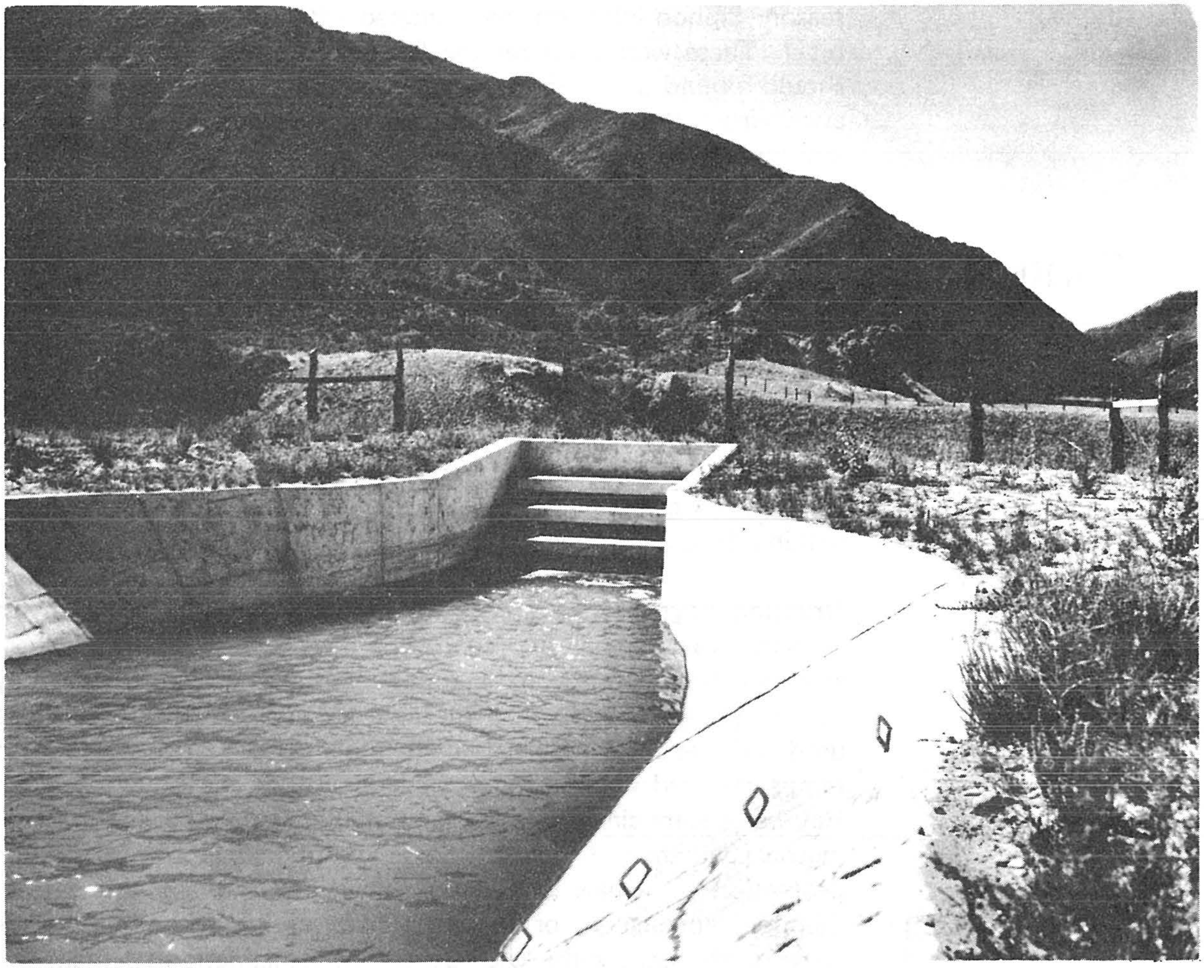


Exhibit 1. Stepped siphon inlet at the Gateway Canal, Utah.

Description

A few other methods for protecting wildlife at canals have been proposed or applied. They include earthen canal linings, stepped siphon inlets, drinking bays, and temporary escape devices such as hay bales and dirt ramps. Since the major problem is with concrete–lined canals, earth linings offer an alternative in areas where wildlife losses are significant. Another possibility is alternating sections of earth–lined and concrete–lined canal walls.

At the canal of the Navajo Indian Irrigation Project in New Mexico, deer were attracted into the dry canals by water in the siphons. Once in the canal, they could not get out because of the steep banks, and would drown in the siphons, die from injuries sustained while trying to escape, or be killed by poachers. Hay bales and dirt ramps can provide temporary escape after the close of the irrigation season. Siphon inlets can be equipped with steps as shown in Exhibit 1. These were built on the Gateway Canal in Utah. The steps should extend below the water surface. Drinking bays can be built away from the main canal to reduce the likelihood of animals entering the canal in search of water.

Evaluation

Earth—lined canals seldom contribute to losses of adult wildlife but may remain a hazard for fawns and other young animals (Latham and Verzuh, 1971). Earthen canals can present some additional operation and maintenance problems such as sedimentation, excessive water seepage and additional growth of aquatic plants. Stepped siphon inlets are effective when the canal flow is at or near full capacity. The steps require special design, however, and cannot be adapted to existing facilities. Also, they tend to collect trash, making them unpopular with canal operators.

Drinking bays are credited with reducing wildlife losses at the Howard Prairie Canal in Oregon. The bays themselves are inexpensive with few operation and maintenance needs. However, they may further attract animals into the area and consequently should be used only when the canal is completely fenced or enclosed. Dirt ramps reduced wildlife losses considerably at the Navajo Project. Hay bales were similarly successful at the Yakima Project in Washington (Latham and Verzuh). Some additional methods for wildlife protection at canals have been considered and are noteworthy. Stepped, corrugated, or flattened canal linings for animal escape were researched by the U.S. Bureau of Reclamation (Latham and Verzuh), but were deemed uneconomical for an entire canal when their costs were compared to costs for fencing. Chemical repellents also have been found to be uneconomical and in most cases ineffective in warding off animals approaching canals.

Reference

Latham, H. S., and J. M. Verzuh, "Reducing Hazards to People and Animals on Reclamation Canals," U.S. Bureau of Reclamation, Report No. REC—ERC—71—36, September 1971.

Appendix A

List of Projects Investigated

Agency Abbreviations: U.S. Bureau of Reclamation (BR); U.S. Army Corps of Engineers (CE); Federal Energy Regulatory Commission (FERC), formerly Federal Power Commission (FPC); U.S. Soil Conservation Service (SCS); U.S. Bureau of Indian Affairs (BIA).

FWS Region 1

CALIFORNIA

Iron Gate Dam, Klamath River (FERC)
New Bullards Bar Dam, North Yuba River (CE)
Nimbus Dam, American River (BR)
Oroville Dam, Feather River (FERC)
Red Bank (Bluff) Diversion Dam, Sacramento River (BR)
Rock Creek Diversion Dam, North Fork Feather River (FERC)
Sacramento River Division, Sacramento River (BR)
Shasta Dam, Sacramento River (BR)
Stampede Dam, Little Truckee River (BR)
Tehama–Colusa Canal, Sacramento River (BR)
Trinity River Division, Trinity River (BR)

IDAHO

Anderson Ranch Dam, South Fork Boise River (BR)
Cascade Dam, North Fork Payette River (BR)
Dworshak Dam, North Fork Clearwater River (CE)
Hell's Canyon Dam, Middle Snake River (FERC)
Lucky Peak Dam, Boise River (CE)
Minidoka Dam, Snake River (BR)
Palisades Dam, Snake River (BR)

OREGON

Clearwater Dams No. 1 and 2, Clearwater River (FERC)
Fall Creek Dam, Fall Creek (CE)
Foster Dam, South Santiam River (CE)
Lemolo Dams No. 1 and 2, North Umpqua River (FERC)
Mason Dam, Powder River (BR)
Prineville Dam, Crooked River (BR)
Scoggins Dam, Scoggins Creek (BR)

WASHINGTON

Aberdeen Diversion Dam, Wynoochee River (CE)
Ice Harbor Dam, Snake River (CE)
Palmer Dam, Okanogan River (BR)
Roza Diversion Dam, Yakima River (BR)
Wynoochee Dam, Wynoochee River (CE)

FWS Region 2

ARIZONA

Alamo Dam, Bill Williams River (CE)
Glen Canyon Dam, Colorado River (BR)
Parker Division, Colorado River (BR)
TAT Momolikot Dam, Santa Rosa Wash (BIA)
Yuma Division, Colorado River (BR)

NEW MEXICO

Abiquiu Dam, Rio Chama (CE)
Cochiti Dam, Rio Grande (CE)
Navajo Dam, San Juan River (BR)
Navajo Indian Irrigation Projects, San Juan River (BIA)

OKLAHOMA

Arbuckle Dam, Rock Creek (BR)
Broken Bow Dam, Mountain Fork River (CE)
Brushy–Peaceable Creeks Watershed Project (SCS)
Copan Dam, North Canadian River (CE)
Eufaula Dam, Canadian River (CE)
Fort Gibson Dam, Grand River (CE)
Kickapoo Nations Watershed Project, Deep Fork River (SCS)
Mountain Park Dam, Otter Creek (BR)
Optima Dam, Canadian River (CE)
Reach III Segment, Washita River Watershed Project (SCS)
Robert S. Kerr Lock and Dam, Arkansas River (CE)
Upper Red Rock Creek Watershed Project (SCS)

TEXAS

Belton Dam, Leon River (CE)
Benbrook Dam, Clear Fork Trinity River (CE)
Canyon Dam, Guadalupe River (CE)
East Bay Bayou Watershed Project (SCS)
Palmetto Bend Dam, Lavaca and Navidad Rivers (BR)
Pat Mayse Dam, Sanders Creek (CE)
Sam Rayburn Dam, Angelina River (CE)
Somerville Dam, Yegua Creek (CE)
Town Bluff Dam, Neches River (CE)

FWS Region 6

COLORADO

Blanco Diversion Dam, Rio Blanco (BR)
Jackson Gulch Dam, West Mancos River (BR)
Lemon Dam, Florida River (BR)
Oso Diversion Dam, Navajo River (BR)
Pueblo Dam, Arkansas River (BR)

Ruedi Dam, Fryingpan River (BR)
Sugarloaf Dam, Arkansas River (BR)

IOWA

Rathbun Dam, Chariton River (CE)

KANSAS

Glen Elder Dam, Solomon River (BR)
Kirwin Dam, North Fork Solomon River (BR)
Lovewell Dam, White Rock Creek (BR)
Wilson Dam, Saline River (CE)

MISSOURI

Bear Creek Watershed Project (SCS)

MONTANA

Beaver Creek Watershed Project (SCS)
Clark Canyon Dam, Beaverhead River (BR)
Libby Dam, Kootenai River (CE)
Tiber Dam, Marias River (BR)
Yellowtail Dam, Big Horn River (BR)

NEBRASKA

Merritt Dam, Snake River (BR)
Trenton Dam, Republican River (BR)

NORTH DAKOTA

Baldhill Dam, Sheyenne River (CE)

SOUTH DAKOTA

Angostura Dam, Cheyenne River (BR)
Big Bend Dam, Missouri River (CE)
Cold Brook Dam, Cold Brook (CE)

UTAH

Flaming Gorge Dam, Green River (BR)
Joe's Valley Dam, Seely Creek (BR)

WYOMING

Boysen Dam, Wind River (BR)
Fontenelle Dam, Green River (BR)
Gray Reef Dam, North Platte River (BR)
Meeks Cabin Dam, Black's Fork River (BR)

List of Handbook Reviewers

Agency Abbreviations: U.S. Bureau of Reclamation (BR); U.S. Army Corps of Engineers (CE); Federal Energy Regulatory Commission (FERC), formerly Federal Power Commission (FPC); U.S. Soil Conservation Service (SCS); U.S. Bureau of Indian Affairs (BIA).

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Norm Behrens, Portland (Oregon Fish & Wildlife)
Chuck Chambers, Olympia (FWS)
Bob Cleary, Portland (FWS)
John Gill, Portland (CE)
Terry Holubetz, Boise (Idaho Fish and Game)
Joe Kathrein, Albuquerque (FWS)
Jerry Leach, San Francisco (FERC)
Paget Leh, San Francisco (CE)
Ed Mains, Portland (CE)
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FWS Region 2

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Tom Cloud, Ft. Worth (FWS)
Sten Freeland, Boulder City, NV (BR)
Dean Johanson, Boulder City, NV (BR)
Joe Kathrein, Albuquerque (FWS)
Howard Lieberman, San Francisco (CE)
Warren McNall, Santa Fe (New Mexico Game & Fish)
Richard Morgan, Phoenix (FWS)
Bill Muller, Albuquerque (CE)
William Nailon, Dallas (CE)

Dale Pierce, Los Angeles (CE)
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Collaboration in study design and funding for handbook design and production by the Division of Planning and Technical Services, Engineering and Research Center, U.S. Bureau of Reclamation.

16. Abstract (Limit: 200 words)

The handbook is a guide for selecting more effective measures to recommend and negotiate among administrators, biologists and engineers of fish and game and construction agencies. The guide is based primarily on measures shown to be effective in the past at a representative selection of 90 dam and reservoir projects in 19 western states. The major effort in preparing the guide was devoted to investigation into the historical success of approximately 286 individual improvement measures. Secondarily, the guide presents measures believed to be potentially effective by investigators involved in current research or authors of recent literature. The measures considered generally involved structural and operational features as well as direct habitat modification and population control. For each class of habitat and population improvement measures which are available and considered feasible for incorporation into project design, the handbook presents selected engineering features, hydrological and biological effects, relative costs, and references. The guide classifies 60 categories of habitat and population measures into two parts and 11 divisions.

17. Document Analysis a. Descriptors

fish
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habitat improvement
population improvement
water resources
dams
reservoirs
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reservoir flood basins
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wildlife enhancement

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Fish and Wildlife Service

U.S. Department of the Interior