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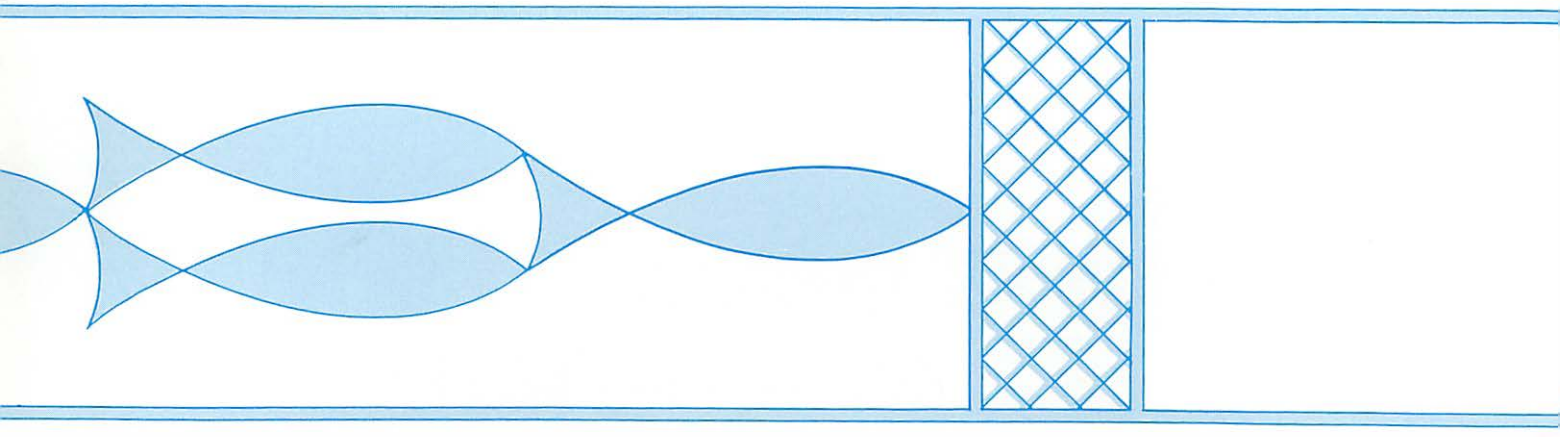
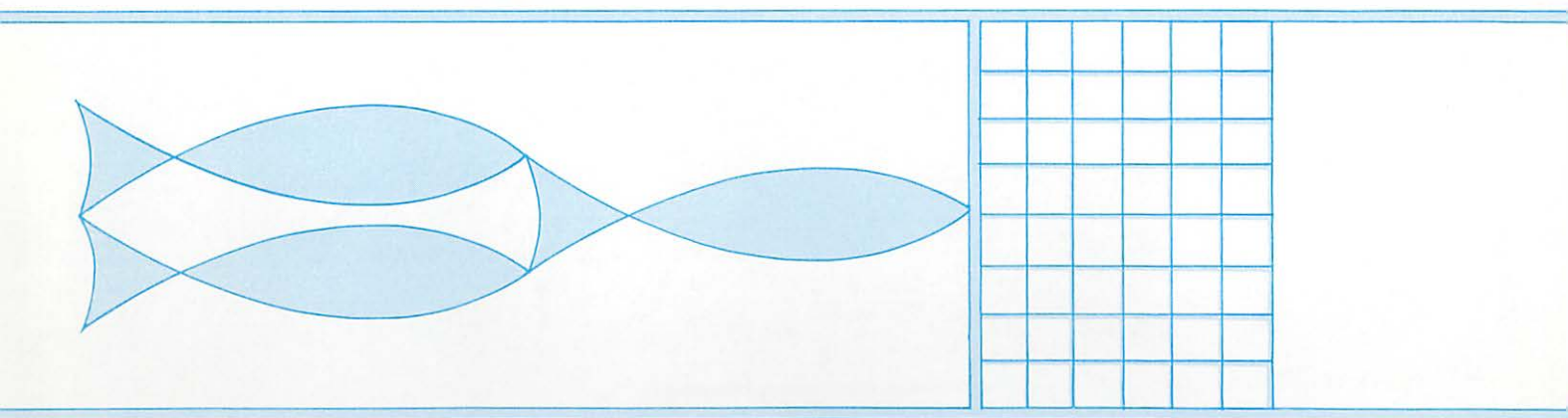
McClusky Canal Fish Screen Development and Verification



DECEMBER 1982
UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

McClusky Canal Fish Screening Facility



Development and Verification

DECEMBER 1982
UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

United States Department of the Interior

BUREAU OF RECLAMATION
Upper Missouri Region
P.O. Box 2553
Billings, Montana 59103

IN REPLY
REFER TO: UM-200

December 7, 1982

Memorandum

To: Regional Director, Billings, Montana

From: Chairman, McClusky Canal Fish Screen Facility Task Force

Subject: Fish Screen Task Force Report, Garrison Diversion Unit, North Dakota

The Fish Screen Task Force, appointed in December 1977, has completed the research and investigation necessary to prepare a report of its findings. The enclosed report and appendices document the research and testing conducted by the task force. It includes our findings, conclusions, recommendations, and feasibility designs for a fish screen structure on the McClusky Canal. We have concluded that a fish screen facility which will effectively remove all fish, fish eggs, and larvae of concern to Canada before the water flows into Lonetree Reservoir can be constructed and operated in the McClusky Canal. However, the current status of a fish screen structure or structures in Garrison Diversion Unit water conveyance facilities is uncertain.

During meetings held in early 1982 with representatives of the Department of the Interior and the State of North Dakota, North Dakota representatives advised they did not support construction of the fish screen because of Canada's reluctance to recognize the reliability of the facility. In the October 1982 diplomatic note from the United States to Canada, the United States advised it is considering deferral of construction of the fish screen if the proposal for phased development of Garrison Diversion Unit is adopted. Under Phase I of the proposal, Missouri River water would not be transferred into the Canadian drainage.

Although it appears a fish screen may not be constructed in the McClusky Canal, the technology for construction and operation of a screen facility has now been developed. We feel there are potential applications for this type of facility on other water resource developments or perhaps on the Garrison Diversion Unit during later construction phases. A screen facility provides an option not previously available to water resource managers, that is, delivering water to an area without also introducing unwanted fish species.

The fish screen development for the McClusky Canal is expensive to construct and operate because of its physical size and distance from Audubon Lake. Fish screening facilities would be more cost effective if they were located at the water source. This would eliminate water regulation difficulties should the screens become totally plugged and result in much smaller facilities.

The task force considers its assignment completed. Limited testing and data gathering activities will continue at the field test facility. This has become routine and the Project Manager, Bismarck, can supervise this activity. The task force should be disbanded unless design of the screen is initiated. Then the task force should be assigned an overview responsibility for design, construction, and startup operation activities.

James M. Verzuh

FISH SCREEN TASK FORCE REPORT
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CONCLUSIONS AND RECOMMENDATIONS

In December 1977, a six-member multidiscipline task force was appointed from the Bureau of Reclamation to determine the effectiveness of the McClusky Canal Fish Screening Facility as a barrier to fish, fish eggs, and fish larvae. They have completed 4 years of extensive research, development, and testing work in the laboratory, in addition to approximately 8 months of field testing (over three separate field seasons) at the fish screen test facility near Turtle Lake, North Dakota. The task force feels they have collected sufficient data to prepare this report on their findings and to make specific recommendations regarding the fish screen.

Based on data presented in this report, the task force has made the following conclusions and recommendations.

Conclusions

1. A 70-mesh screen will stop passage of fish, fish eggs, and larvae of fish species found in the Missouri River (upstream from the Garrison Dam) that the Canadian government has determined to be objectionable.

2. Rectangular pneumatic seals effectively seal the screen frames to the screen structure. Pneumatic seals compress against the supporting framework and easily accommodate any minor structural shifting or structural irregularities in the metal work.

3. A fish screen facility, using 70-mesh screen, can be constructed and operated in the McClusky Canal effectively removing all undesirable fish, fish eggs, and larvae from the canal water before it flows into Lonetree Reservoir. The structure (described in Chapter Four) could be designed for an initial capacity of 1,000 ft^3/s with provisions for future additional capacity. The structure would cost approximately $40 million (in 1981 dollars) with an annual O&M cost of $1.3 million.

4. It is infeasible to modify the existing McClusky Canal Fish Screen facility to accomplish the objective of effectively stopping fish passage.

5. All recommendations concerning the fish screen made by the International Garrison Diversion Study Board and the Ontario Department of Fisheries and Environment review have been followed to a logical conclusion (see Figure 1).

6. Current technology does not permit monitoring canal flows to detect screen passsage of fish eggs or larvae. The integrity of the fish screen can be maintained by using a redundant screen design (i.e., two sets of screens) coupled with extensive use of automated monitoring and control devices along with rigid quality control and operation programs.

Recommendations

1. After the 1982 field testing is complete, feasibility designs on the McClusky Canal Fish Screen should be reviewed for cost effectiveness.

2. The task force should be given overview responsibility for final designs, construction, and development of operating criteria for fish screen facilities.

Figure 1

MATRIX SHOWING RELATIONSHIP BETWEEN IJC RELATED FISH SCREEN RECOMMENDATIONS AND TASK FORCE FINDINGS

Recommendations	Agree	Part. Agree	Disagree	Task Force Findings
IJC Study Board:				
4.a. Use 60-mesh screen		X		Laboratory test results indicate a 70-mesh screen is required.
4.b. Continuous lower screen seal with screen removal possible only after complete structure shutdown.		X		With the six-bay modular design on proposed structure, screen panels could be removed by shutting down one bay. Continuous screens were found to be infeasible.
4.c. Provide backwash system to clean screens.	X			Field testing demonstrated a cleaning system was required for 70-mesh screen. A backwash spray system effectively cleaned the screens.
4.d. Provide automatic backwash and emergency shutdown control.	X			Automatic control techniques were successfully used under field conditions and will be incorporated in the fish screen design.
4.e. Plug auxiliary screens and pump all water back up stream.	X			Auxiliary screens are not included in the proposed facility.
4.f. Develop and verify procedures prior to placing McClusky Canal fish screen in operation.	X			Operation and maintenance procedures will be developed based on results of field test facility operations.
4.g. Install an upstream traveling screen.			X	Preliminary results from test facility indicate a traveling prescreen is not effective in removing small debris. A traveling trash rack will be used to remove coarse debris.
4.h. The structure be operated by the USBR.	X			The structure will be operated by the USBR.

Figure 1

MATRIX SHOWING RELATIONSHIP BETWEEN IJC RELATED FISH SCREEN RECOMMENDATIONS AND TASK FORCE FINDINGS
(CONTINUED)

Recommendations	Agree	Part. Agree	Disagree	Task Force Findings
IJC Study Board: (cont.)				
5. Conduct full-scale test of structure well in advance of irrigation operation.		X		Most of the testing suggested in this recommendation was accomplished at the field test facility. Full-scale testing at the McClusky Canal structure will be limited to advance "shake-down runs" prior to filling Lonetree Reservoir and a rigorous evaluation of operation and maintenance procedures.
Ontario Dept. of Fisheries and Environmental Review:				
I.a. Test a full-size sectional model of the fish screen.	X			The field test facility contains four full-size screen panels and (on a smaller scale) operating conditions at the McClusky Canal fish screen were simulated.
I.b. Conduct laboratory testing on screen hydraulic capacities, screen wear and fatigue, siltation, icing, cleaning, etc.	X			An extensive laboratory research and testing program was conducted. In most cases, laboratory results were verified by field testing.
II. Support system beneath screens be designed to support combined debris, human, and hydraulic head load.	X			The support system is designed for maximum loading which would occur if the screen bays ever "flooded." Field tests have verified the design.

Figure 1

MATRIX SHOWING RELATIONSHIP BETWEEN IJC RELATED FISH SCREEN RECOMMENDATIONS AND TASK FORCE FINDINGS
(CONTINUED)

Recommendations	Agree	Part. Agree	Disagree	Task Force Findings
Ontario Dept. of Fisheries and Environmental Review:				
III. Construct a low-level dike so spillway flows cannot bypass structure and construct a security fence around the structure.	X			The proposed facility will be constructed so water cannot bypass the structure during either normal or emergency conditions. Security measures at the facility will be implemented to prevent both intentional or inadvertent sabotage of the facility.
IV. Construct a low-level weir in the outlet channel to contain spillage during shutdown.	X			The proposed facility contains weirs with pump-down capabilities upstream of the screens so there will be no spillage during shutdown for screen maintenance.
V. Plug ports on the upper level at the downstream end of the structure.	X			The proposed facility does not contain these ports.

INTRODUCTION

Background

The Garrison Diversion Unit (GDU) in North Dakota is one of the developments in the Pick-Sloan Missouri Basin Program authorized by the Flood Control Act of 1944. GDU provides irrigation development, fish and wildlife conservation and enhancement, recreation development, water for municipal and industrial purposes, and flood control in several basins in the State.

The first detailed plans for GDU in 1957 involved developing 1,007,000 irrigated acres.[1/] Later, this plan was scaled down to an initial development of 250,000 acres, a report on the first stage being completed in 1959.[2/] A Definite Plan Report, written in 1962, was revised and reissued in 1965, which served as the basis for reauthorization of the unit by the Congress in that year (see Map 769-603-14400).

The Fish and Wildlife Service (FWS) also studied the GDU and issued companion reports on mitigation and enhancement of fish and wildlife resources.

The National Environmental Policy Act (1969) required studies of the environmental aspects of GDU. Several studies, including two environmental statements, have been completed on the project.

A final environmental statement (INT FES 74-3) covering the principal supply works in detail and the cumulative overall impacts of the 250,000-acre initial stage was filed with the Council on Environmental Quality (CEQ) January 10, 1974. A supplement to this statement answered other questions the FWS raised about fish and wildlife aspects of the statement. The other statement, a final comprehensive supplementary environmental statement (INT FES 79-7) was filed on March 7, 1979. This statement presented seven plans ranging from the authorized plan down to no development. Detailed descriptions of the authorized plan, as well as optional plans, can be found in these documents.

In summary, the Garrison Diversion Unit has Missouri River water being pumped from Lake Sakakawea by the Snake Creek Pumping Plant into Audubon Lake. Audubon Lake (a subimpoundment of Lake Sakakawea) serves as the supply reservoir for the 74-mile long McClusky Canal, where water flows by gravity to Lonetree Reservoir for re-regulation.

From Lonetree Reservoir, water would be diverted to project areas in the basins of the Souris River, Sheyenne River, Wild Rice River, James River, and Devils Lake Chain. The first three rivers drain into the Hudson Bay drainage so some of the Missouri River water diverted to these river basins would eventually flow into Canada.

1/House Document No. 472 and Senate Document No. 247, 78th Cong., 2d Sess., (1944)

2/House Document No. 325, Garrison Diversion Unit, 86th Cong., 2d Sess., February 4, 1960).

Because of Canadian concerns, development of the 250,000-acre plan in stages is being considered. North Dakota officials have proposed to initially develop areas in the authorized plan that do not drain into Hudson Bay, including about 85,000 acres of irrigation in the James River and the Devils Lake Basin in Phase I. All direct connections for water transfer to Canada would be eliminated from Phase I. Municipal and industrial water for the Sheyenne River (which flows to the Red River and eventually to Canada) would be discharged through a filter.

Construction of Garrison began in 1967. Since 1977, however, little has been completed because of legal actions against the project. Still, principal supply works - the Snake Creek Pumping Plant and McClusky Canal and one (of two) dams for Lonetree Reservoir - have been built. Twenty-nine percent (by length) of the GDU supply system has been constructed and 63 percent of the rights-of-way needed for project water supply and drainage features have been acquired, including most of that needed for the Lonetree Reservoir (INT FES 79-7, Vol. 2, Tables 2 and 3).

A fish screen, designed to prevent certain fish, fish eggs, and larvae from being transferred from the Missouri River into Lonetree Reservoir, has been partially completed on the McClusky Canal. Screens, trashracks, debris-handling, and other miscellaneous equipment were not installed in the structure.

Preliminary Fish Screen Design

During the planning and early construction phases, concerns were raised that undesirable fish species might be transferred from the Missouri River to the Hudson Bay drainages via GDU. Some governmental and private agencies in the Canadian Province of Manitoba felt that diverted Missouri River water would transport undesirable fish species, fish disease, and fish parasites into the Hudson Bay drainage, adversely affecting sport and commercial fisheries in Manitoba. Possible impacts included: (1) direct competition with native fish, (2) population irruptions of the introduced fish, (3) reduction in populations of native fish in Lake Winnipeg and other waters, and (4) predation by the introduced species on native fish. Four fish species that could be transferred with a possible high negative impact on Manitoba waters were identified: rainbow smelt (Osmerus mordax), Utah chub (Gila atraria), gizzard shad (Dorosoma cepedianum), and common carp (Cyprinus carpio). In addition to impacts on other fish it was also feared that carp would reduce the value of some areas as feeding and nesting grounds for waterfowl in both the United States and Canada. Because all life history developmental stages of the undesirable fish species would be present during some part of the project operating season, and because they could not be controlled discriminately, the Bureau of Reclamation (BR) decided to develop a fish control system to prevent downstream migration of all adult fish, fish larvae, and fish eggs.

A study team was organized at the Engineering and Research (E&R) Center of the Bureau of Reclamation to determine and evaluate methods for controlling these fish. Control techniques considered were poisons, violent hydraulic action, electrocution, ultrasonics, ozone, and extremely high or low pressures. All were found inadequate because of safety considerations to other wildlife species or humans, cost, or undependability. Various screening or filtering methods were then considered and two alternatives looked promising. A rapid sand filter

INDEX MAP

EXPLANATION

AUTHORIZED FEATURES

- AREA BENEFITED BY PROJECT WORKS
- CANAL OR LATERAL
- PUMPING PLANT
- SIPHON
- PROJECT DRAIN
- DAM AND RESERVOIR
- FISH AND WILDLIFE DEVELOPMENT AREA (ORIGINAL PLAN)
- NATIONAL PARK SERVICE RECREATION DEVELOPMENT AREA

EXISTING FEATURES

- DAM AND RESERVOIR
- TRANSMISSION LINE (USBR)
- SUBSTATION (USBR)
- PUBLIC POWER PLANT (STEAM NON-FEDERAL)
- U.S. GOVERNMENT HYDRO POWER PLANT (USCE)
- GARRISON CONSERVANCY DISTRICT BOUNDARY
- NATIONAL PARK SERVICE RECREATION DEVELOPMENT AREA

UNITED STATES
DEPARTMENT OF THE INTERIOR
CECIL D. ANDRUS, SECRETARY

BUREAU OF RECLAMATION
R. KEITH HIGGINSON, COMMISSIONER

PICK-SLOAN MISSOURI BASIN PROGRAM

GARRISON DIVERSION UNIT

INITIAL STAGE - 250,000 ACRES
NORTH DAKOTA

MAP NO. 769-603-14400

SCALE OF MILES
SCALE OF KILOMETERS

SEPTEMBER 1977

GPO 842-564

FACTUAL DATA ON THE INITIAL STAGE OF GARRISON DIVERSION UNIT

WATER SUPPLY

The water supply will be obtained from Lake Sakakawea formed by Garrison Dam on the Missouri River. Storage capacity of this reservoir is 23,000,000 acre-feet at maximum normal operating pool elevation of 1850. Average annual runoff to Lake Sakakawea is 17,600,000 acre-feet from a drainage area of 181,000 square miles. Quality of water in Lake Sakakawea is good, containing an average of about 435 parts per million total dissolved solids.

FEATURES OF THE UNIT PLAN

The principal supply works for the initial stage consist of the Snake Creek Pumping Plant with a capacity of 2,050 cubic feet per second; Audubon Lake, 396,000 acre-feet (constructed); McClusky Canal, with a capacity of 1,950 cubic feet per second and 74 miles long; and Lonetree Reservoir, with 280,000 acre-feet of conservation storage. Other irrigation works included in the initial stage are 907 miles of canals and laterals, three regulating reservoirs (one of which, Jamestown Reservoir, is constructed), 75 pumping plants, 2,050 miles of drains and electrical facilities for pumping plants.

IRRIGATION PLAN

Water will be pumped by Snake Creek Pumping Plant into Audubon Lake. Pumping head will range from 0 to 75 feet, depending upon the fluctuations of storage levels in Lake Sakakawea between elevations 1775 and 1850 above mean sea level. From Audubon Lake the water will flow through the 74-mile-long McClusky Canal to Lonetree Reservoir. At Lonetree Reservoir water can be diverted by gravity into three separate river basins in which the irrigable lands are located. The water will be distributed to the irrigable lands by systems of canals, laterals, pipe distribution systems, and pumping plants. Most of the irrigation will be accomplished with sprinkler equipment.

NUMBER OF IRRIGABLE ACRES

It is planned to develop 250,000 acres for irrigation. About 20 years are estimated for the period of construction and development. However, rate of development may vary according to the interest of the landowners and funds allocated by the Congress for construction.

CHARACTER OF SOIL IN IRRIGABLE AREA

Irrigable lands on the Garrison Diversion Unit are characterized by water-reworked soils of glacial origin which are located in outwash fans, outwash channels, and glacial lake beds. They have good to excellent drainability and are generally free of stone, excess alkalinity, and salinity.

ALTITUDE OF THE UNIT

The altitude of unit lands ranges from 1,800 to 1,300 feet above sea level.

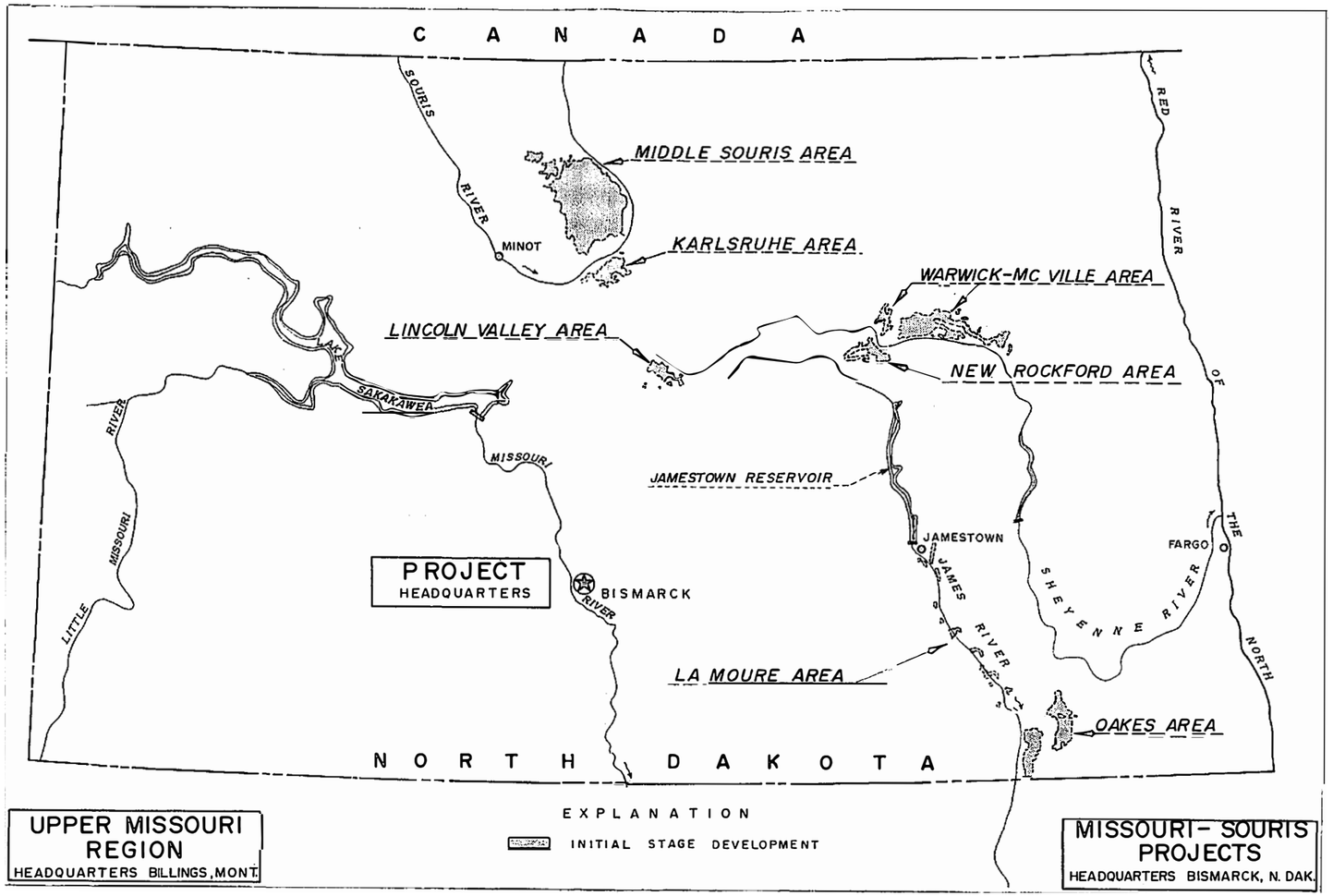
CLIMATE

Average annual rainfall ranges from 16 inches in the Souris Area to 19 inches in the Oakes Area. The average annual temperature is 40°F. Temperatures have ranged from -49°F. to 116°F. The irrigation season is expected to extend from May 1 until about October 1, or approximately 5 months. The average frost-free growing period is about 135 days.

The average annual diversion requirement is 2.64 acre-feet per acre. Average farm delivery requirement is 1.47 acre-feet per acre.

PRINCIPAL PRODUCTS

Under present dryland farming, the principal agricultural products are wheat and other small grains, and beef cattle. Under irrigation, principal products are expected to be livestock feeds grown for the production and fattening of livestock. Improtant feed crops will be alfalfa, rotation pasture, corn silage, and small grains. It is expected that high value cash crops such as sugar beets, soybeans, and potatoes will be produced.



MARKETS

Marketing facilities are generally adequate to handle the increased production from irrigation. Changes are not expected in livestock marketing that now occurs through sales rings, contract buyers and meat processing centers. Specialty crops such as vegetables and other truck garden crops will find markets available at urban centers and through canneries that can be expected to be located in the area. Grain marketing will continue through the present normal channels of local elevators and other grain marketing organizations.

DEVILS LAKE RESTORATION

An integral part of the Garrison Diversion Unit will be the restoration of Devils Lake and other lakes of the Devils Lake Chain. Missouri River water will be delivered to the lakes from project facilities to stabilize the level of the lakes, freshen their water from present saline conditions, and provide valuable recreation opportunity and fish and wildlife enhancement.

RECREATION, FISH AND WILDLIFE

Nine recreation areas are planned in conjunction with the 250,000-acre initial stage. The Jamestown recreation and fish and wildlife development is now constructed. The other areas are located principally at lakes and reservoirs which are affected or can be supplied from project works and some are new areas.

Thirty-six major areas and a larger number of small areas are planned for development for fish and wildlife purposes.

MUNICIPAL AND INDUSTRIAL WATER

Offpeak delivery of water from project works to 15 municipalities and several unidentified industrial water users is proposed in the plan for initial development. Some municipal and industrial water users may construct conveyance works to receive water from the irrigation system while others, such as Minot, will be constructed by the Federal government.

ADDITIONAL INFORMATION

Address inquiries to:

Regional Director
Bureau of Reclamation
Upper Missouri Region
P.O. Box 2553
Billings, Montana 59103

or

Project Manager
Bureau of Reclamation
Missouri-Souris Projects Office
P.O. Box 1017
Bismarck, North Dakota 58501

would easily achieve the desired goal; but, preliminary evaluation indicated a sand filter capable of handling the maximum canal discharge of 1,950 ft^3/s would have a prohibitive cost. A fixed horizontal screen (sloped slightly downward) was also thought to be effective. Screen mesh would need to be fine enough to meet the filtration requirements and the seals around the fixed screens must be tight enough so that no flow would pass around the screens. Field experience indicated that with the screen weave so fine (24- to 80-mesh or wires per inch), the screen would have a slick, fabric-like texture which would give it good self-cleaning characteristics. Openings in the screen are generally small enough that materials will not cling to individual wires.

Fixed horizontal screens had not been previously used to filter fish eggs and larvae, although they had been used for filtering weed seeds from irrigation water, collecting biological samples from small streams, and filtering industrial intake water. These systems were relatively small, however, with capacities less than 100 ft^3/s. A major effort was required to develop a design that would meet the needs of GDU.

An initial screen design was developed, using a full-scale sectional model built at the E&R Center in Denver, Colorado. This model tested discharge, dimensional parameters, and self-cleaning characteristics of the screen.[1/] The design used a 40-mesh screen supported by a 2-mesh screen, with both attached to a metal framework by a clamp bar arrangement. Each screen frame was sealed into the structure by rubber compression seals compressed with a series of bolts.

From information gained from the model, a fish screen facility was designed and partially constructed on the McClusky Canal in 1977. The structure was built, but the screens and mechanical equipment were not installed.

International Joint Commission Review

There was limited exchange of technical information on the Garrison Diversion Unit between Canada and the United States during the late 1950's and early 1960's. Information was provided by BR planning reports and through various International Joint Commission (IJC) activities in the Souris, Red, and Pembina River basins. When GDU was authorized by Congress in 1965, Canadian concerns about possible negative effects on their country intensified. Several diplomatic notes were exchanged between the two Governments on the subject while GDU construction proceeded.

In 1974, several meetings of officials from both countries were held to discuss the Canadian concerns. At one meeting in January 1975, the two sides agreed to recommend that the governments appoint an appropriate group to make a joint examination of certain aspects of GDU to insure that the provisions of Article IV of the 1909 Boundary Waters Treaty were honored.

On October 22, 1975, Canada and the United States referred to the IJC the matter of potential pollution of boundary waters by the GDU. The reference asked the Commission to examine and report on:

1/Johnson 1975.

1. The present state of water quality in the Souris and Red Rivers, their tributaries, and other downstream waters, with particular reference to the Canadian portions which might be affected by the GDU;

2. Present and reasonably anticipated uses of these waters;

3. Effects of present water quality on these uses;

4. Impacts on the quality and quantity of these waters resulting from completion and operation of the GDU;

5. Impacts of the completion and operation of the GDU on present uses and on reasonably anticipated uses of these waters; and

6. Impact on commercial and recreational fisheries in Manitoba of the possible introduction by the GDU of foreign fish species, fish diseases, and fish parasites.

IJC Study Board Recommendations

The IJC established an International Garrison Diversion Study Board (IGDSB) to investigate and advise on all matters which the Commission would have to consider in its report. The 12 members and two secretaries of this Board were from the following organizations:

United States	Canada
U.S Environmental Protection Agency	Economic Council of Canada
U.S. Department of Agriculture	Agriculture Canada
U.S. Department of the Army	Environment Canada
U.S. Department of the Interior	Manitoba Department of Mines, Resources, and Environmental Management
Minnesota Pollution Control Agency	
North Dakota State University	

In a report dated October 1976, the IGDSB presented its findings to the IJC. The report contained two recommendations regarding the fish screen:

"4. To Reduce the Possibility of Transfer of Fish, Fish Eggs, Fish Larvae and Fish Parasites to the Portion of the McClusky Canal in the Hudson Bay Watershed, the fish screen structure presently under construction be completed, the following modifications made and procedures developed:

'a. Screens of 60-mesh be installed in place of the planned 40-mesh screens.

'b. The lower screen be continuous and sealed in place along both sides and both ends in such a way that it can be removed only after complete shutdown of the structure.

'c. Provision be made for routine cleaning of the screens by back-washing from underneath with moving jets of screened water.

'd. Sensors be installed near the lower edge of the main screens to indicate when screens are becoming clogged. The sensors be connected to the upstream control gates so that when flow through the lower edge of the screens becomes substantial the gates will automatically close.

'e. The wells with the auxiliary screens be plugged and provision made to ensure that all water by-passing the main screens is pumped back upstream of the structure.

'f. Procedures be developed and verified prior to placing the structure in operation, to ensure proper inspection of the screens, handling of debris and detritus, cleaning of screens, screen removal, dewatering of the structure and shutdown.

'g. A suitable upstream travelling screen be installed prior to placing the structure in operation.

'h. The operation and maintenance of the structure be performed by the USBR.

'5. To ensure that All Aspects of the Design and Operation of the McClusky Canal Fish Screen Structure Have Been Fully and Satisfactorily Developed, a full scale test of the structure be undertaken well in advance of the beginning of irrigation operations. This test must fully evaluate the maintenance, cleaning, shutdown, detritus handling, dewatering and inspection procedures. Particular attention must be paid to the emergency shutdown and dewatering procedures to determine the advisability and necessity of installing an automatic, quick-closing gate structure immediately upstream of the fish screen. During this testing program careful and thorough biological monitoring is to take place both upstream and downstream of the structure to determine whether or not any foreign fish, fish larvae or fish eggs are present. If these are detected downstream of the structure, the test shall be immediately stopped until the inadequacies in the structure have been located and eliminated. All fish life in any water which has passed through the structure shall be immediately irradicated [sic]."

A Review by the Ontario Department of Fisheries and Environment

After this report was released, the Ontario Department of Fisheries and Environment (DFE) appointed a Garrison Fish Screening review group.

The main purpose of the group was to provide an engineering expertise to review and supplement the IGDSB findings concerning the proposed McClusky Canal Fish Screening structure. Members individually had many years of direct association with both the theory and application of such projects. The review group consisted of:

R. L. Dryden, P. Eng. (Chairman)
Fisheries & Marine Service
Dept. of Fisheries & the Environment
Ottawa, Ontario

R. J. Finnigan, P. Eng.
Fisheries & Marine Service
Dept. of Fisheries & the Environment
Vancouver, British Columbia

P. Ryan, P. Eng.
Fisheries and Marine Service
Dept. of Fisheries & the Environment
Vancouver, British Columbia

K. H. Kupka, P. Eng.
Environmental Protection Service
Dept. of Fisheries & the Environment
Vancouver, British Columbia

F. J. Andrews, P. Eng.
Int'l Pacific Salmon Fisheries Com.
Vancouver, British Columbia

M. C. Bell, P. Eng.
Consultant, Univ. of Washington
Seattle, Washington

The review group submitted a report on March 21, 1977, to the IJC. The group essentially agreed with the recommendations; but recommended additional testing to support the IGDSB recommendations. The review group agreed field testing was needed, but did not feel it should be done at the existing McClusky Canal Fish Screening Structure.

The review group's report to the IJC also contained the following additional suggestions:

"Group Recommendation 1 - Testing

The uniqueness of the McClusky Canal screening concept both in design and objective (100 percent efficiency) necessitates the implementation of a thorough and long-term testing program. Both field and laboratory testing is [sic] is recommended.

'a. Field/Prototype Tests:

'The Review Group concurs with the Engineering Committee findings that it is 'imperative that prior to being placed in service, operational modelling should be carried out to provide data for the final design details and the development of O&M procedures. Such a model should consist of a full-size sectional replica of the prototype, perhaps several screen panels wide...'. The Review Group, however, considers it essential to have at least two panels, in order to evaluate and test the very important centre-joint between adjacent panels. Both upper and lower main screens should also be included. The lower screen should be continuous with permanent perimeter seals. The model must be capable of duplicating the full range of hydraulic conditions which will be encountered during irrigation implementation.

'The Review Group is convinced that the screen structure presently in existence does not have the flexibility for a comprehensive testing program. In addition, testing of screens within this structure could potentially result in an accidental transfer of biota from one basin to another. For these reasons, it is suggested that an independent hydraulic modelling station be provided; preferably in or very near the McClusky Canal and on the Missouri side of the drainage divide. Testing should continue for the equivalent of two irrigation seasons. The initial year would be used to study and refine the design and operational possibilities. The second year would be used to evaluate and develop the selected procedures. A complementary biological monitoring program should be required to ensure the effectiveness of procedures.

'Some of the main design and operational factors to be tested would include:

'(1) Clogging frequency and severity of different mesh screens;

'(2) Clogging prevention and cleaning methods; methods tested would include (but not be limited to) manual brushing, mobile mechanical brushes, water jets, self-cleaning, or combinations thereof;

'(3) Sensor design and placement;

'(4) Leakage of panel joints and perimeter seals as a result of vibration, age, temperature cycling, etc.;

'(5) Frequency and effectiveness of visual inspections;

'(6) Flow hydraulics over and through screens;

'(7) Operating procedures for screen removal, maintenance and repair, detritus removal, dewatering of structure, irradication of biota within the structure, etc.

'b. Laboratory Tests

'Screen testing facilities already exist in the United States (e.g., Hood Testing Facility, near Sacramento, California). Some of the factors which should be evaluated under laboratory conditions include:

'(1) Hydraulic capacities of different mesh size;

'(2) Accelerated wear of screen material resulting from continual abrasion and electrolysis;

'(3) Vibration and metal fatigue;

'(4) Siltation and sediment transport calculations to determine the potential for stream bed level drainage pipes (as presently proposed) becoming inoperative;

'(5) Icing problems;

'(6) Cleaning apparatus effectiveness

'Group Recommendation II - Structural Support System

'Although operating procedures should strongly discourage human traffic on screen surfaces, practical experience indicates that such occurrences are frequently unavoidable. Both routine and emergency maintenance and cleaning tasks will result in personnel walking on the screens. It is therefore recommended that the support systems beneath the screens be redesigned to support a combined debris, human, and hydraulic head load, in the event of a severe clogging and failure of shut-down systems.

'Group Recommendation III - Separation Dyke and Fence

'The present McClusky Canal Screening Structure is located on the Hudson Bay side of the drainage basin boundary. Any accidental spillage of water adjacent to the structure, during maintenance, cleaning, dewatering or debris removal, will tend to flow downstream to the Hudson Bay drainage basin. It is therefore recommended that a low-level dyke be constructed such that spillway flows cannot by-pass the screening structure. It is also recommended that the entire structure be fenced to prevent entry of unauthorized personnel.

'Group Recommendation IV - Provision of an Outlet Weir

'It is recommended that a low-level weir be constructed across the entire width of the discharge (or outlet) channel. When the screening structure is shut down and dewatered for screen repair or cleaning, there is a good likelihood that a small quantity of water will continue to splash or drip from the screens into the outlet channel. This likelihood will increase during patching or removal of the lower main screen. An outlet weir would contain this spillage and allow an opportunity for chemical irradication of biota prior to start-up.

'Group Recommendation V - Ports on Downstream End of Structure

'It is recommended that the ports on the upper level at the downstream end of the screening structure should be plugged. This will remove the temptation to discard debris through these openings."

IJC Recommendations

The IJC submitted their report to the Governments of Canada and the United States in 1977 regarding transboundary implications of the Garrison Diversion Unit. Their report contained two recommendations relating to the fish screen as follows:

"1. That because the "closed system" and the McClusky Canal fish screen cannot with any certainty prevent biota and disease transfers which would cause severe irreversible damage to the ecosystem and, in particular, to the commercial and sport fisheries in Canada, those portions of the Garrison Diversion Unit which could affect waters flowing into Canada not be built at this time. This is not intended to preclude construction of Lonetree Reservoir, subject to the conditions set forth in Chapter VIII.

'2. That, if and when the Governments of Canada and the United States agree that methods have been proven that will eliminate the risk of biota transfer, or if the question of biota transfer is agreed to be no longer a matter of concern, then the construction of that portion of the Garrison Diversion Unit which would affect waters flowing into Canada may be undertaken provided the following conditions are met:

'(a) Any agreed modifications or other measures required to resolve the interbasin transfer issue are incorporated into the Project."

Since the report was issued in 1977, the IJC has not been actively involved in GDU.

Fish Screen Task Force

The IGDSB conducted several in-depth studies on potential biota transfer and the McClusky Canal Fish Screen designed to prevent such occurrences. BR personnel were members on various IGDSB committees doing these studies and also provided information for special meetings with the IGDSB Engineering, Biology, and other committees. During formulation of the committee findings and subsequent reports by the IGDSB, DFE, and IJC, it became apparent that many questions about fish screen design, operation, and maintenance were still unanswered.

The Upper Missouri Regional Director of the Bureau of Reclamation appointed a Fish Screen Task Force to review the McClusky Canal Fish Screen in December 1977 in respect to the concerns of the Canadian Government. The task force consisted of the following people:

Mr. James M. Verzuh (Chairman)
Regional Engineer
Billings, Montana

Mr. Perry L. Johnson
Hydraulic Engineer
Hydraulics Branch
E&R Center, Denver, Colorado

Mr. James A. DeLapp
Head, Gates & Valves Section
Mechanical Branch
E&R Center, Denver, Colorado

LATER REPLACED BY:

Mr. Philip Nelson
Supervisory Mechanical Engineer
Mechanical Branch
E&R Center, Denver, Colorado

Mr. Danny L. King*
Chief, Hydraulics Branch
E&R Center, Denver, Colorado

Mr. Elwood Seaman
Environmental Specialist (Research)
Commissioner's Office
Washington, D.C.

LATER REPLACED BY:

Dr. Steve Grabowski
Research Fishery Biologist
Applied Sciences Branch
E&R Center, Denver, Colorado

Mr. John E. Knoll, Chief
Water and Land Operations Division
Bismarck, North Dakota

Mr. John G. Starbuck, Supervisor
Design Unit No. 1
Canal & Diversion Structure Section
Water Conveyance Branch
E&R Center, Denver, Colorado

Mr. Eric B. Soderquist**
Mechanical Engineer
Water and Land Operations Division
Bismarck, North Dakota

*Laboratory Testing Coordinator
**Field Testing Supervisor

The task force used expertise available in the BR supplemented by Fish and Wildlife Service personnel, outside research contracts, and consultants when necessary. However, the task force was not permitted to consult with Canadian scientists or officials. The following consultants were used to provide a critical review of task force investigations and findings:

Mr. Milo Bell
Consulting Engineer
Mukileteo, Washington

Mr. Dave Tomljanovich
Tennessee Valley Authority
Norris, Tennessee

Mr. Robert Pollock (Retired)
National Marine Fisheries Service
Portland, Oregon

Mr. C. Richard Weaver (Retired)
National Marine Fisheries Service
Portland, Oregon

Mr. Dale Henegar, Commissioner
(Former Chief of Fisheries)
N. D. State Game and Fish Department
Bismarck, North Dakota

During the early part of the investigation, the following personnel from the U.S. Fish and Wildlife Service participated as advisors to the task force:

Mr. Tom Jackson
Fishery Research Biologist
Denver Field Station
Columbia Nat'l Fisheries Research Lab.
Denver, Colorado

Mr. Lee Mills
Senior Staff Biologist
Fishery Management
Rocky Mountain Region
Denver, Colorado

The task force was to determine the effectiveness of the McClusky Canal Fish Screening Facility as a barrier to fish, fish eggs, and fish larvae. The task force was also to satisfy the concerns, conclusions, and recommendations of (a) the IGDSB, and (b) technical evaluation by the Panel of Fish Screen Experts, Department of Fisheries and Environment, Government of Canada.

To accomplish its objective, the task force divided the work into three basic steps. The first was to identify basic design criteria to be followed to prevent interbasin transfer by GDU facilities. These criteria were then developed through the second and third steps, the research and testing programs, both in the laboratory and in the field. The rest of this report discusses each of the three items, with a chapter describing feasibility designs and operation for the McClusky Canal Fish Screen.

FISH SCREEN DESIGN PARAMETERS

The task force was directed to determine the modifications necessary to make the existing fish screen an effective barrier to the downstream movement of undesirable fish, fish eggs, and fish larvae. Their investigation was not limited just to refining the existing structure. A literature search was conducted, and the previous work done at the E&R Center was reviewed. Operational techniques, sand filters, traveling screens, poisons, violent hydraulic action, electrocution, etc., were reconsidered and re-evaluated. As with the earlier studies, however, the task force concluded that a stationary screening system had the greatest potential of feasibly meeting the task force objective.

After the task force reaffirmed the stationary screening concept, the following general outline was used to guide the study effort:

I. Analysis of problem
   - A. Review initial USBR design
   - B. Analyze comments of others concerning facility
   - C. Literature search
     1. Verify problem fish species and acquire data on these species
     2. Update previous literature search on status of screening technology (design, problems, and degree of success)
   - D. Design screens and seals
   - E. Devise screen cleaning and replacement concepts
   - F. Determine method of canal shutdown (mathematical model of McClusky Canal operation)
     1. Radial gate at facility
     2. Wasteway
     3. Other
   - G. Determine methods of construction quality control to assure integrity of screen
   - H. Determine method to assure integrity of screen during operation

II. Research studies at E&R Center laboratory
   - A. Objectives
     1. Determine the effectiveness of various size screens to stop the passage of fertilized eggs, eyed eggs, sac fry, and swim-up fry under various hydraulic conditions
     2. Determine hydraulic characteristics of screen material selected
     3. Test effectiveness of seal design
     4. Determine the effect of debris on screen operation
     5. Verify screen cleaning system concept
     6. Provide information on debris handling procedures
     7. Augment design recommendations for field test facility and for field tests
   - B. Work tasks
     1. Design hydraulic lab model
     2. Develop testing plan
     3. Construct model
     4. Establish priority of species testing
     5. Acquire fish eggs and larvae
     6. Manage fish eggs and larvae in laboratory
     7. Measure size of eggs and larvae
     8. Conduct tests

III. Field evaluations
   - A. Field test facility (model)
     1. Objectives
        - a. Determine the effectiveness of the field test screening facility in preventing passage of fish eggs, larvae, fry, and adults
        - b. Field test self-cleaning concept (i.e., susceptibility to clogging)
        - c. Determine cleaning frequency of sloping screen
        - d. Quantify volume of detritus removed by screens
        - e. Determine susceptibility of screen to sustained growths (molds, algae, etc.)
        - f. Verify hydraulic capabilities of screen in field
        - g. Determine necessity of traveling prescreen
        - h. Provide information on handling and disposing of debris
        - i. Determine durability of screen, i.e., susceptibility to corrosion
        - j. Develop effective cleaning methods, gear, and procedures for operating and repairing screens under normal and emergency conditions
        - k. Develop and test fail-safe device(s) for emergency situations
        - l. Identify unforeseen operating problems
     2. Work tasks
        - a. Select field site
        - b. Develop field testing plan
        - c. Resolve who will operate field test facility
        - d. Design model
        - e. Prepare contract for model construction (completion by force account)
        - f. Construct model
        - g. Operate model
   - B. Field trips
     1. Visit other screening facilities to determine potential design defects and operational problems
     2. McClusky Canal screening facility to review lighting, ventilation, and safety problems and identify modification required
   - C. Other field tests
     1. Test various screen materials in Lake Sakakawea for aquatic growth
     2. Sample Lake Sakakawea
     3. Sample Audubon Lake

IV. Determine McClusky fish screen operation and maintenance procedures and requirements
   - A. Operation procedure
     1. Daily operations
        - a. Security requirements
        - b. Monitoring of screen operation
        - c. Screen cleaning
        - d. Trash removal from screen
        - e. Trash disposal equipment, facilities, and procedures
        - f. Stop or reduce canal discharge
        - g. Number and types of personnel to man facility
   - B. Maintenance requirements and procedures
     1. Screen repair procedure
     2. Screen replacement procedure
     3. Equipment and facility requirements
     4. Frequency of replacements
     5. Inventory of stores, spare parts, etc.

The consultants periodically reviewed these task force activities. Specifically, consultants were asked to critically review the laboratory fish eggs and larvae testing program, the study plan, task force conclusions and recommendations, and overall laboratory and field testing operations and feasibility designs.

Design Fish Species

The IGDSB identified nine fish species they considered problem species which could be introduced by GDU facilities, become established, and have an adverse impact on Manitoban fish populations. The species were: pallid sturgeon, shovelnose sturgeon, paddlefish, shortnose gar, smallmouth buffalo, river carpsucker, Utah chub, gizzard shad, and rainbow smelt. Rainbow smelt were considered to be the most serious of the problem species. Utah chub and gizzard shad were also listed as having a higher potential for causing biological impacts than the other six species. Carp were identified as the tenth problem species. GDU would increase flows and oxygen levels in the Souris River. The IGDSB predicted that carp would be introduced and become established in reaches of the river in North Dakota and Manitoba where they currently do not occur.

The task force decided to use eggs and larvae from rainbow smelt, Utah chub, gizzard shad, and the common carp as a basis for conducting laboratory filtration testing to determine screen sizing. Rainbow smelt and gizzard shad have small eggs and larvae, and it was felt that a screen system that could filter eggs and larvae of these species would effectively screen out eggs and larvae of larger undesirable fish species also. Research was directed primarily at evaluating screen passage of rainbow smelt eggs and larvae. These species were selected for the following reasons:

1. Smelt exist in both Lake Sakakawea and Audubon Lake, and it is likely they will become established in the McClusky Canal upstream from a fish screen. Although smelt already occur in some areas in the Hudson Bay drainage and represent a potential source for smelt migration into Lake Winnipeg, GDU facilities, without a fish barrier, would provide a second potential source for smelt transfer into Lake Winnipeg.

2. Utah chub have not been found in the Missouri River drainage in North Dakota; the nearest established chub population is at Canyon Ferry Reservoir in western Montana, about 840 river miles from Audubon Lake. In the past 43 years, this species has moved 195 miles downstream from Hebgen Lake, and it is uncertain they would become established in Lake Sakakawea. The screen must filter out chub eggs and larvae, but the task force felt that initial sizing studies of Utah chub eggs and larvae might show that they are larger than rainbow smelt. Therefore, filtration testing with Utah chub eggs and larvae might not be necessary.

3. Gizzard shad are in the James River in South Dakota, and do not generally occur in the upper Missouri River drainage. In 1963, however, one gizzard shad was collected below the Garrison Dam. The Garrison Dam prevents upstream migration from the lower Missouri River basin. Therefore, the fish screen in the McClusky Canal would not be subjected to gizzard shad eggs or larvae. The task force decided that laboratory data on gizzard shad should be

collected; however, in the event a fish screen were to be proposed in the Oakes section of the GDU, that screen would have to preclude transfer of gizzard shad to the Red River if this species were to migrate up the James River from South Dakota.

4. Carp are widely dispursed throughout most of the United States and Canada and are generally a serious problem for natural resource managers. Because of their abundance and significance as a problem fish species, it was felt that carp eggs and larvae would be easy to obtain and filtration data should be collected. A carp barrier in the McClusky Canal would not preclude all of the carp associated impacts that were predicted with the Garrison Diversion Unit because carp already occur in most areas to be served by the project. However, it was felt that these data would be useful to natural resource managers in North Dakota and other areas where carp control may be desirable. The task force anticipated that preliminary laboratory studies would indicate carp eggs and larvae are considerably larger than rainbow smelt eggs and larvae so extensive filtration tests with carp eggs and larvae would not be necessary.

Screen and Seal Design

As previously described, the preliminary design for the screen located in the McClusky Canal featured a 40-mesh screen supported by a 2-mesh screen, with both screens attached to a framework by a clamp bar arrangement. Each screen frame was to be sealed to the structure with bolted rubber compression seals. The IJC and others raised several questions about this design. After some additional initial laboratory testing, the task force reviewed the initial screen system design. The following critical design criteria were developed by the task force for redesigning the screen and screen seals:

1. The screen mesh must be sized to prevent passage of fish eggs and fish larvae encountered.

2. The method used to attach the fine screen to the support framework must also prevent egg or larvae passage around the screen.

3. The seal system used to seal the screen panels into the structure must prevent egg and larvae passage.

4. There must be a backup system to provide filtration if the primary system fails.

5. The system should be as simple and foolproof as possible.

6. The system should minimize the demand placed on operation and maintenance personnel.

7. The system must not allow egg and larvae passage during maintenance periods.

8. The system must have sufficient strength to withstand complete fouling of the screen without failure.

LABORATORY STUDIES

The laboratory studies were conducted at the Bureau of Reclamation Engineering and Research Center, Denver, Colorado. Objectives of the studies were:

1. Determine a screen mesh size and type that would be capable of filtering fish eggs and larvae from the canal water.

2. Develop an appropriate screen seal system.

3. Conduct preliminary investigations on various screen-related equipment and procedures for additional testing and verification in the field. This included items such as screen configuration, screen cleaning, screen installation and repair, seal monitoring systems, etc.

A fixed screen, sloping slightly downward (Figure 2) was thought to fit the requirements for a fish barrier and the studies were developed based on this concept. Openings in the screen would have to be small enough to prevent passage of fish eggs or larvae of the four selected species. The seals around the screens would have to prevent passage of all material.

Live eggs and larvae were required for testing. The greatest success was achieved by collecting and shipping eggs and adult fish to the E&R Center laboratory in Denver for testing and hatching to produce larvae.

Special laboratory equipment was devised to provide methods for verifying screen integrity, determining screen wear, selecting screen repair techniques, and develop the best method for attaching the screen to the frame.

The focus was on laboratory test apparatus design, testing, and developing test programs to insure statistically verified filtration reliability. Results of laboratory testing provided information for the selecting screen mesh size, developing the seal design, designing screen cleaning devices, and determining the screen flow capacity.

In the years 1978, 1979, and 1980, filtration tests were conducted in the Hydraulics Laboratory, using eggs and/or larvae of the four fish species. Due to handling and spawning difficulties with gizzard shad, no larvae were available at the E&R Center for testing those years. Tests with live gizzard shad larvae were conducted at the Tennessee Valley Authority (TVA) laboratories in Norris, Tennessee, in 1981, which was near a source of adult spawning gizzard shad.

Egg and Larvae Sizing Studies

The task force consultants recommended measuring freshly spawned eggs of the four design fish species to compare egg size among species and to the openings in the fish screen. Measurements could be obtained using a microscope equipped with an ocular micrometer, but this is a time-consuming process. Fish eggs imbibe water during water hardening and generally increase in size up to the time of hatching. Since all freshly spawned eggs could not be measured simultaneously the eggs measured early would be smaller in average diameter than eggs measured later. Recently spawned eggs would exhibit their smallest and most critical size for determining screen size prior to water hardening.

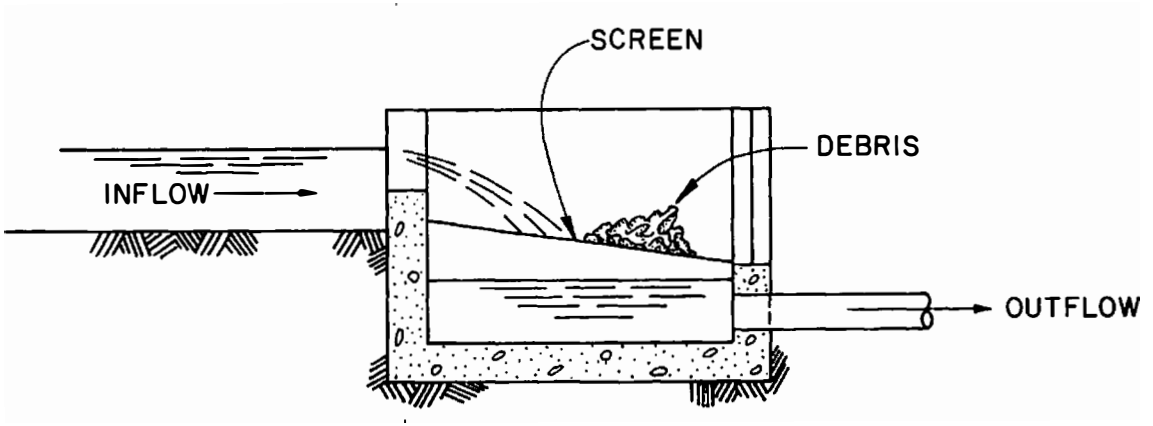


FIGURE 2 - GENERAL FIXED SCREEN CONCEPT

To provide an accurate and rapid method for determining the diameter of recently spawned fish eggs, a photographic method was developed. This method described below, was also used to photograph the screen material used at the field test facility which is described later.

Methods and Material

Equipment used to photograph eggs and larvae included a camera body, a 55-mm f/3.5 micro lens, two lens extension tubes, and a flash unit. A 1/4-inch piece of white plexiglass on top of the flash unit served to diffuse the flash. A copy stand, which allowed flash unit placement 7 inches below the bottom of a 1/4-inch white plexiglass stage was fabricated. Fish eggs were placed on a 1-inch by 3-inch glass microscope slide and placed on the stage. When the eggs were in focus, the distance from the eggs to the end of the micro lens was about 1-5/8 inches. A 5-mm round ocular micrometer was placed next to the slide on the stage. About one-third of the micrometer disk was ground off parallel with the scale to increase the area of the microscope slide that could hold fish eggs and thus increase the sample size. Since the thickness of the glass slide and the micrometer disk were similar, the plane of the micrometer scale was approximately the same as the plane of the fish eggs.

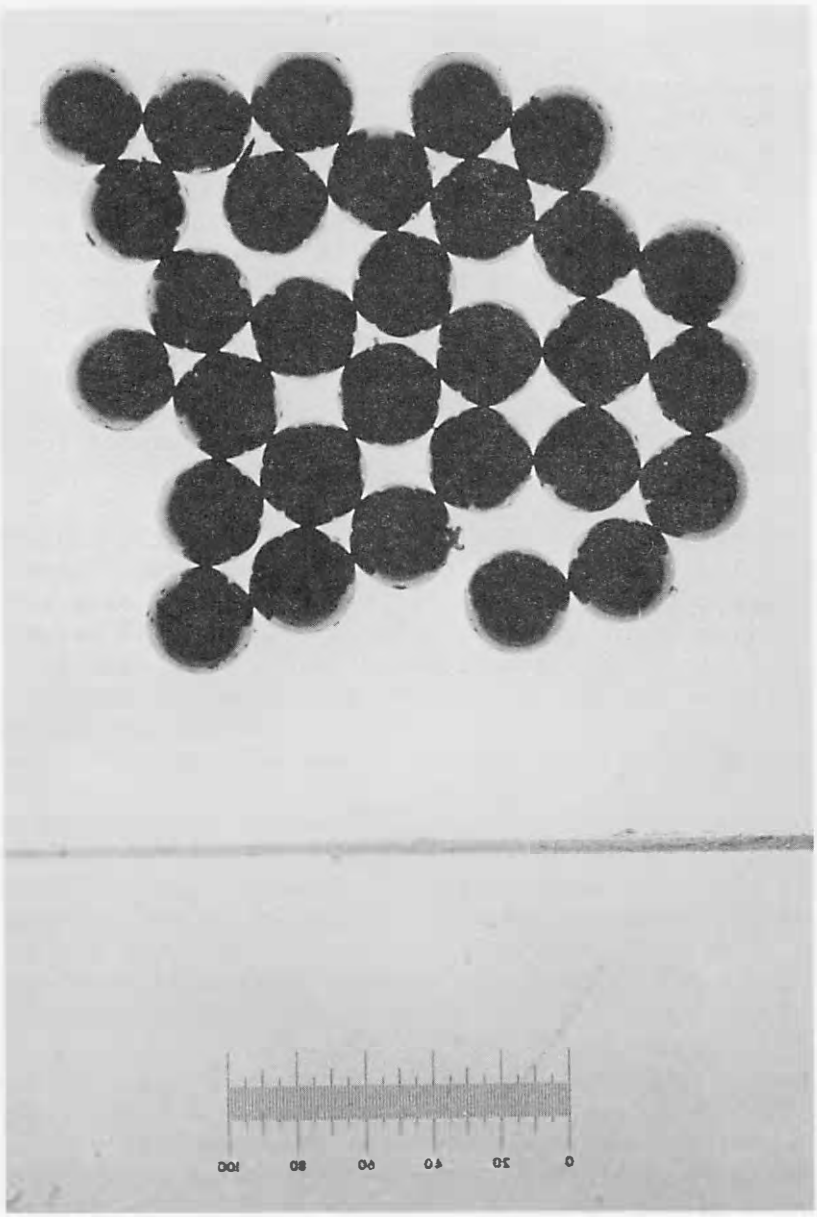
Ilford FP4 black and white film, ASA 125, was used almost exclusively. On a few occasions, Kodak PX 135 Plux-X Pan film, ASA 125, was used. Generally, 8-inch by 10-inch photographic enlargements made from the Ilford film were sharper and clearer than those from Kodak film. Shutter speed was 1/60 second, and three photographs of each set of eggs were taken at F/22, F/16, and F/11 to bracket the correct exposure. A record of each photograph was maintained. Magnification of eggs was about 12 to 13 times. Contact sheets were made of all photographs and the most suitable exposures were selected for enlargement.

A pair of fine-point mechanic's dividers was used to measure the diameter of fish eggs on the 8-inch by 10-inch enlargements. The points of the dividers were placed across the eggs being measured. When the opening of the dividers was exactly the diameter of the egg, the opening width was measured directly from the enlarged 5-mm scale in the photograph. This value was recorded as the diameter of that egg. Uncrowded, undistorted, "normal looking" eggs were measured by this procedure.

To verify the accuracy of the enlargements, 30 grade 25, chrome steel balls, 1/16 inch (1.5875 mm) in diameter were photographed and their diameters independently measured by three individuals from the 8-inch by 10-inch photographic enlargements. The steel balls were also measured using a binocular dissecting microscope, equipped with a 0.0 to 0.2 ocular micrometer calibrated so that 0.20 equals 2.0 mm.

Results and Discussion

Eggs and/or larvae from rainbow smelt, Utah chub, gizzard shad, and common carp were measured during 1980 and 1981. Generally, carp and Utah chub eggs were larger than 1.0 mm in diameter, while smelt and gizzard shad eggs were often less than 1.0 mm in diameter. Total body length of recently hatched smelt averaged around 5.0 mm, while body length of chub larvae generally exceeded 5.5 mm. Gizzard shad larvae generally exceeded 4.0 mm total length, although a



CHROME STEEL BALLS (1/16 INCH OR 1.5875 mm), SCALE: 100=5 mm

few larvae measured slightly less than 4.0 mm. The results of these measurement studies are summarized on Table 1.

Different batches of freshly spawned rainbow smelt eggs averaged 0.82 mm to 0.93 mm in diameter. In some fish from Parshall Bay, North Dakota, egg diameter differed according to the size of the female fish. One large female from Beaver Bay had eggs smaller in diameter than those measured from Parshall. As expected, incubating eggs were larger than freshly spawned eggs. A time series of photographs taken of eggs of a 180-mm Beaver Bay female smelt showed that the egg diameter increased from 0.98 to 1.06 mm during a 30-minute period following fertilization.

Smelt larvae were measured directly without anesthetic. Previous work with smelt larvae indicated that, even at low quinaldine concentrations, the larvae were killed easily, and the bodies became distorted and difficult to measure. Larvae were placed on a slide and measured under a dissecting microscope and a calibrated ocular micrometer while they were at rest. Ninety-six larvae, 4 to 6 hours old, averaged 4.82 mm total length while 100 larvae, about 24 hours old, averaged 5.50 mm total length.

Freshly spawned Utah chub eggs were larger than rainbow smelt eggs. Eggs from chub collected in Flaming Gorge Reservoir in mid-May 1980 averaged from 0.99 mm to 1.34 mm in diameter. The lot of eggs that averaged 0.99 mm in diameter contained some eggs that were not completely ripe, which may have reduced the average diameter. Average diameter of eggs from Utah chub collected in Flaming Gorge Reservoir in 1979 and from Hebgen Lake ranged from 1.28 mm to 1.41 mm.

These chub which had been held in the laboratory over winter and had been induced to spawn in mid-March, were larger than the fish collected in 1980 in Flaming Gorge Reservoir. Egg diameter was also greater. A direct relationship of brood fish length to egg diameter was suggested by the results of four adult spawners.

Several different lots of recently hatched Utah chub larvae were anesthetized in 0.063-0.125 mg/L of quinaldine and measured. For these lots, average total length ranged from 5.51 mm to 6.10 mm. In two lots of chub larvae, head width and/or body depth were measured. Head width was measured across the eyes, and body depth was the maximum vertical dimension across the yolk sac and body.

Freshly spawned carp eggs were also larger in average diameter than rainbow smelt eggs. Average diameter of eggs from several carp measured in early June ranged from 1.11 mm to 1.35 mm. The lengths of these adult carp were not recorded.

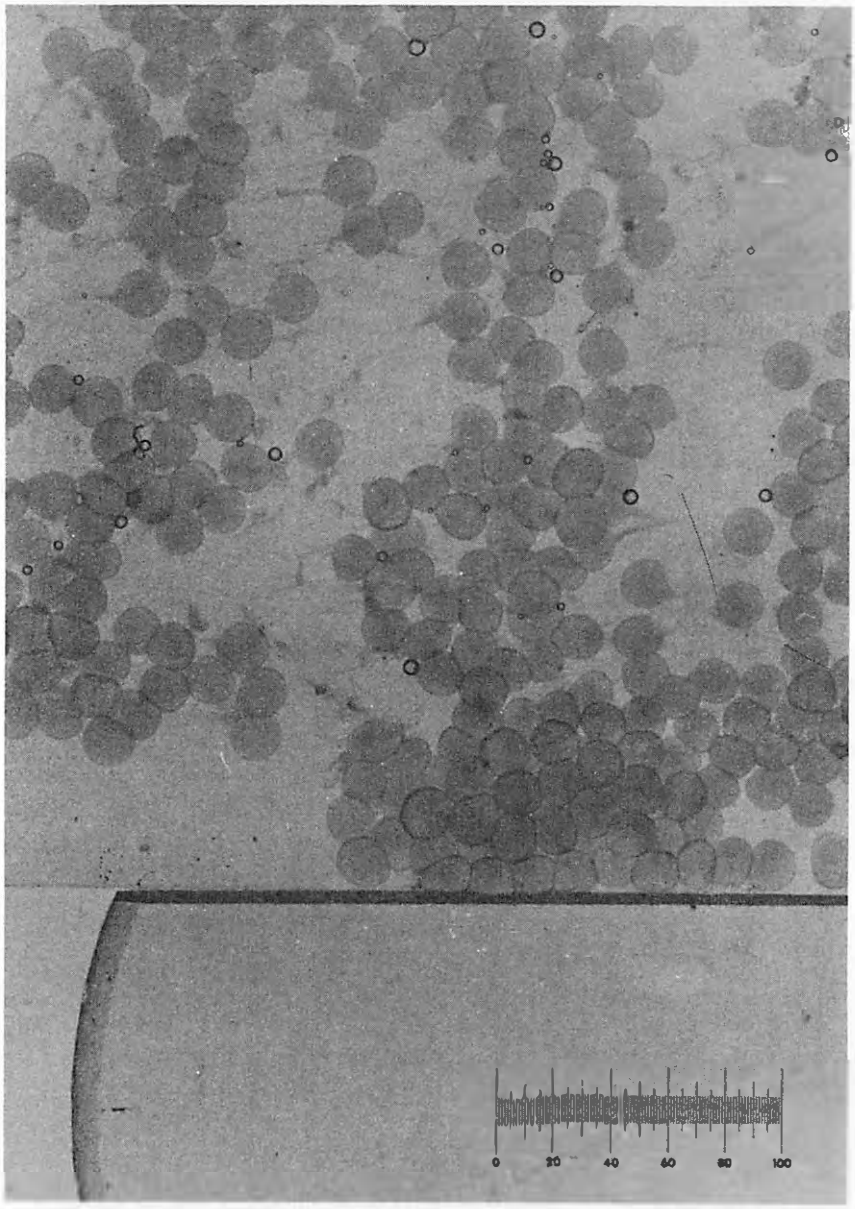
Gizzard shad eggs, photographed at TVA's Fort Loudoun Reservoir, using Ilford FP-4 film were difficult to measure because recently spawned eggs did not contrast greatly with the background. Bracketing exposures did not alleviate the problem. Because of poor contrast, only 10 eggs from each 8-inch by 10-inch enlargement were measured. Average diameter for eggs from several female shad was about 0.71 mm (Kodak Technical Pan Film 2415 was later tried in the laboratory in Denver and produced better, clearer enlargements with excellent contrast; however, it was not available when the egg sizing studies were accomplished).

Table 1

EGG AND LARVAE SIZES - RAINBOW SMELT, UTAH CHUB, CARP, AND GIZZARD SHAD

Source	Female Species and Length (mm)	Date	Larvae or Egg Age	Eggs			Larvae								
							Body Length			Body Depth			Head Width		
				N	X (mm)	Range (mm)	N	X (mm)	Range (mm)	N	X (mm)	Range (mm)	N	X (mm)	Range (mm)
	Rainbow Smelt														
Beaver Bay	173	April 12, 1980	--	40	0.85	0.75-0.95	--	--	--	--	--	--	--	--	--
Parshall Bay	137	April 24, 1980	--	10	0.82	0.75-0.85	--	--	--	--	--	--	--	--	--
	143	April 24, 1980	--	15	0.80	0.75-0.90	--	--	--	--	--	--	--	--	--
	143	April 24, 1980	--	20	0.84	0.80-0.90	--	--	--	--	--	--	--	--	--
	146	April 24, 1980	--	10	0.90	0.90-0.90	--	--	--	--	--	--	--	--	--
	146	April 24, 1980	--	10	0.93	0.90-0.95	--	--	--	--	--	--	--	--	--
Vermont	--	May 2, 1980	--	20	1.01	0.90-1.15	--	--	--	--	--	--	--	--	--
Beaver Bay	Not Measured	May 24, 1980	--	20	1.09	0.95-1.15	--	--	--	--	--	--	--	--	--
Unknown	180	April 12, 1980[1/]	0 min	20	0.98	0.90-1.05	--	--	--	--	--	--	--	--	--
	--	April 12, 1980	6 min	20	0.98	0.85-1.05	--	--	--	--	--	--	--	--	--
	--	April 12, 1980	18 min	30	0.98	0.90-1.05	--	--	--	--	--	--	--	--	--
	--	April 12, 1980	23 min	30	1.02	0.95-1.10	--	--	--	--	--	--	--	--	--
	--	April 12, 1980	30 min	30	1.06	1.00-1.10	--	--	--	--	--	--	--	--	--
Unknown		April 20, 1981	2-6 hours	--	--	--	96	4.82	4.40-5.28	--	--	--	--	--	--
		April 21, 1981	24 hours	--	--	--	100	5.50	4.52-6.32	--	--	--	--	--	--
	Utah Chub														
Hebgen Lake	290	March 25, 1980	1 min	20	1.41	1.30-1.55	--	--	--	--	--	--	--	--	--
Flaming Gorge Reservoir	246	March 19, 1980	1 min	10	1.28	1.28-1.50	--	--	--	--	--	--	--	--	--
	250	March 19, 1980	1 min	15	1.37	1.15-1.60	--	--	--	--	--	--	--	--	--
	265	March 19, 1980	1 min	10	1.40	1.35-1.45	--	--	--	--	--	--	--	--	--
Unknown	230	April 28, 1980	1 min	20	1.08	0.95-1.25	--	--	--	--	--	--	--	--	--
	245	April 28, 1980	1 min	40	1.01	0.95-1.10	--	--	--	--	--	--	--	--	--
	245	April 28, 1980	1 min	20	1.16	1.05-1.30	--	--	--	--	--	--	--	--	--
Unknown	200	April 29, 1980	1 min	15	0.99	0.95-1.05	--	--	--	--	--	--	--	--	--
	210	April 29, 1980	1 min	20	1.24	1.15-1.30	--	--	--	--	--	--	--	--	--
	220	April 29, 1980	1 min	20	1.34	1.10-1.65	--	--	--	--	--	--	--	--	--
	232	April 29, 1980	1 min	20	1.23	1.15-1.30	--	--	--	--	--	--	--	--	--
	Not Measured	April 7, 1981	<12 hours	--	--	--	100	5.81	4.20-6.28	--	--	--	--	--	--
	Not Measured	April 7, 1981	<12 hours	--	--	--	50	5.95	5.48-6.28	--	--	--	--	--	--
	Not Measured	April 7, 1981	< 6 hours	--	--	--	100	5.51	4.16-6.12	--	--	--	--	--	--
	Not Measured	April 8, 1981	<24 hours	--	--	--	100	6.11	4.80-6.48	--	--	--	--	--	--
	Not Measured	April 8, 1981	<24 hours	--	--	--	50	5.82	4.92-6.28	--	--	--	10	0.78	0.64-0.92
	Not Measured	April 9, 1981	<24 hours	--	--	--	100	6.00	4.40-6.56	--	--	--	--	--	--
	Not Measured	April 9, 1981	<24 hours	--	--	--	25	6.06	4.68-6.56	25	0.94	0.80-1.12	25	0.86	0.72-1.00
	Not Measured	April 9, 1981	<24 hours	--	--	--	100	5.69	4.32-6.32	--	--	--	--	--	--
	Carp														
	Not Measured	June 3, 1980	1 min	15	1.35	1.25-1.45	--	--	--	--	--	--	--	--	--
		June 3, 1980	1 min	25	1.11	1.00-1.20	--	--	--	--	--	--	--	--	--
		June 10, 1980	1 min	50	1.31	1.20-1.45	--	--	--	--	--	--	--	--	--
	Gizzard Shad	(1981)													
Prewitt Reservoir	Not Measured	May-June	24 hours	5	0.91	0.90-0.95	--	--	--	--	--	--	--	--	--
		May-June	24 hours	5	0.90	0.85-0.95	--	--	--	--	--	--	--	--	--
		May-June	24 hours	--	--	--	9	4.79	4.50-5.10	9	0.43	0.40-0.45	--	--	--
		May-June	72 hours	--	--	--	4	5.30	5.25-5.35	--	--	--	10	0.42	0.40-0.45
Tennessee	Not Measured	May-June	<24 hours	--	--	--	5	3.97	3.85-4.05	5	0.49	0.45-0.55	1	0.35	--
Colorado	Not Measured	May-June	<24 hours	--	--	--	9	4.79	4.50-5.10	9	0.43	0.40-0.45	--	--	--
Fort Loudoun Reservoir	120	May	1 min	10	0.71	0.65-0.75	--	--	--	--	--	--	--	--	--
	126	May	1 min	10	0.71	0.65-0.75	--	--	--	--	--	--	--	--	--
	130	May	1 min	10	0.69	0.60-0.75	--	--	--	--	--	--	--	--	--
	137	May	1 min	10	0.70	0.60-0.75	--	--	--	--	--	--	--	--	--
	137	May	1 min	10	0.72	0.65-0.75	--	--	--	--	--	--	--	--	--

1/ Fertile eggs were taken from a single female smelt and measured over a 30-minute period.



RECENTLY SPAWNED RAINBOW SMELT EGGS (SCALE: 100=5 mm)

Only five shad eggs from two different photographs were measured because of the distortion of some eggs from fish collected in Prewitt Reservoir on May 27, 1981. Egg diameter averaged 0.91 mm 24 hours after spawning. Recently hatched shad larvae from Prewitt Reservoir averaged 4.79 mm total length and 0.43 mm body depth; 72-hour-old shad larvae averaged 5.30 mm total length with an average head width of 0.42 mm. Recently hatched larvae from Fort Loudoun Reservoir, Tennessee, averaged 3.97 mm total length and 0.35 mm head width. Sample size, however, was small in both cases.

Few photographs suitable for measuring shad larvae were obtained. Recently hatched Tennessee shad larvae are somewhat smaller (3.97 mm) than recently hatched Colorado larvae (4.79 mm). Body depth was the maximum vertical dimension across the yolk sac and body. Since body depth decreases as the larva grows and absorbs the yolk sac, the slightly smaller depth of the Colorado shad larvae may indicate that they were slightly older, although they were still less than 24 hours old when measured.

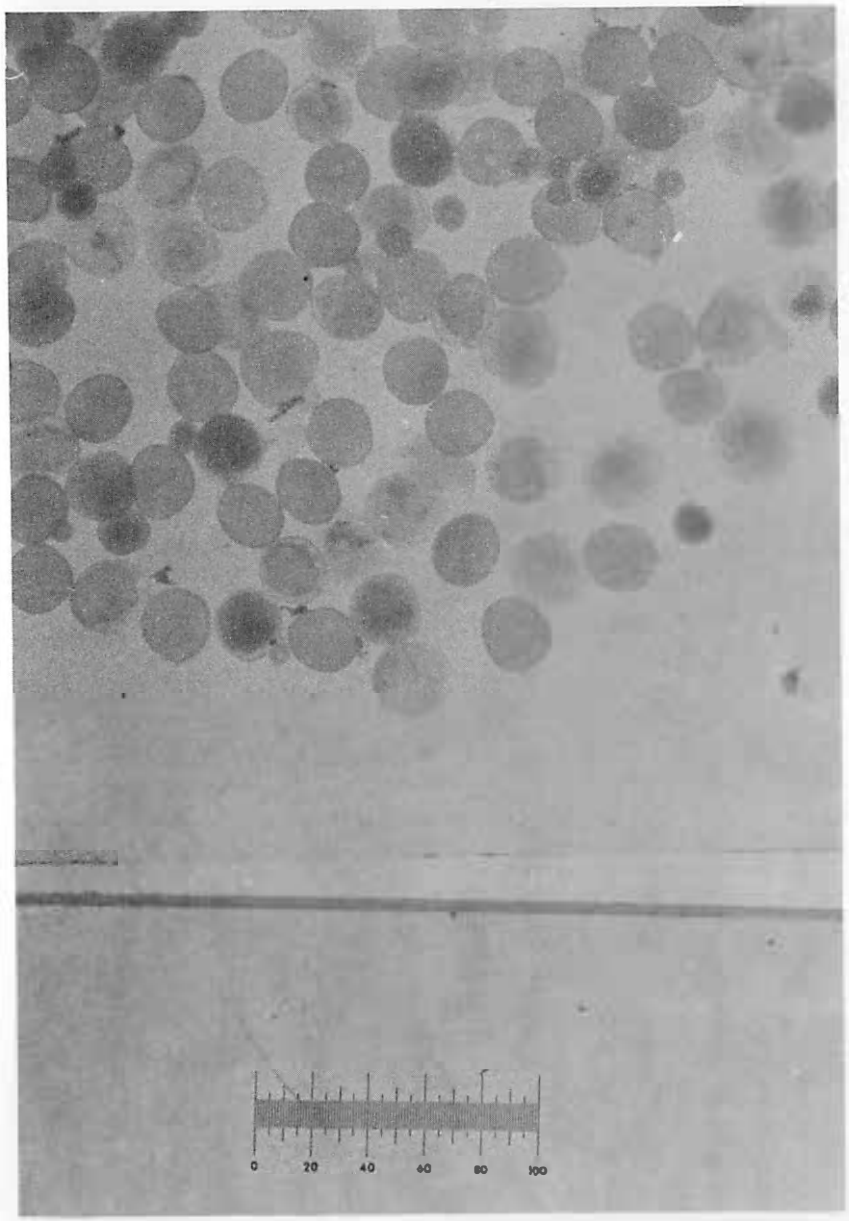
Since the maximum dimensions of the eggs and larvae of Utah chub and carp exceed those of the rainbow smelt, their inclusion in screen testing was not critical, but could serve as final verification of the screen design. Gizzard shad were of special interest because their larvae are slightly smaller than the larvae of rainbow smelt. Miller (1960) states that the body depth of the recently hatched gizzard shad larvae, including a continuous fin fold arising on the dorsal surface of the body, continuing around the posterior end, and anteriorally along the ventral side, is 0.2 mm. However, this measurement does not include the body depth at the yolk sac. Prewitt Reservoir gizzard shad larvae had a body depth at the yolk sac of 0.43 mm. No data could be found in the literature as to head size. Presumably, head sizes would be somewhat larger than the body.

The nominal size of the steel balls used to verify the egg and larvae photo measurements was 1.59 m. The size obtained by microscopic measurement ranged from 1.58 mm to 1.59 mm, while the size obtained from the 8-inch by 10-inch enlargement ranged from 1.59 mm to 1.60 mm.

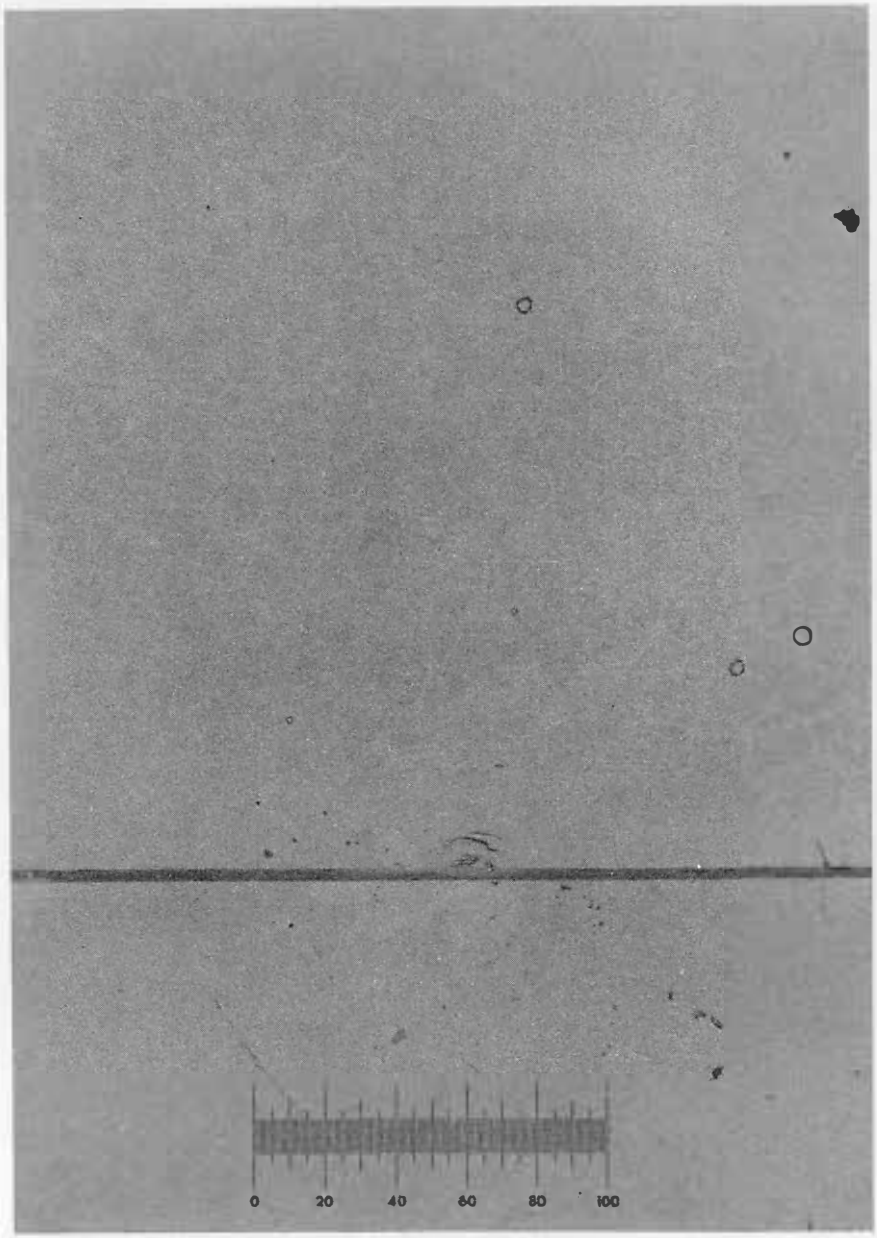
Steel Ball Measurements

	Microscope		Photograph	
Individual	x (mm)	Range (mm)	x (mm)	Range (mm)
1	1.59	1.58 - 1.60	1.59	1.57 - 1.60
2	1.58	1.58 - 1.59	1.60	1.58 - 1.62
3	1.59	1.58 - 1.60	1.60	1.59 - 1.60
Average	1.59		1.59	

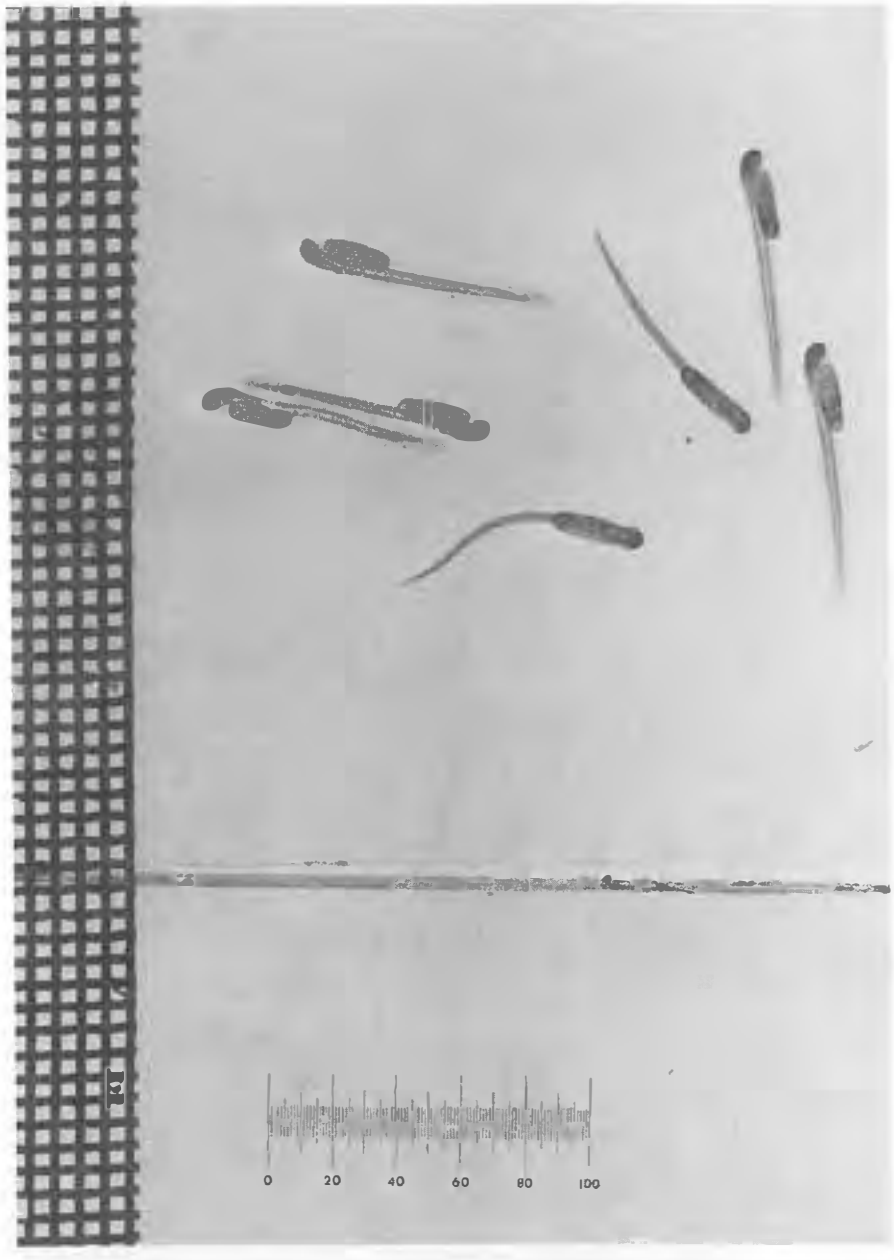
Average diameter of 30 chrome steel balls measured under the microscope was nearly identical with the nominal size stated by the manufacturer. The average diameter measured from an 8-inch by 10-inch photographic enlargement was only 0.37 percent greater than the manufacturer's stated size. This indicates that the photographic method of measuring the diameter of fish eggs or the size of other small objects is valid.



UNFERTILIZED UTAH CHUB EGGS SPAWNED 2 MINUTES PRIOR TO PHOTOGRAPHING (SCALE: 100=5 mm)



GIZZARD SHAD SPAWNED AT FORT LOUDOUN RESERVOIR ON MAY 1, 1981, 2 MINUTES AFTER SPAWNING (SCALE: 100=5 mm)



RECENTLY HATCHED GIZZARD SHAD LARVAE FROM SPAWN COLLECTED IN FORT LOUDOUN RESERVOIR, TENNESSEE, AND INCUBATED AT TVA'S LARVAL FISH LABORATORY. SCREEN IS 70 MESH (SCALE: 100=5 mm)

Screen Material Tested

Report REC-ERC-75-6, "Hydraulic Model Study of a Fish Screen Structure for the McClusky Canal," (Johnson 1975) described laboratory development of a 40-mesh, self-cleaning, sloping screen to filter fish eggs and larvae from the McClusky Canal. That study did not use live organisms to verify the filtering capability of the 40-mesh screen; however, the 40-mesh screen was selected from a comparison of literature, egg and larvae measurements, and screen-opening size measurements. The following screens were used in the laboratory tests described later in this chapter.

Woven Screen

Characteristics of the screens used were:

Mesh	Stainless Steel Wire Dia. (in.)	Nominal Opening Size (mm)	Measured Aperture Size Range (mm)	Nominal Open Area (Percent)
40	0.008	0.432	--	46.2
50	0.009	0.279	--	30.3
50	0.0075	0.318	--	39.1
60	0.0075	0.234	--	30.5
70	0.0065	0.198	0.17 - 0.27	29.8

A visual survey of 16 square inches of 70-mesh stainless steel screen, using a 5.6X microscope, showed a normal aperture size from 0.20 mm to 0.24 mm, with a minimum opening of 0.17 mm and a maximum opening of 0.27 mm. These findings imply that closer tolerances may be needed for the actual fish screen. Also, extreme care will be necessary during cutting, stretching, and installing the screen.

Federal Specification E43771 is the industry standard for 70-mesh screen. The standards are stated as:

$$\text{Wire diameter} = 0.0065 \text{ inch} \pm 0.00025 \text{ inch}$$

$$\text{Mesh: Warp (longitudinal)} = 70 \pm 1.4$$
$$\text{Cross Weave} = 70 \pm 2.8$$

With these tolerances, the largest allowable aperture size is 0.219 mm and the smallest allowable aperture is 0.177 mm. The observed sample described above exceeded these limits. More rigorous inspection than called for in the Federal specifications may be necessary to insure that screen material is manufactured within specified tolerances.

In addition, opening size data were collected at over 30 locations on various screen materials. The majority of this data was collected for 70-mesh monel screen which is the screen recommended for final use. At each location, 100 openings were sized. These data were collected in conjunction with the evaluation of damage and wear on screens at the field test facility which is discussed later in this report. As of this writing, the statistical analysis on these data have not been completed. However, the data show that for the 70-mesh

screen, a maximum opening dimension is approximately 0.256 mm and a minimum opening size is approximately 0.131 mm.

The smallest eggs of the four fish species are much larger (60% to 160%) than the nominal openings in even a 40-mesh screen. The smallest dimension measured on a gizzard shad larva (0.35 mm) exceeded the largest aperture measured in a 70-mesh screen (0.27 mm) and the maximum allowable aperture of 0.22 mm. The larvae of the other three species are larger than those of gizzard shad.

Johnson Well Screen

Johnson well (stainless steel) screen with the following characteristics was also tested:

Nominal Opening Size (mm)	Measured Aperture Size Range (mm)	Nominal Open Area (Percent)
0.20	0.19 - 0.21	11.6
0.10	0.02 - 0.10	6.1

This screen uses the smallest wedge wire size presently available. The percent open areas are thus maximum available values.

Laboratory Testing

This section describes equipment and procedures used to determine screen size, seal designs, screen cleaning methods, screen installation methods plus techniques for repairing the screen material and verifying screen integrity.

All laboratory testing was recorded on film. Documentaton included black-and-white still photograph, 35-mm color slide photography, color movies, and color videotape. All are on file and available for reference.

Standpipe Apparatus

A standpipe (Figure 3) was fabricated to evaluate the filtration capability of various screens. A 2.3-foot head against the screen was created by supplying water from a weir-controlled constant head headbox to a 4-inch-diameter vertical pipe. The head was controlled by a 1¼-inch-orifice plate sealed to the pipe's lower end. The 2.3-foot head exceeds the maximum drop of 2 feet expected for the McClusky Canal Fish Screen. Although the standpipe did not correctly model flow conditions across the proposed screen, it did allow a quick determination of whether the various screen materials could supply the required filtration.

The use of the standpipe was an outgrowth of consultant Milo Bell's suggestion to test the passage of eggs and larvae through hypodermic needles of various sizes. To our knowledge, it is a unique approach.

Preparation.--

1. The screen to be tested was mounted at the base of the 4-inch diameter standpipe and washed to remove dust.

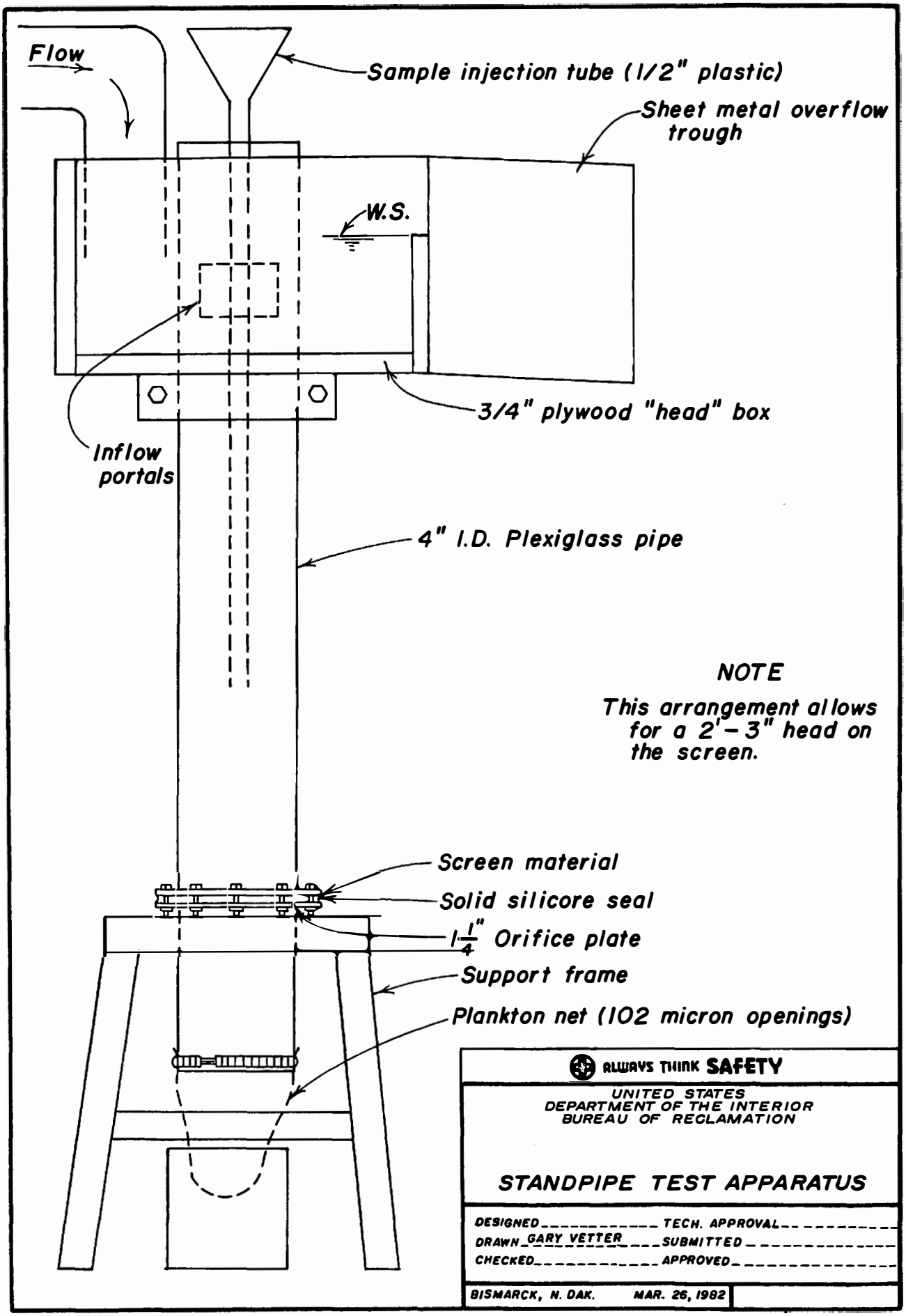

Flow
Sample injection tube (1/2" plastic)
Sheet metal overflow trough
W.S.
3/4" plywood "head" box
Inflow portals
4" I.D. Plexiglass pipe
NOTE
This arrangement allows for a 2'-3" head on the screen.
Screen material
Solid silicore seal
1 1/4" Orifice plate
Support frame
Plankton net (102 micron openings)
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
STANDPIPE TEST APPARATUS
DESIGNED
TECH. APPROVAL
DRAWN GARY VETTER
SUBMITTED
CHECKED
APPROVED
BISMARCK, N. DAK. MAR. 26, 1982

FIGURE 3

2. The standpipe was suspended under the water supply pipe so that the supply pipe was behind a filter and stilling screen. The model was also supported and leveled beneath the overflow weir by a removable frame.

3. The 102-micron plankton net collection bag was placed around the base of the standpipe (in which the screen sample is installed) and fastened with a circular clamp. Everything passing the screen sample entered the collection bag.

4. A bucket was placed under the standpipe so the lower portion of the collection bag was submerged. The water in the bucket provided a stilling pool to reduce turbulence and lessen possible damage to organisms that pass the screen.

Operation.--

1. Water was introduced into the standpipe through two rectangular holes in the standpipe wall. A constant head of approximately 2.3 feet was maintained on the screen. Water passed through the screen, collection bag, and bucket.

2. Excess water introduced to the headbox flowed across an overflow weir and was recirculated. Total inflow was set to produce a continuous flow across the overflow weir, which maintained a constant head on the screen and a constant discharge through it.

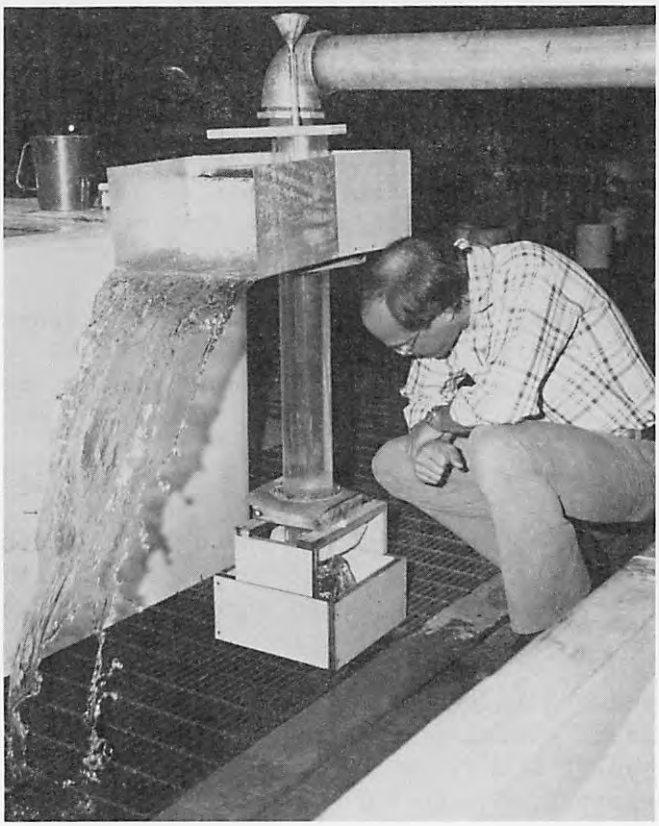
3. Standpipe operation before sample injection was minimized to reduce screen fouling.

4. A stained sample of 100 fish eggs and 100 fish larvae was injected into the standpipe through a 3/4-inch-diameter PVC pipe, positioned so the bottom of the PVC pipe was about 6 inches below the holes in the standpipe wall. This insured that injected eggs and larvae were not lost over the overflow weir. About 1 quart of water was poured through the PVC pipe so that all eggs and larvae were rinsed into the water above the screen. The standpipe was then operated for 45 minutes.

5. After the water was turned off and the standpipe allowed to drain, the circular clamp was loosened and the collection bag was carefully removed. The bag is was then gently washed out into a clean 5-gallon bucket.

6. The contents of the bucket were carefully strained through a 1-foot square piece of plankton netting. Stained eggs and larvae and pieces were collected, counted, and preserved in 10-percent formalin.

7. The plywood support was removed from beneath the overflow weir and the support chain was unhooked from the standpipe box. The apparatus was completely washed.



STANDPIPE TEST APPARATUS

8. The standpipe was then repositioned under the water supply pipe immediately after washdown to conduct another test. Stain colors were alternated between tests to check for possible contamination from previous tests. With this procedure, six tests could be made in a normal working day.

Results and Discussion.--The standpipe was used to test 40-, 50-, 60-, and 70-mesh stainless steel screen and Johnson well screen with 0.1-mm slots.

FY 1978, Smelt and Carp.--Standpipe test results using 40-, 50-, and 60-mesh screen are shown in Table 2 and Figure 4. With the exception of three headless smelt larvae, no eggs or larvae passed the 60-mesh screen. Carp eggs and larvae and smelt eggs did not pass the 50-mesh screen; however, one smelt larva did pass. The results of the 40-mesh tests eliminated that screen from further consideration for smelt so it was not tested with carp.

Table 3 gives the results of standpipe tests with a Johnson well screen with a slot width of 0.1 mm. However, while nothing passed the screen, the 0.1-mm slot width has a very small percentage of open area and this is a low hydraulic efficiency. An earlier test with well screen with a slot width of 0.20 mm passed one damaged egg, three whole larvae, and 40 headless larvae from a sample of 100 preserved eggs and 100 preserved larvae of rainbow smelt.

Table 2

EGG AND LARVAE STANDPIPE FILTRATION TEST WITH 40-, 50-, AND 60-MESH SCREEN
(PRESERVED CARP AND SMELT)

Screen (Mesh)	Date (1978)	Length of Test (Min.)	Sample Tested		Sample Recovered In Plankton Net					
			Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae
			Carp:							
60	7-7	45	100	100	0	0	0	0	0	0
60	7-7	45	100	100	0	0	0	0	0	0
60	7-11	45	100	100	0	0	0	0	0	0
60	7-11	45	100	100	0	0	0	0	0	0
60	7-12	45	100	100	0	0	0	0	0	0
			Smelt:							
60	7-12	45	100	100	0	0	0	0	0	0
60	7-19	45	100	100	0	0	0	0	0	0
60	7-20	45	100	100	0	0	0	0	1	0
60	7-21	45	100	100	0	0	0	0	0	0
60	7-21	45	100	100	0	0	0	0	0	0
			Smelt:							
60	9-1	45	100	100	0	0	0	0	2	0
60	9-1	45	100	100	0	0	0	0	0	0
60	9-1	45	100	100	0	0	0	0	0	0
60	9-1	45	100	100	0	0	0	0	0	0
60	9-1	45	100	100	0	0	0	0	0	0
			Carp:							
50	8-25	45	100	100	0	0	0	0	0	0
50	8-25	45	100	100	0	0	0	0	0	0
50	8-25	45	100	100	0	0	0	0	0	0
50	8-28	45	100	100	0	0	0	0	0	0
50	8-28	45	100	100	0	0	0	0	0	0
			Smelt:							
50	8-22	45	100	100	0	0	0	1	1	0
50	8-22	45	100	100	0	0	0	0	1	1
50	8-23	45	100	100	0	0	0	1*	2	0
50	8-23	45	100	100	0	0	0	0	1	1
50	8-23	45	100	100	0	0	0	0	0	1
			Smelt:							
40	8-7	45	100	100	0	0	0	4	0	2
40	8-7	45	100	100	0	0	0	2	0	5
40	8-8	45	100	100	0	0	0	2	0	2
40	8-8	45	100	100	0	0	0	0	0	2
40	8-9	45	100	100	0	0	0	3	0	3

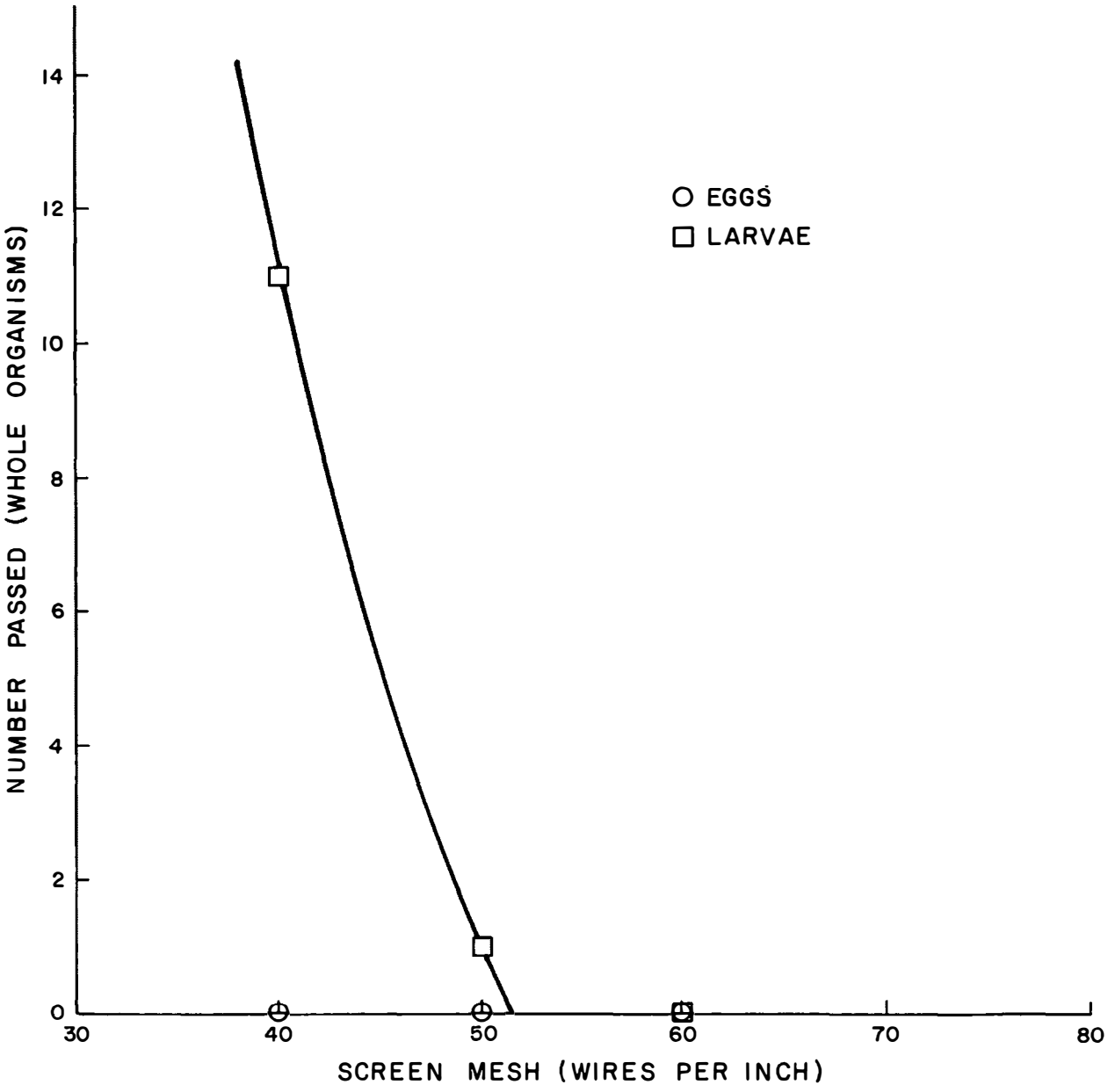


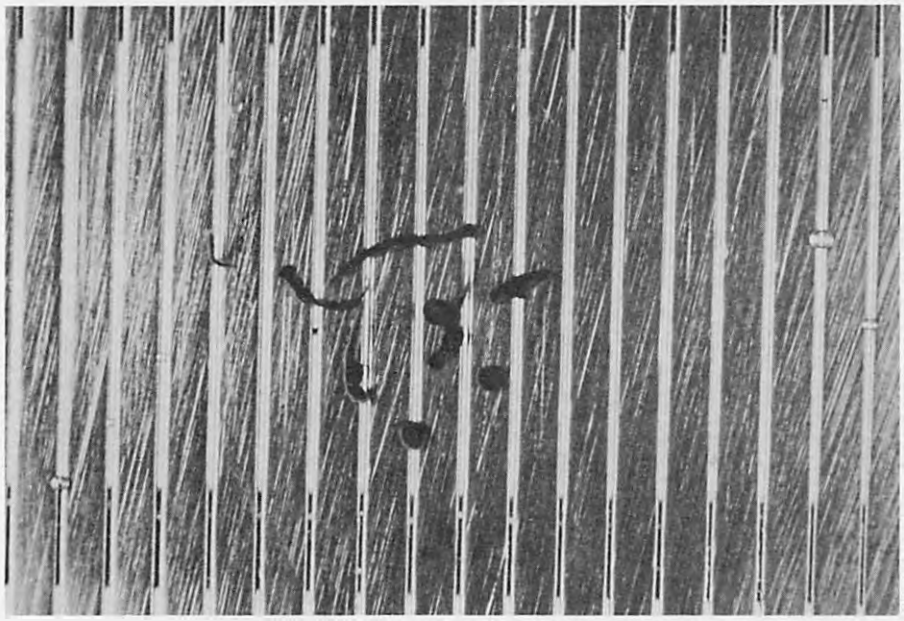
FIGURE 4 - STANDPIPE FILTRATION RESULTS

Table 3

EGGS AND LARVAE STANDPIPE FILTRATION TEST - JOHNSON WELL SCREEN, 0.1 MM SLOT
(PRESERVED SMELT)

Screen Size (mm)	Date	Discharge (ft^3/s)	Length of Test (Min.)	Approx. Sample Size		Number of Organisms Recovered In Plankton Net						Stain
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae	
0.1	2/16/79	*	45	100	100	0	0	0	0	0	0	Blue
0.1	2/16/79	.025	45	100	100	0	0	0	0	0	0	Red
0.1	2/16/79	.025	45	100	100	0	0	0	0	0	0	Green
0.1	2/21/79	.025	45	100	100	0	0	0	0	0	0	Blue
0.1	2/21/79	.025	45	100	100	0	0	0	0	0	0	Red
0.1	2/21/79	.025	45	100	100	0	0	0	0	0	0	Green
0.1	2/21/79	.025	45	100	100	0	0	0	0	0	0	Violet

*Reduced discharge, apparently due to initial condition of well screen



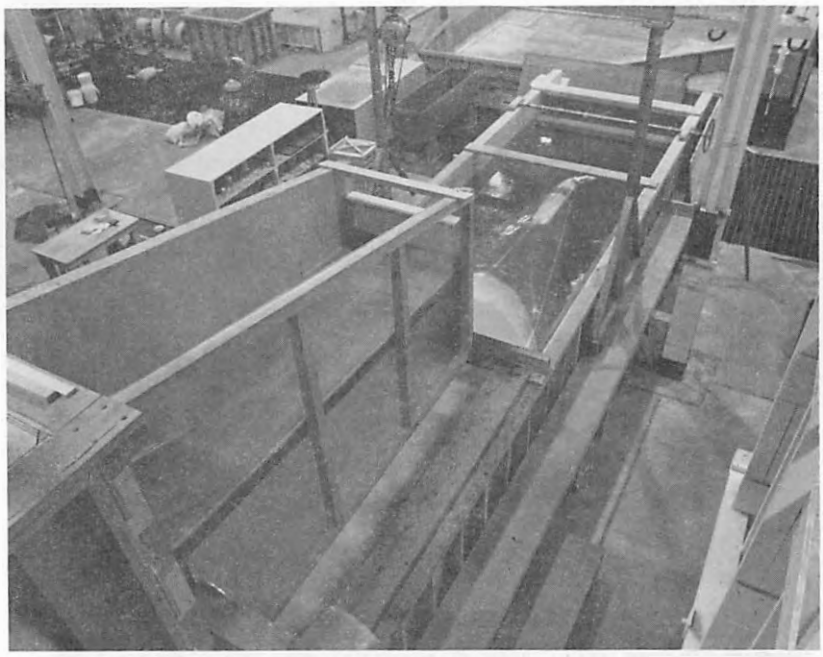
JOHNSON WELL SCREEN, 0.1-MM SLOT WIDTH WITH RAINBOW SMELT EGGS AND LARVAE

FY 1981, Gizzard Shad.--In seven 45-minute standpipe tests with 70-mesh screen using 100 to 150 live 2- to 3-day old shad larvae per test, 36 larvae with damaged heads were found in the plankton net. At least one damaged larva was observed in each test; a high of 16 damaged larvae were recovered in one test run. These shad larvae had absorbed their yolk sacs and had developed eyes and some pigmentation. Gizzard shad larvae are poorly developed at hatching, with no distinguishable eyes or mouth, and only a rudimentary alimentary canal. Distinctive anatomical features, such as the respiratory and alimentary systems, develop within a few days after hatching, concomitant with yolk sac absorption.

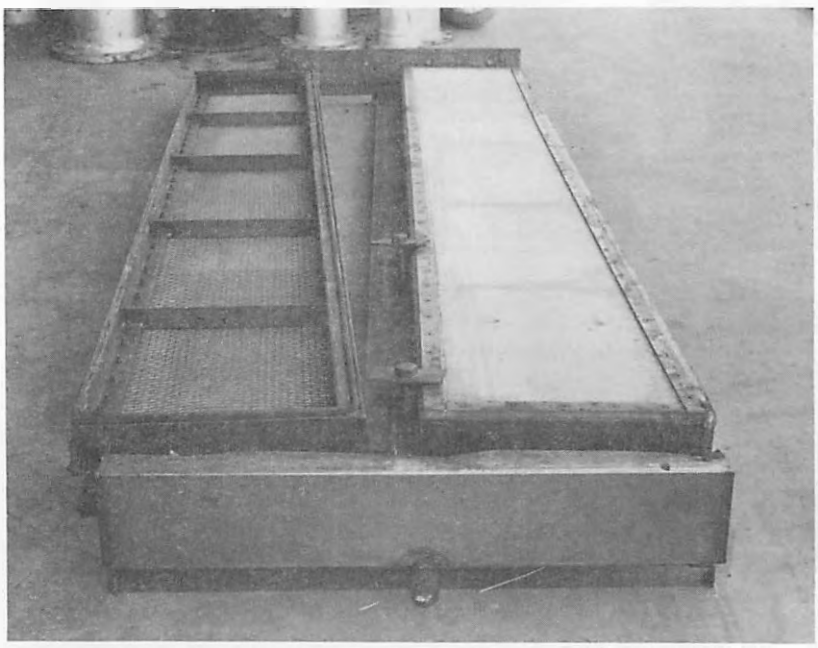
Sectional Model

Laboratory efforts concentrated on a sectional model of the proposed McClusky Canal Fish Screen. The model, which simulated a full-scale slice from the final structure, accommodated a 3-foot by 12.5-foot screen panel. Water flowed over the screen and dropped into the tail box, where a large plankton net collected any eggs or larvae that may have passed through the screen.

The model could hold either one full width screen panel or two half-width panels; the latter configuration was used to study the effects of seals and structural connections between adjacent panels.

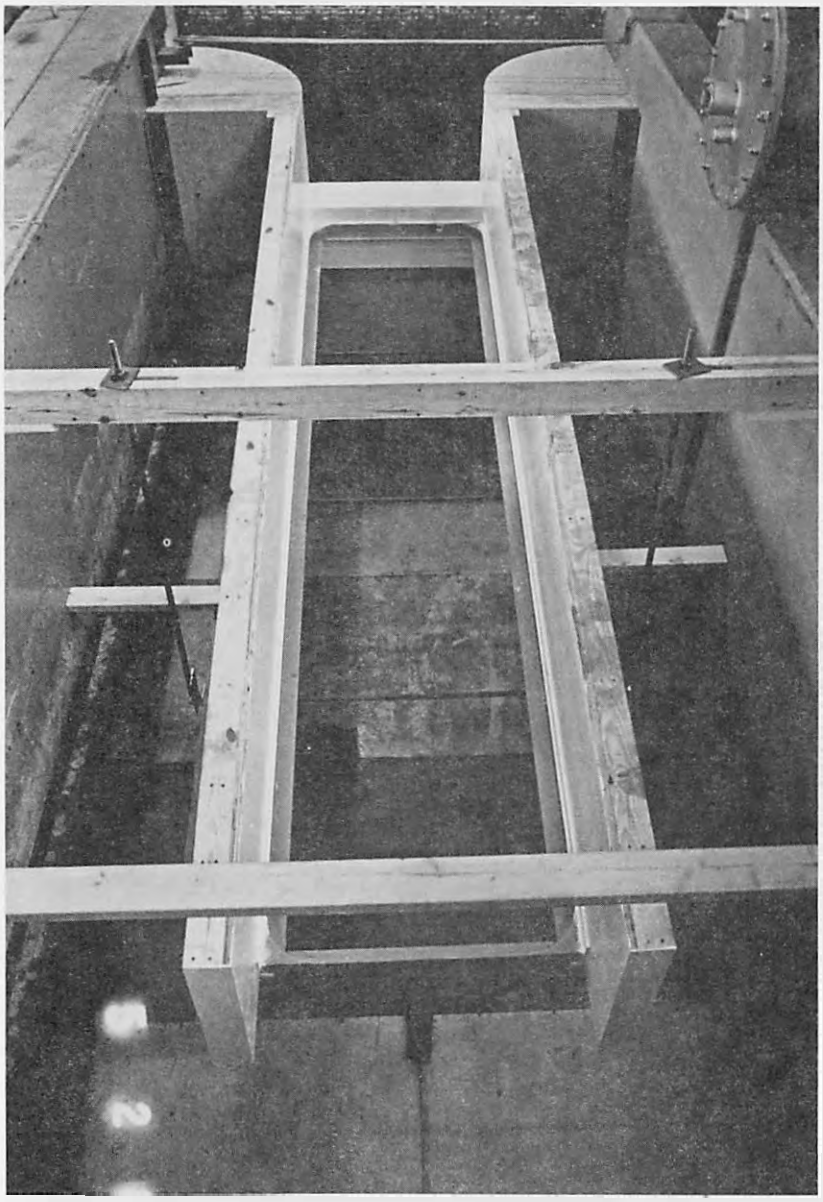


OVERALL VIEW OF FULL-SCALE SECTIONAL MODEL, LOOKING DOWNSTREAM. PLANKTON NET IS VISIBLE IN TAIL BOX.



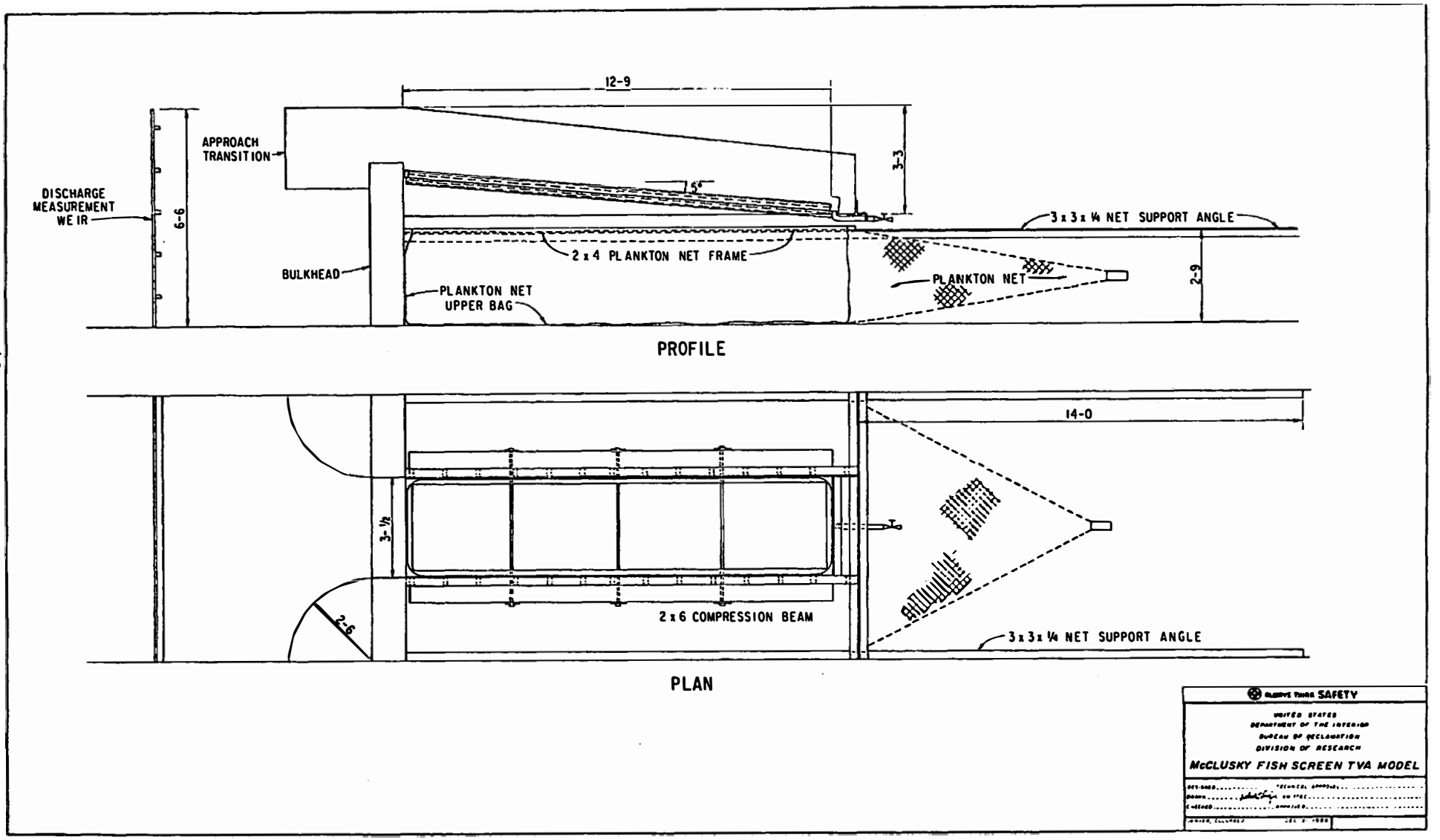
HALF-PANEL CONFIGURATION BEFORE INSTALLATION. PANEL ON LEFT IS UPSIDE DOWN AND SHOWS SUPPORT SCREEN AND SEAL.

A similar sectional model was also used at the TVA Engineering Laboratory, Norris, Tennessee, for testing with live gizzard shad eggs and larvae. Using BR designs, TVA shop personnel constructed a wooden model to accommodate the 3-foot by 12.5-foot screen panel used at the E&R Center. The panel was placed inside an 8-foot by 8-foot by 40-foot-long concrete flume in TVA's Hydraulic Laboratory (Figure 5). Pumps provided a maximum flow of 12.3 ft^3/s with lesser discharges of 3 ft^3/s and 9 ft^3/s to the screen for filtration and recovery tests.



SECTIONAL MODEL AT TVA LABORATORY WITH 70-MESH SCREEN

Figure 5


12-9
APPROACH TRANSITION
DISCHARGE MEASUREMENT WE IR
6-6
3-3
5"
3 x 3 x ¼ NET SUPPORT ANGLE
2 x 4 PLANKTON NET FRAME
BULKHEAD
PLANKTON NET
PLANKTON NET UPPER BAG
2-9
PROFILE
14-0
3-½
2-6
2 x 6 COMPRESSION BEAM
3 x 3 x ¼ NET SUPPORT ANGLE
PLAN
SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DIVISION OF RESEARCH
McCLUSKY FISH SCREEN TVA MODEL

Test Preparation.--

1. The plankton net collection bag, which was a large rubberized nylon bag suspended from a rectangular wooden frame with an open cone of plankton (102-micron) netting attached to the downstream end of the bag was set in place. A plastic collection cup was attached to the plankton net.

2. A fine mesh (102-micron) collection bag was secured inside the plastic collection cup.

3. After securing the collection cup to the net, the nylon bag was positioned beneath the screen.

4. The sample size of fish eggs and larvae was counted or estimated volumetrically and then stained. Fertilized or unfertilized eggs were used depending upon availability.

   Eggs and/or larvae were stained with neutral red, fast green, toluidine blue O, methylene blue, or Nile blue A. The organisms were allowed to stain from 30 to 60 minutes in a 1-percent staining solution before being used in a test run. Alternate batches were stained different colors to identify eggs or larvae from particular test runs. (Most of the eggs and larvae retained the stain for the 45-minute duration of the test run. Recently hatched gizzard shad eggs, however, took up the stain only moderately; all stains except Nile blue A leached out of the shad larvae during the 45-minute filtration test.)

Operation.--To insure appropriate test replication, a testing schedule was developed by Dr. Thomas Keefe, a consulting environmental statistician. The sectional model was operated based on the schedule shown on Table 4. He also analyzed the data on screen apertures and egg/larvae sizing described previously.

1. Water was introduced to the headbox through a rock baffle to distribute and still the flow. It then passed from the headbox over a broad-crested weir and onto the screen. The weir represents the screen headwall in the McClusky Canal Fish Screen. The design discharge, determined from hydraulic property tests, was used in addition to low and intermediate discharges to represent a range of operating conditions.

2. Water that flowed over the downstream end of the screen, and not passing through the screen and collection net, was collected and filtered.

3. The screen would tend to foul in the area where the flow first hit the screen so operation was minimized prior to injecting the sample of eggs or larvae.

4. One of two methods of injecting fish eggs and larvae into the flow above the screen was used, depending on the purpose of the test:

Table 4

STATISTICAL DESIGN TO TEST FOR PASSAGE OF LARVAE AND EGGS - SECTIONAL MODEL

		Rainbow Smelt				Utah Chub				Carp and Gizzard Shad			
			Flow Rates				Flow Rates				Flow Rates		
Replicate	Test Series	Operation Mode	1st Run	2nd Run	3rd Run	Operation Mode	1st Run	2nd Run	3rd Run	Operation Mode	1st Run	2nd Run	3rd Run
I*	1	Normal	H	M	L	Cleaning	H	M	L	Cleaning	M	L	H
	2	Cleaning	H	M	L	Normal	H	L	M	Normal	L	H	M
II	3	Cleaning	L	H	M	Cleaning	M	L	H	Normal	M	L	H
	4	Normal	M	L	H	Normal	M	H	L	Cleaning	H	M	L
III	5	Normal	L	H	M	Normal	L	M	H	Normal	H	M	L
	6	Cleaning	M	L	H	Cleaning	L	H	M	Cleaning	L	H	M
IV*	7	Normal	M	H	L	Cleaning	M	H	L	Cleaning	H	L	M
	8	Cleaning	M	L	H	Normal	M	H	L	Normal	M	L	H
V	9	Normal	L	M	H	Normal	L	M	H	Normal	H	M	L
	10	Cleaning	H	M	L	Cleaning	H	L	M	Cleaning	M	H	L
VI	11	Cleaning	L	H	M	Cleaning	L	M	H	Cleaning	L	M	H
	12	Normal	H	L	M	Normal	H	L	M	Normal	L	H	M
VII*	13	Cleaning	H	M	L	Normal	M	H	L	Normal	H	M	L
	14	Normal	M	L	H	Cleaning	M	L	H	Cleaning	M	H	L
VIII	15	Normal	L	H	M	Normal	H	L	M	Cleaning	L	M	H
	16	Cleaning	L	H	M	Cleaning	H	M	L	Normal	L	H	M
IX	17	Cleaning	M	L	H	Cleaning	L	H	M	Normal	M	L	H
	18	Normal	H	M	L	Normal	L	M	H	Cleaning	H	L	M

*Replicates with recovery runs included.

H=high discharge (15 ft^3/s)
M=medium discharge (9 ft^3/s)
L=low discharge (3 ft^3/s)

a. Three injection locations in the headbox were used to insure a representative distribution of eggs and larvae across the screen. These locations were about 2 feet upstream from the weir, at the quarter points of the model's width. At each location, about one-third of the stained sample of fish eggs and larvae was poured through a 1½-inch-diameter PVC pipe, positioned so that the bottom of the pipe was 1 inch below the water surface for the center location, and at the elevation of the broad-crested weir for the two outer locations. After sample injection, about 1 quart of water was rinsed through each 1½-inch injection pipe. The model was then operated for 45 minutes. Discharges used for testing under these conditions were 3 ft^3/s, 9 ft^3/s, and 18 ft^3/s, or maximum discharge if screen capacity was less than 18 ft^3/s.

b. Testing of the different screen seal designs required injection of fish eggs and larvae directly into the areas of the seals. Three standard 3/4-inch-diameter hose sections were installed for injecting eggs and larvae just below the wieir at the outside edge of each half panel. About one-third of the stained sample of fish eggs and larvae were poured into each hose and rinsed down with about 1 quart of water. The model was operated for 45 minutes. Discharges used for testing the seals with the two half-panels were 3 ft^3/s, 9 ft^3/s, and 15 ft^3/s. Maximum discharge was based on the effective screen area outside the seals.

5. Recovery tests were run periodically to confirm the effectiveness of the collection bag/net to capture any eggs or larvae that may have passed the screen. In the recovery tests, 100 stained eggs and 100 stained larvae were released into the water below the screen. After the model had been operated for 45 minutes, the bag and net were rinsed and the test eggs and larvae were removed from the collection cup as described below. Discharge flows for recovery tests were the same as for regular tests.

Sample Removal.--

1. After the model was turned off and allowed to drain, the wooden plankton net frame was slid from beneath the screen. The bag and net were then thoroughly rinsed starting from the bag and working towards the collection cup.

2. The collection cup was placed inside a clean 5-gallon bucket where it was carefully disassembled and rinsed. The fine mesh net in the cup was then rinsed inside the bucket and the contents strained through another 1-foot-square piece of plankton netting to concentrate the eggs and larvae so they could be transferred to a vial and preserved in 10-percent formalin.

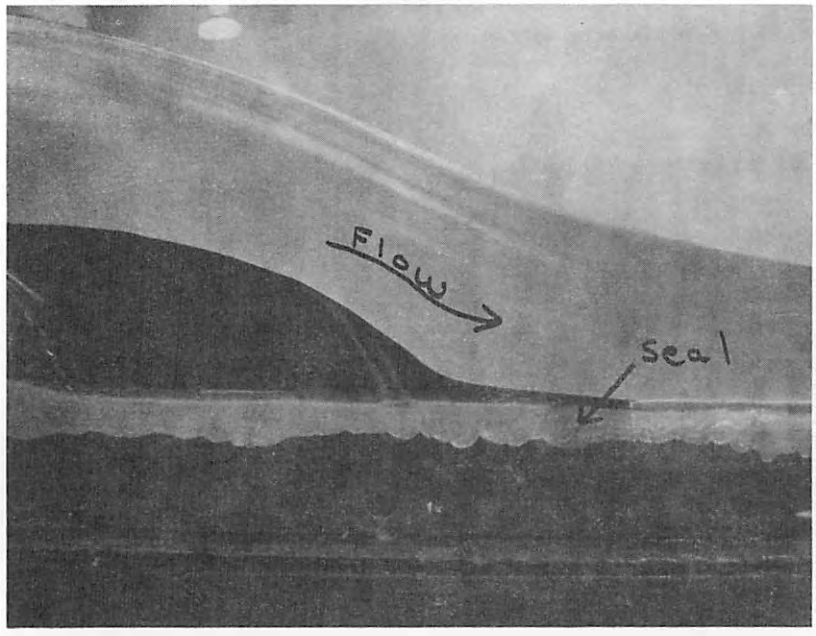
3. The nylon bag and plankton net were then hosed down a second time, using the procedures outlined above.

4. Different color stains were used on the organisms for each test, to distinguish eggs and larvae from previous tests. The net was elevated to dry thoroughly overnight by attaching ropes from a hoist to each corner of the nylon bag's frame and lifting the bag above the model floor. Complete drying would cause a permanent change in the appearance of any organisms that inadvertently remained in the collection net, allowing a positive identification if recovered in a succeeding day's test. Organisms detected this way were noted in the test results. With this procedure, four tests could be made during a normal working day.

Results and Discussion.--The sectional model at the E&R Center was tested with 40-, 50-, 60-, and 70-mesh screens during 1978, 1979, and 1980. The model at the TVA laboratories was tested during 1981 with a 70-mesh screen and live gizzard shad eggs and larvae.

Based on these tests, it was concluded that **a screen system using a 70-mesh screen with pneumatic seals to seal the screen frame to the structure will effectively filter the eggs and larvae of the four species of concern.**

FY 1978 Tests (Smelt and Carp).--For these tests, the screens were sealed to the screen frames with silcone calking. Both Table 5 (rainbow smelt) and Table 6 (common carp) show the passage of eggs and larvae over the range of screen sizes tested. Inconsistency in the data was attributed to passage of organisms through the silicone rubber seal around the upstream and side edges of the model where the receptacle for the screen frame was sealed to the side walls of the model. The large numbers of undamaged eggs and larvae recovered supported to this conclusion. The calking technique to seal the screen frame receptacle was improved for subsequent test years.



SILICONE RUBBER SEAL WHERE SCREEN FRAME RECEPTABLE WAS SEALED TO THE SIDE WALL OF THE SECTIONAL MODEL

Table 5

SECTIONAL MODEL FILTRATION TEST WITH 40-, 50-, AND 60-MESH SCREEN, SILICONE SEAL
(LIVE SMELT EGGS AND LARVAE)

Screen (Mesh)	Date (1978)	Discharge (ft^3/s)	Length of Test (Min.)	Sample Tested 1/		Sample Recovered In Plankton Net						Comments
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae	
40	4-29	18	15	100	100	100	0	0	88	0	0	Recovery test
40	5-1	18	30	5,000	500	24	64	0	2	10	0	
50	5-3	18	120	10,000	1,000,000	400	0	0	36	600	0	Larvae in water supply 2/
50	5-4	18	45	30,000	15,000	464	9	0	31	340	0	
60	5-6	17.6	45	5,000	30,000	17	18	0	20	39	26	
60	5-6	9	45	5,000	30,000	3	13	0	7	8	10	
60	5-8	18	45	0	0	2	3	0	2	2	0	Control test 3/
60	5-9	3	45	30,000	15,000	1	1	0	2	0	2	
60	5-9	12	45	30,000	15,000	20	14	0	40	9	0	Ogee approach resealed
60	5-10	12	45	30,000	15,000	3	0	0	0	0	0	Ogee approach resealed
60	5-11	17	45	10,000	15,000	0	3	0	0	4	3	Resealed
60	5-11	18	15	100	100	90	22	0	104 4/	0	0	Recovery test
60	5-12	3	45	10,000	15,000	0	0	2	1 5/	0	0	
50	5-16	9	45	30,000 6/	50,000 6/	110	112	112	110	118	0	

1/Numbers of organisms introduced into the headbox of the model
2/Many eggs hatched in the incubator during the night of May 3 and larvae found their way into the laboratories recirculating water supply system.
3/A test to determine the thoroughness of the previous net washdown
4/This run shows more larvae recovered than were introduced. The number of larvae introduced were probably miscounted.
5/This whole larva presumably passed by the silicone rubber seals of the receptable for the screen frame.
6/Preserved eggs and larvae

Table 6

SECTIONAL MODEL FILTRATION TEST WITH 40-, 50-, AND 60-MESH SCREEN, SILICONE SEAL
(CARP EGGS AND LARVAE)

Screen (Mesh)	Date (1978)	Discharge (ft^3/s)	Length of Test (Min.)	Sample Tested		Sample Recovered in Plankton Net						Comments
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae	
50	6-16	12	45	2,000 1/	0	0	0	0	0	0	0	
50	6-16	17	45	4,000 1/	4,000	0	1	0	0	4	0	
50	6-20	17	45	4,000	3,500 2/	0	0	0	0	0	0	
50	6-21	12	45	4,000	3,500 2/	0	1	0	0	1	0	
50	6-22	3	45	4,000	4,000 2/	0	0	0	0	0	0	
40	6-23	3	90	4,000 2/	4,000 2/	0	many	0	2	>50	1	One larva without tail
40	6-23	18	45	4,000 1/	4,000	2	many	1	0	>120	0	
40	6-26	18	45	4,000 2/	4,000	0	several	0	0	3	1	
40	6-27	18	45	4,000 2,3/	4,000	0	many	0	0	1	0	
60	6-28	17	45	4,000 2,3/	6,000	2	few	0	0	1	0	
60	6-29	3	45	2,000 2/ 2,000 2,3/	4,000	1	several	0	0	0	2	
60	6-30	3	45	4,000 2,3/	4,000	1	0	0	0	0	0	
60	6-30	18	45	4,000 2,3/	4,000 2/	0	0	1	2	0	1	

1/Eyed eggs
2/Preserved
3/Unfertilized eggs

Results of FY 1978 full-scale sectional model testing provided direction for subsequent testing and experience with methods of introducing, collecting, and sampling eggs and larvae.

At this point, the standpipe studies described earlier were actually conducted. Based on results from the standpipe model (refer back to Table 2), it was concluded that a 60-mesh screen was capable of filtering rainbow smelt eggs and larvae. The Task Force decided to go one size smaller and conduct all future sectional model filtration testing with 70-mesh screen. If the 70-mesh screen was shown to be effective in the sectional model, testing would continue to determine hydraulic efficiency, to develop seal design, determine self-cleaning characteristics, and to develop mechanical cleaning concepts.

FY 1979 Tests (Smelt).--As shown in Table 7, 21 test runs with silicone screen seals were conducted using approximately 210,000 smelt eggs and 210,000 smelt larvae with the 70-mesh screen. No whole eggs or larvae passed the screen. Only one headless larva was collected in the plankton net. **With this verification of the filtration efficiency of the 70-mesh screen, subsequent testing concentrated on development of the seal design.**

To increase the lineal feet of seal available for testing and to provide a panel-to-panel connection, two one-half size (1.5-foot wide) screen panels were installed in the 3-foot wide sectional model frame. A compression-type seal was used and 24 test runs were made with approximately 205,000 smelt eggs and 240,000 smelt larvae (see Table 8). In 23 out of 24 tests, no whole eggs or larvae were recovered. In the third test run conducted on January 9, several whole eggs and larvae were recovered in the plankton net under the 70-mesh screen. These specimens apparently had passed through an area where the screen frame receptacle was inadequately sealed to the side wall of the model. This problem was similar to the one experienced in 1978 and the testing was suspended until the receptacle was recalked. In subsequent test runs, no whole eggs or larvae passed the screen or seals.

Twelve recovery runs were conducted during this series of tests with the 1.5-foot-wide screen panels. As shown on Table 8, when 100 eggs and 100 larvae were introduced below the screen directly into the collection bag and plankton net, recovery was usually less than 100 percent. In low discharge recovery runs, recovery was generally less than for the higher discharges. This pattern was typical for all recovery runs with the sectional model.

The reduced organism recovery probably resulted from disintegration of the organisms in the turbulent flow in and around the collection bag and plankton net. At low discharge runs, the bottom of the watertight collection bag would float just below the water level in the outlet channel which may have increased turbulence or caused more "battering" of eggs and larvae than at runs with higher discharge rates. In a portion of the tests, straps were used to hold the bag to the bottom of the outlet channel.

Table 7

SECTIONAL MODEL FILTRATION TEST - 70-MESH SCREEN, SILCONE SEAL
(PRESERVED SMELT)

Screen Size	Date	Discharge (ft^3/s)	Length of Test (Min.)	Approx. Sample Size		Number of Organisms Recovered In Plankton Net						Stain[1/]
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae	
70	11/02/78	13.6	45	10,000 2/	10,000	0	0	0	0	0	0	Blue
70	11/03/78	13.9	45	10,000 2/	10,000	0	0	0	0	0	0	Red
70	11/06/78	14.6	45	10,000 2/	10,000	0	0	0	0	0	0	Green
70	11/06/78	14.6	45	10,000 2/	10,000	0	0	0	0	0	0	Blue
70	11/07/78	14.8	45	10,000	10,000	0	0	0	0	0	0	Red
70	11/08/78	15.6	45	10,000	10,000	0	0	0	0	0	0	Green
70	11/08/78	15.9	45	10,000	10,000	0	0	0	0	0	0	Blue
70	11/28/78	3	45	10,000	10,000	0	0	0	0	0	0	Blue
70	11/29/78	3	45	10,000	10,000	0	0	0	0	0	0	Red
70	11/29/78	3	45	10,000	10,000	2 3/	0	0	0	0	0	Green
70	11/30/78	3	45	10,000	10,000	0	0	0	0	0	0	Blue
70	11/30/78	3	45	10,000	10,000	0	0	0	0	1	0	Red
70	12/01/78	3	45	10,000	10,000	0	0	0	0	0	0	Green
70	12/01/78	3	45	10,000	10,000	0	0	0	0	0	0	Blue
70	12/04/78	9	45	10,000	10,000	0	0	0	0	0	0	Red
70	12/04/78	9	45	10,000	10,000	0	0	0	0	0	0	Green
70	12/05/78	9	45	10,000	10,000	0	0	0	0	0	0	Blue
70	12/05/78	9	45	10,000	10,000	0	0	0	0	0	0	Red
70	12/06/78	9	45	10,000	10,000	0	0	0	0	0	0	Green
70	12/06/78	9	45	10,000	10,000	0	0	0	0	0	0	Blue
70	12/07/78	9	45	10,000	10,000	0	0	0	0	0	0	Red

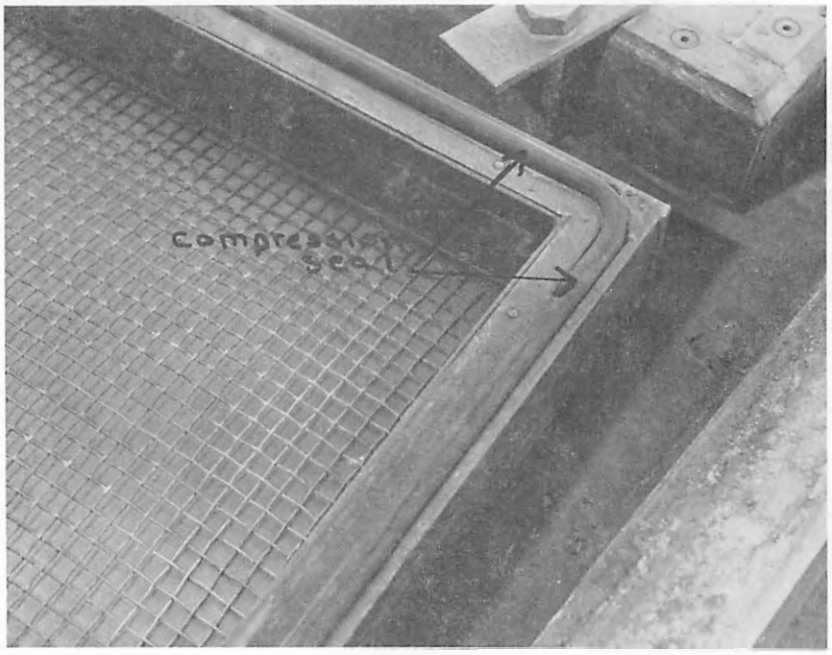
1/Eggs and larvae were stained to detect and assess contamination by organisms from previous runs
2/Fertilized eggs, all other eggs unfertilized
3/Two whole eggs were recovered from this sample. They were dyed red and, therefore, were considered as contamination from the previous run. Some splashing may have occurred during screen washing.

Table 8

SECTIONAL MODEL FILTRATION TEST - 70-MESH SCREEN, TWO HALF PANELS (COMPRESSION SEAL)
(PRESERVED SMELT EGGS AND LARVAE)

Screen Size	Date	Discharge (ft^3/s)	Length of Test (Min.)	Approx. Sample Size		Number of Organisms Recovered In Plankton Net						Stain
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae	
70	01/03/79	3	45	5,000*	10,000	0	0	1	0	1	0	Red
70	01/03/79	3	45	5,000*	10,000	0	0	0	0	1	0	Red
70 1/	01/09/79	3	45	1,000**	10,000	30	0	2	31	11	1	Green
70	01/16/79	3	45	5,000**	10,000	2 2/	0	0	0	0	0	Blue
70	01/17/79	3	45	1,000**	10,000	0	0	0	0	0	0	Violet
70	01/18/79	3	45	5,000**	10,000	0	0	0	0	0	0	Brown
70	01/18/79	3	45	5,000**	10,000	0	0	0	0	0	0	Green
70	01/19/79	3	45	5,000**	10,000	0	0	0	0	0	0	Red
70	01/22/71	3	45	1,000*	10,000	0	0	0	0	0	0	Violet
70	01/22/79	3	45	1,000*	10,000	0	0	0	0	0	0	Red
70	01/24/79	9	45	5,000**	10,000	0	0	0	0	4	0	Violet
70	01/25/79	9	45	1,000*	10,000	0	0	0	0	0	0	Red
70	01/26/79	9	45	1,000*	10,000	0	0	0	0	0	0	Green
70	01/29/79	9	45	1,000*	10,000	0	0	0	0	0	0	Blue
70	01/30/79	9	45	1,000*	10,000	0	0	0	0	0	0	Red
70	01/30/79	9	45	1,000*	10,000	0	0	0	0	0	0	Green
70	01/30/79	9	45	1,000*	10,000	0	0	0	0	0	0	Blue
70	02/01/79	15	45	1,000*	10,000	0	0	0	0	2	0	Violet
70	02/02/79	15	45	1,000*	10,000	0	0	0	0	0	0	Blue
70	02/02/79	15	45	1,000*	10,000	0	0	0	0	0	0	Green
70	02/02/79	15	45	1,000*	10,000	0	0	0	0	0	0	Red
70	02/05/79	15	45	1,000*	10,000	0	0	0	0	0	0	Blue
70	02/05/79	15	45	1,000*	10,000	0	0	0	0	0	0	Red
70	02/06/79	15	45	1,000*	10,000	0	0	0	0	0	0	Blue
70	01/02/79	3	45	3/*	3/	100	0	0	73	27	2	Red
70 4/	01/04/79	3	45	3/**	3/	83	0	10	77	18	0	Blue
70	01/17/79	3	45	3/**	3/	98	5	0	82	18	0	Blue
70	01/19/79	3	45	3/**	3/	99	1	0	71	25	0	Green
70	01/25/79	9	45	3/*	3/	100	0	0	85	12	0	Green
70	01/31/79	9	45	3/*	3/	100	0	0	98	3	0	Red
70	02/01/79	15	45	3/**	3/	98	0	0	99	2	0	Red
70	02/06/79	15	45	3/*	3/	99	0	0	95	5	0	Red
70 (cup)	02/09/79 5/	3	45	3/*	3/	60	0	1	54	0	0	Red
70 (net)	02/09/79	3	45			29	0	0	34	2	0	
						89	0	1	88	2	0	
70 (cup)	02/09/79	3	45	3/**	3/	32	0	0	19	0	0	Blue
70 (net)	02/09/79	3	45			51	0	0	64	1	0	
						83	0	0	83	1	0	

1/Test organisms introduced onto seal areas
2/Two green eggs recovered from previous test. Resealing of upper portion as done previous to this test.
3/Recovery test-Introduced 100 eggs and 100 larvae under the screen panel
4/Small holes in net above plankton net
5/Recovery tests of unwashed net. Introduced 100 eggs and 100 larvae under the screen panel. This test was to determine if washing the net is accounting for a large percentage of headless larvae appearing during a normal recovery run. Only the lower 0.3 m of the net was rinsed.
* Unfertilized eggs
**Fertilized eggs



CLOSE-UP VIEW OF PANEL WITH COMPRESSION SEAL

No whole eggs or larvae were identified as having passed the compression seals during testing in the sectional model. However, after working with and using the compression seals, it was not certain that an adequate seal could always be obtained. The actual seal contact area was small and the entire seal system was considered rather inflexible. With compression seals, it might be difficult to accommodate any minor structural irregularities or minor shifting of the screen frame receptacle. The task force also felt that a seal could be developed that would more closely comply with their "simple and foolproof" criteria for a fish screen structure.

A rubber inflatable seal was subsequently designed and tested in the model. The design called for a continuous rubber rectangular seal (similar to a narrow tire innertube) that could be set in the screen frame perimeter and inflated with air after the frame was set in the model (see seal detail in Figure 6). However, rectangular seals required special fabrication and were not readily available for testing. Preliminary testing was done with an oval-shaped seal pending delivery of the rectangular seal. A full-size screen panel (3' x 12.5') was used for testing inflatable seals.

Twenty test runs using approximately 115,000 smelt eggs and 200,000 smelt larvae were conducted with the oval seal (Table 9). **In these tests, no eggs or larvae passed the screen and seal.**

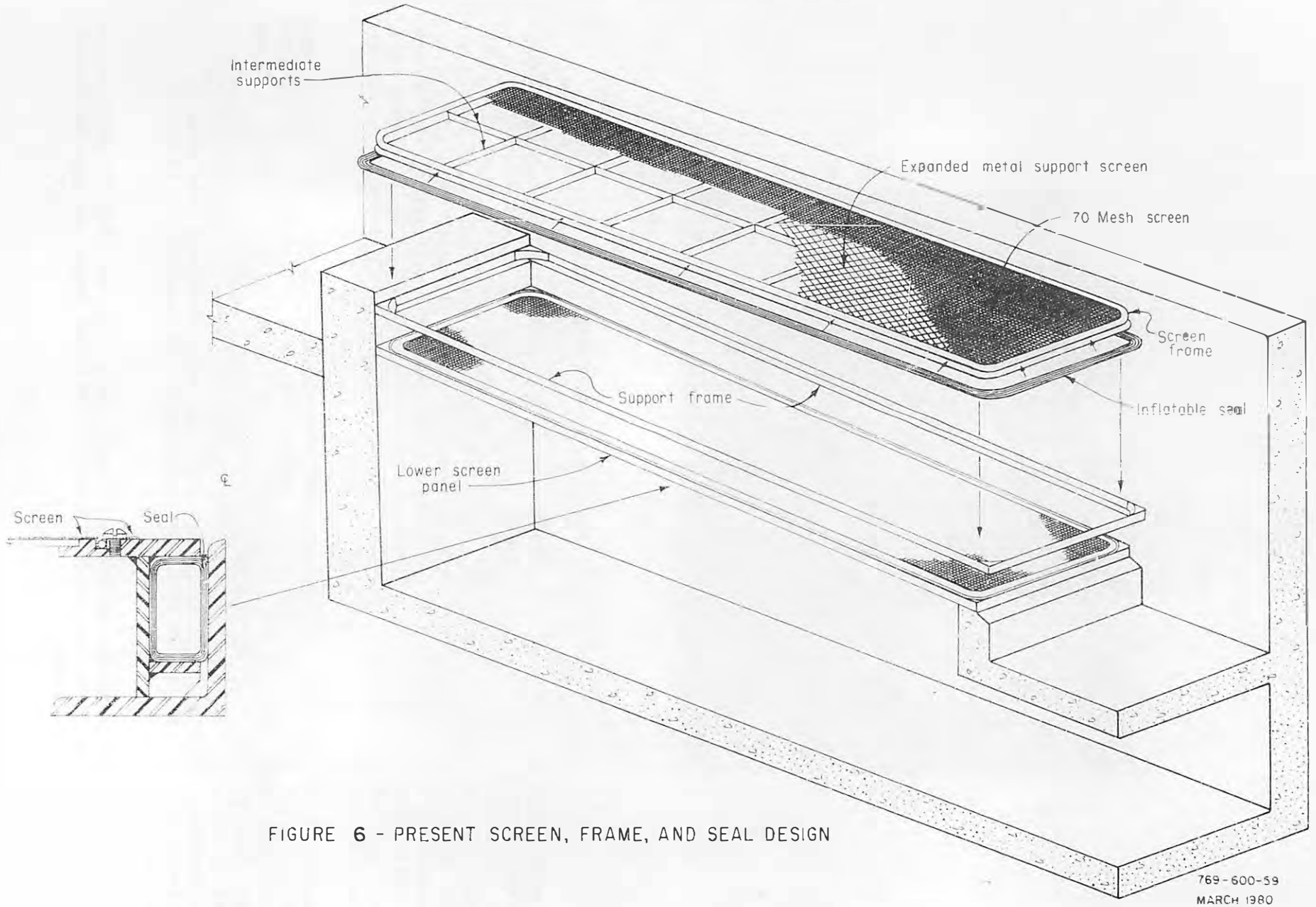


FIGURE 6 - PRESENT SCREEN, FRAME, AND SEAL DESIGN

Table 9

SECTIONAL MODEL FILTRATION TEST - 70-MESH SCREEN, OVAL INFLATABLE SEAL
(PRESERVED SMELT EGGS AND LARVAE)

Screen Size	Date	Discharge (ft^3/s)	Length of Test (Min.)	Approx. Sample Size		Number of Organisms Recovered in Plankton Net						Stain
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae	
70	05/09/79 1/	15	45	10,000	10,000	0	0	0	0	0	0	Methylene Blue
70	05/10/79 2/	9	45	10,000	10,000	0	0	0	0	0	0	Neutral Red
70	05/11/79	3	45	10,000	10,000	0	0	0	0	0	0	Methylene Blue
70	05/11/79	9	45	10,000	10,000	0	0	0	0	0	0	Neutral Red
70	05/12/79	3	45	10,000	10,000	0	0	0	0	0	0	Janus Green B
70	05/12/79	15	45	10,000	10,000	0 3/	0	0	0 3/	0	0	Toluidine Blue 0
70	05/14/79	3	45	10,000	10,000	2 3/	0	0	3 3/	0	0	Neutral Red
70	05/14/79	15	45	10,000	10,000	0	0	0	0	0	0	Toluidine Blue 0
70	05/14/79	9	45	10,000	10,000	0	0	0	0	0	0	Janus Green B
70	05/16/79	9	45	10,000	10,000	0	0	0	1 4/	0	0	Neutral Red
70	05/16/79	15	45	7,000	10,000	0	0	0	0	0	0	Methylene Blue
70	05/16/79	3	45	0	10,000	0	0	0	0	0	0	Janus Green B
70	05/17/79	3	45	0	10,000	0	0	0	0	0	0	Neutral Red
70	05/17/79	9	45	5,000	10,000	0	0	0	0	0	0	Janus Green B
70	05/17/79	15	45	500	10,000	0	0	0	0	0	0	Toluidine Blue 0
70	05/17/79	15	45	0	10,000	0	0	0	0	0	0	Neutral Red
70	05/18/79	3	45	0	10,000	0	0	0	0	0	0	Janus Green B
70	05/18/79	9	45	0	10,000	0	0	0	0	0	0	Toluidine Blue
70	05/18/79	9	45	3,000	10,000	0	0	0	0	0	0	Neutral Red
70	05/18/79	3	45	0	10,000	0	0	0	0	0	0	Nile Blue A
70	05/15/79	3	45	5/	5/	97	0	0	36	0	0	Neutral Red
70	05/15/79	9	45	5/	5/	99	0	0	96	0	0	Methylene Blue
70	05/16/79	15	45	5/	5/	8	0	89	95	3	2 pc=1	Janus Green B

1/ We observed another tear in the collection bag in the vicinity of the previous tear. Dan King suggested that we count this run, but note that a 1-inch tear occurred.

2/ Net seemed to hold up well enough; did not rip again.

3/ The eggs and larvae recovered in this run were not stained red and were determined to be from the side of the bucket used to collect and concentrate the material in the plankton net. This same bucket was used to collect material in the 15 ft^3/s run, and the larvae adhering to the sides were noticed after the second bucket of collected material was strained through plankton netting.

4/ The one larva was stained a dark green and was determined to be from the previous run.

5/ Recovery test-introduced 100 eggs and 100 larvae under the screen panel.

Two whole eggs and three whole larvae collected from one run and one whole larva collected from another run were left over from previous recovery runs (the technique of using alternate stains from test to test proved invaluable in identifying the origin of collected materials).

When the rectangular inflatable seal became available, the oval seal was replaced. Twenty-one tests were conducted with the rectangular seal using approximately 207,000 Utah chub eggs and 207,000 rainbow smelt larvae (Table 10). **No whole eggs or larvae were identified as having passed the screen or seals in the 21 test runs.**

FY 1980 Tests, Smelt (Utah Chub, Carp, and Gizzard Shad).--Testing of the model, using the 70-mesh screen with a rectangular inflatable seal continued in 1980.

A potential leakage problem past an improperly vulcanized splice in the inflatable seal had been identified. The vulcanized splice was more rigid than other portions of the seal. This was partially resolved by a modification, and can be fully resolved in seals for the McClusky Canal Fish Screen structure.

All four species were used for testing in 1980; however, supplies of eggs and larvae for Utah chub, gizzard shad, and common carp were inadequate to complete testing for those species (Tables 11 and 12). **In the limited number of tests, including the complete series for rainbow smelt, no whole or even pieces of eggs or larvae were recovered below the screen. The 70-mesh screen with inflatable seals was determined to be completely effective in blocking the passage of eggs and larvae. The screen and seal system shown in Figure 6 was recommended for final design.** At that point, it only remained to test for gizzard shad.

FY 1981 Tests (Gizzard Shad).--Sectional model testing in 1981 consisted of filtration testing at the TVA Laboratories using live gizzard shad larvae. The screen, frame, and seal that was used at the E&R Center was also used at the TVA model.

In 21 filtration runs at three different discharges, eight damaged gizzard shad larvae were found in the examined debris (Table 13). These eight damaged larvae were all found in the debris collected during high (12.3 ft^3/s) discharge runs, examined under a binocular dissecting microscope without any prior sample cleanup. No whole, undamaged larvae were found in any of the runs and no damaged larvae were found in the debris from low or medium discharge runs after the collected debris was cleaned up by rinsing over an 80-mesh screen to remove silt and other finer debris.

Two recovery runs were conducted at each of the three discharges. The number of larvae recovered ranged from 39 to 94 (Table 13). All but one larva were damaged either by loss of the yolk sac or damage to the head or both. In the six recovery runs, only one whole larva out of 600 was recovered. This indicates that gizzard shad larvae are relatively easily damaged in turbulent flow. These findings also indicate that, if shad larvae should enter the turbulent flow at a field fish screen, they will likely be damaged.

Table 10

SECTIONAL MODEL FILTRATION TEST - 70-MESH SCREEN, RECTANGULAR INFLATABLE SEAL
(PRESERVED SMELT LARVAE AND CHUB EGGS)

Screen Size	Date	Discharge (ft^3/s)	Length of Test (Min.)	Approx. Sample Size		Number of Organisms Recovered In Plankton Net						Stain
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae	
70	07/11/79	3	45	10,000	10,000	0	0	0	0	0	0	Toluidine Blue
70	07/11/79	9	45	10,000	10,000	0	0	0	0	0	0	Malachite Green
70	07/11/79	9	45	10,000	10,000	0	0	0	0	0	0	Neutral Red
70	07/12/79	16.5	45	10,000	10,000	1 1/	0	0	0	0	0	Malachite Green
70	07/12/79	3	45	10,000	10,000	0	0	0	0	0	0	Neutral Red
70	07/12/79	3	45	10,000	10,000	0	0	0	0	0	0	Nile Blue A
70	07/13/79	9	45	10,000	10,000	0	0	0	0	0	0	Malachite Green
70	07/13/79	16.5	45	10,000	10,000	0	0	0	0	0	0	Neutral Red
70	07/13/79	9	45	10,000	10,000	0	0	0	0	0	0	Nile Blue A
70	07/17/79	16.5	45	10,000	10,000	0	0	0	0	0	0	Neutral Red
70	07/17/79	3	45	10,000	10,000	1 2/	0	0	0	0	0	Toluidine Blue
70	07/17/79	3	45	10,000	10,000	0	0	0	0	0	0	Green
70	07/18/79	9	45	10,000	10,000	0	0	0	0	0	0	Toluidine Blue
70	07/18/79	16.5-4.5 3/	45	7,000	7,000	0	0	0	0	0	0	Neutral Red
70	07/18/79	16.5	45	10,000	10,000	0	0	0	0	0	0	Fast Green
70	07/19/79	3	45	10,000	10,000	0	0	0	0	0	1 4/	Toluidine Blue
70	07/19/79 5/	9	45	10,000	10,000	0	0	0	0	0	0	Neutral Red
70	07/20/79 6/	16.5	45	10,000	10,000	0	0	0	0	0	0	Fast Green
70	07/20/79 7/	16.5	45	10,000	10,000	0	1 8/	0	0	0	4 9/	Toluidine Blue
70	07/20/79	3	45	10,000	10,000	0	0	0	0	0	1 10/	Neutral Red
70	07/23/79	9	45	10,000	10,000	0	0	0	0	0	0	Fast Green
70	07/16/79	16.5	45	11/	11/	97	2	0	83	15	2 12/	Nile Blue A
70	07/16/79	9	45	11/	11/	98	0	0	93	8	2 12/	Neutral Red
70	07/16/79	3	45	11/	11/	98	0	1	82	11	0	Malachite Green
70	07/23/79	3	45	11/	11/	99	0	4 13/	88	11	0	Neutral Red
70	07/24/79	9	45	11/	11/	98	0	10 14/	98	2	0	Nile Blue A
70	07/24/79	16.5	45	11/	11/	100	0	0	88	8	0	Fast Green
						1 15/						

1/Red egg apparently from screen washdown after the July 11, 9 ft^3/s run.
2/Green egg apparently from 3 ft^3/s recovery run of 07/16/79
3/During injection of organisms into the headbox, the flow suddenly slowed down due to a burned out pump. The estimated flow was, therefore, 4.5 ft^3/s. Hiebert only injected about two-thirds of stained, prepared egg and larvae samples, but the test run was conducted for the normal 45 minutes, and the net was washed down as usual. No eggs or larvae were recovered from the plankton net. J. Fitzwater indicated later that a defective pump coupling caused the problem.
4/The damaged (eyeless) larva found in this run was stained red and was likely from the run of 07/18/79 in which the reduced discharge (4.5 ft^3/s) was used.
5/A high discharge was scheduled between the high (16.5 ft^3/s) of 07/18/79 and the low (3 ft^3/s) of 07/19/79. Since the pump was not yet repaired, we could not get 16.5 ft^3/s, so we did the next run in the schedule. This was the 3 ft^3/s run.
6/This run was to make up for the skipped high run above.
7/Regularly scheduled
8/This egg case was broken and misshapen.
9/Four pieces look like pieces of skin from one larva
10/One very small piece of possible larva or egg case
11/Recovery test-introduced 100 eggs and 100 larvae under the screen panel.
12/Small pieces
13/Four pieces of egg cases
14/Ten small pieces of debris from egg cases.
15/This one blue egg was recovered in subsequent 16.5 ft^3/s recovery run. Egg apparently lodged in pocket of net until washed out in next run.

Table 11

SECTIONAL MODEL FILTRATION TESTS, 70-MESH SCREEN, RECTANGULAR INFLATABLE SEAL
(LIVE SMELT EGGS AND LARVAE)

Screen Size	Date	Discharge (ft^3/s)	Length of Test (Min.)	Approx. Sample Size		Number of Organisms Recovered In Plankton Net						Stain	Source
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae		
70	04/21/80	9	45	10,000	--	0	0	0	--	--	--	Neutral Red	North Dakota
70	04/22/80	13	45	10,000	--	0	0	0	--	--	--	Fast Green	North Dakota
70	04/22/80	9	45	10,000	--	0	0	0	--	--	--	Toluidine Blue 0	Noth Dakota
70	04/22/80	3-2.6 1/	45	10,000	--	0	0	0	--	--	--	Neutral Red	North Dakota
70	04/23/80	3	45	10,000	--	0	0	0	--	--	--	Toluidine Blue 0	Michigan
70	05/04/80	15	45	--	10,000	--	--	--	0	0	0	Neutral Red	North Dakota
70	05/06/80	9	45	--	10,000	--	--	--	0	0	0	Toluidine Blue 0	Maine
70	05/06/80	3	45	--	10,000	--	--	--	0	0	0	Fast Green	Maine
70	05/07/80	15	45	--	10,000	--	--	--	0	0	0	Toluidine Blue 0	Maine
70	05/07/80	3	45	--	10,000	--	--	--	0	0	0	Neutral Red	Maine
70	05/07/80	15	45	--	10,000	--	--	--	0	0	0	Fast Green	Maine
70	05/08/80	9	45	--	10,000	--	--	--	0	0	0	Toluidine Blue 0	Maine
70	05/08/80	9	45	--	10,000	--	--	--	0	0	0	Neutral Red	Maine
70	05/08/80	15	45	--	10,000	--	--	--	0	0	0	Fast Green	Maine
70	05/08/80	3	45	--	10,000	--	--	--	0	0	0	Toluidine Blue 0	Maine
70	05/09/80	3	45	--	10,000	--	--	--	0	0	0	Neutral Red	Maine
70	05/09/80	9	45	--	10,000	--	--	--	0	0	0	Fast Green	Maine
70	05/09/80	15	45	--	10,000	--	--	--	0	0	0	Toluidine Blue 0	Maine
70	05/09/80	15	45	--	10,000	--	--	--	0	0	0	Neutral Red	Maine
70	05/10/80	3	45	--	10,000	--	--	--	0	0	0	Fast Green	Maine
70	05/10/80	9	45	--	5,000	--	--	--	0	0	0	Toluidine Blue 0	Maine
70	05/16/80	9	45	--	6,000	--	--	--	0	0	0	Neutral Red	Vermont
70	05/19/80	3	45	--	10,000	--	--	--	0	0	0	Neutral Red	Vermont
70	04/23/80	15	45	2/	--	82	--	10	--	--	--	Neutral Red	Michigan
70	04/23/80 3/	9	45	2/	--	92	12 4/	4	--	--	--	Fast Green	Michigan
70	04/24/80	3	45	2/	--	91	--	8	--	--	--	Neutral Red	Michigan
70	05/03/80	15	45	--	2/	--	--	--	34	55	--	Neutral Red	North Dakota
70	05/03/80	9	45	--	2/	--	--	--	53	29	--	Toluidine Blue 0	North Dakota
70	05/03/80	3	45	--	2/	--	--	--	84	8	--	Toluidine Blue 0	North Dakota
70	05/04/80	15	45	--	2/	--	--	--	59	30	--	Toluidine Blue 0	North Dakota
70	05/04/80	9	45	--	2/	--	--	--	81	13	--	Fast Green	North Dakota
70	05/15/80	9	45	2/	--	--	--	--	64	13	--	Neutral Red	Vermont
70	05/15/80	15	45	2/	--	--	--	--	57	29	--	Toluidine Blue 0	Vermont
70	05/16/80	3	45	2/	--	--	--	--	68	14	--	Fast Green	Vermont

1/During the 45-minute run, the flow gradually decreased to 2.6 ft^3/s.
2/Recovery test-introduced 100 eggs or larvae under the screen panel.
3/After this run, during washdown, a small tear was observed in the watertight bag near the upper rear corner. The tear was repaired before additional tests were conducted.
4/These 12 pieces were stalk remnants from egg cases.

Table 12

SECTIONAL MODEL FILTRATION TESTS, 70-MESH SCREEN, RECTANGULAR INFLATABLE SEAL
(LIVE CHUB, CARP, AND SHAD EGGS AND LARVAE)

Screen Size	Date	Discharge (ft^3/s)	Length of Test (Min.)	Approx. Sample Size		Number of Organisms Recovered In Plankton Net						Stain	Source
				Eggs	Larvae	Whole Eggs	Egg Cases	Damaged Eggs	Whole Larvae	Headless Larvae	Damaged Larvae		
					Utah Chub								
70	03/25/80	9	45	10,000	10,000	0	0	0	0	0	0	Neutral Red	Wyoming
70	05/30/80	15	45	10,000	--	0	0	0	0	0	0	Toluidine Blue O	Wyoming
70	06/05/80	3	45	10,000	10,000	0	0	0	0	0	0	Neutral Red (Larv) Fast Green (Eggs)	Wyoming
70	07/10/80	9	45	10,000	--	0	0	0	--	--	--	Neutral Red	Wyoming
70	07/14/80	9	45	--	8,000	--	--	--	0	0	0	Neutral Red	Wyoming
70	07/14/80	9	45	--	1/	--	--	--	93	--	--	Fast Green	Wyoming
70	07/14/80	15	45	--	1/	--	--	--	93	--	--	Toluidine Blue O	Wyoming
70	07/14/80	3	45	--	1/	--	--	--	83	--	--	Neutral Red	
					Carp								
70	06/16/80	3	45	10,000	--	0	0	0	--	--	--	Toluidine Blue O	Colorado
70	06/16/80	15	45	10,000	--	0	0	0	--	--	--	Neutral Red	Colorado
70	06/16/80	9	45	10,000	--	0	0	0	--	--	--	Fast Green	Colorado
70	06/17/80	9	45	10,000	--	0	0	0	--	--	--	Toluidine Blue O	Colorado
70	06/17/80	3	45	10,000	--	0	0	0	--	--	--	Neutral Red	Colorado
70	07/17/80	15	45	1/	--	69	--	12	--	--	--	Neutral Red	Colorado
70	07/17/80	3	45	1/	--	79	--	10	--	--	--	Toluidine Blue O	Colorado
70	07/17/80	9	45	1/	--	91	--	0	--	--	--	Fast Green	Colorado
					Gizzard Shad								
70	06/13/80	15	45	10,000	--	0	0	0	--	--	--	Neutral Red	Colorado
70	06/13/80	9	45	10,000	--	0	0	0	--	--	--	Fast Green	Colorado
70	06/13/80	3	45	10,000	--	0	0	0	--	--	--	Neutral Red	Colorado

1/Recovery test-introduced 100 larvae under the screen panel

Table 13

TVA SECTIONAL MODEL FILTRATION TESTS - 70-MESH SCREEN, RECTANGULAR INFLATABLE SEAL
(LIVE GIZZARD SHAD LARVAE)

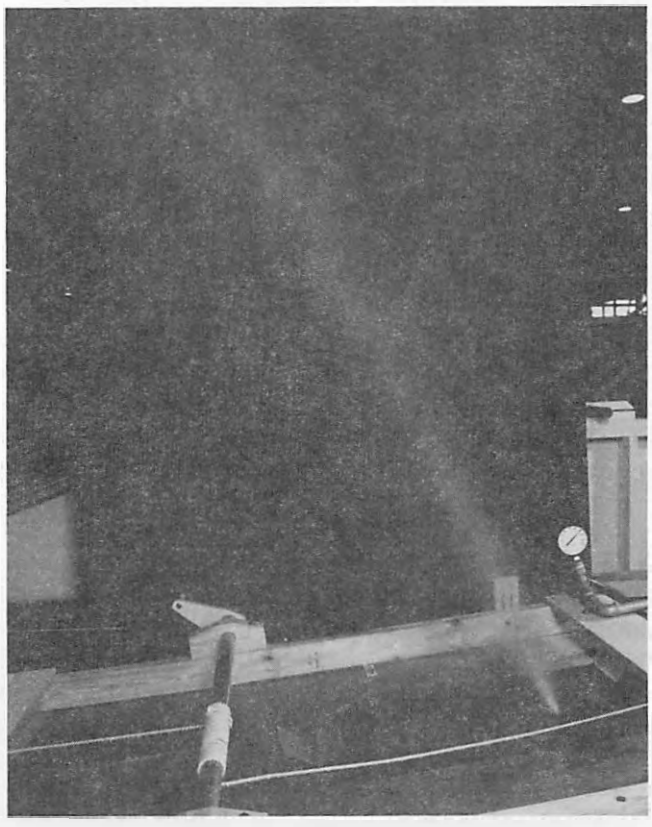
Date (1981)	Time	Length of Test (Min)	Discharge ft^3/s	Larval Age	Sample Size	Stain	Organisms Recovered In Plankton Net: Whole Larvae	Headless Larvae	Damaged Larvae	Remarks
4-30	1430		9.0	--	5,000	Toluidine Blue O	0	0	0	
	1625	45	12.3	< 36 h	5,000	Fast Green	0	0	1	+ 14 yolk sacs
	1750	45	12.3	< 36 h	5,000	Neutral Red	0	0	0	
	1915	45	12.3	< 36 h	9,000	Toluidine Blue O	0	0	0	
5-1	1300	45	12.3	< 24 h	5,000	Nile Blue A	0	0	6	
	1415	45	12.3	< 24 h	5,000	Neutral Red	0	0	1	A possible fragment
	1530	45	12.3	< 24 h	4,000	Fast Green	0	0	0	
	1645	45	12.3	< 24 h	5,000	Nile Blue A	0	0	0	
	1800	45	9.0	< 24 h	5,000	Neutral Red	0	0	0	
	1915	45	9.0	< 60 h	10,000	Toluidine Blue O	0	0	0	
5-4	1600	45	9.0	5 d	--	Fast Green	0	0	0	
5-5	1615	45	9.0	< 48 h	5,000	Fast Green	0	0	0	
5-6	0840	45	9.0	< 48 h	2,000	Neutral Red	0	0	0	
5-7	0815	45	9.0	< 24 h	5,000	Toluidine Blue O	0	0	0	
	0930	45	3.0	< 24 h	5,000	Fast Green	0	0	0	
	1055	45	3.0	< 24 h	5,000	Neutral Red	0	0	0	
	1210	45	3.0	< 24 h	5,000	Nile Blue A	0	0	0	
	1325	45	3.0	< 24 h	5,000	Fast Green	0	0	0	
	1440	45	3.0	< 24 h	3,000	Neutral Red	0	0	0	
	1600	45	3.0	< 24 h	3,000	Nile Blue A	0	0	0	
	1715	45	3.0	< 24 h	3,000	Fast Green	0	0	0	
4-30	1151	45	9.0	< 24 h	100	Neutral Red	1	--	84	Recovery Run
5-1	2052	45	12.3	< 24 h	100	Neutral Red	--	--	94	" "
5-4	1725	45	9.0	< 24 h	100	Toluidine Blue O	--	--	39	" "
	1905	45	12.3	< 24 h	100	Fast Green	--	--	90	" "
	2035	45	3.0	< 24 h	100	Neutral Red	--	--	47	" "
	2150	45	3.0	< 24 h	100	Toluidine Blue O	--	--	60	" "

No gizzard shad eggs were tested at TVA. All eggs collected were used for production of larvae. Three test runs were conducted in 1980 at the E&R Center with gizzard shad eggs collected in Colorado (refer back to Table 12). No eggs passed the 70-mesh screen in that series of filtration tests.

Screen Cleaning

The sloping screen generally cleans itself of water-borne debris, with the exception of fine material which accumulates in the area of impingement where the flow passing over the weir first contacts the screen. Mechanical cleaning methods to remove this material, to remove potential algal growth, and to flush accumulations of debris at the downstream end of the screen were examined.

Fluctuating the discharge over a short period of time was partially effective in moving material in the impingement zone; however, this may not be practical in the field. A squeegee device, consisting of a moveable underflow weir, was also considered, but it required building up a head on the upstream side, which makes it effective only when very near the weir.



SCREEN CLEANING APPARATUS

A screen cleaning test apparatus was constructed to evaluate air and water spray nozzle configurations. The apparatus consisted of a section of screen set at the same slope as the sectional model with a device to allow spraying with nozzles located varying distances above and below the screen. The spray angle could also be adjusted. Various cleaning arrangements were also tested in the sectional model where the influence of operational flows on the cleaning could be evaluated.

Spray cleaning was investigated in some detail, using the screen cleaning test apparatus. Screen samples were placed in waterways at the Denver Federal Center so that biological growth would occur. In preliminary experiments, material called agar was used as a representation of biological materials which might grow on screens, and sawdust was used to represent accumulation of loose debris on the screen. Tests were conducted without water flowing on the screen; the results indicated that air jets moved more material faster than water jets, but that water jets cleaned the screen fibers more completely. Data were collected on pressures, flow rates, jet angles, and rate of nozzle movement down the screen. Laboratory test results were used to design a manifold nozzle arrangement which was evaluated in the field test facility.

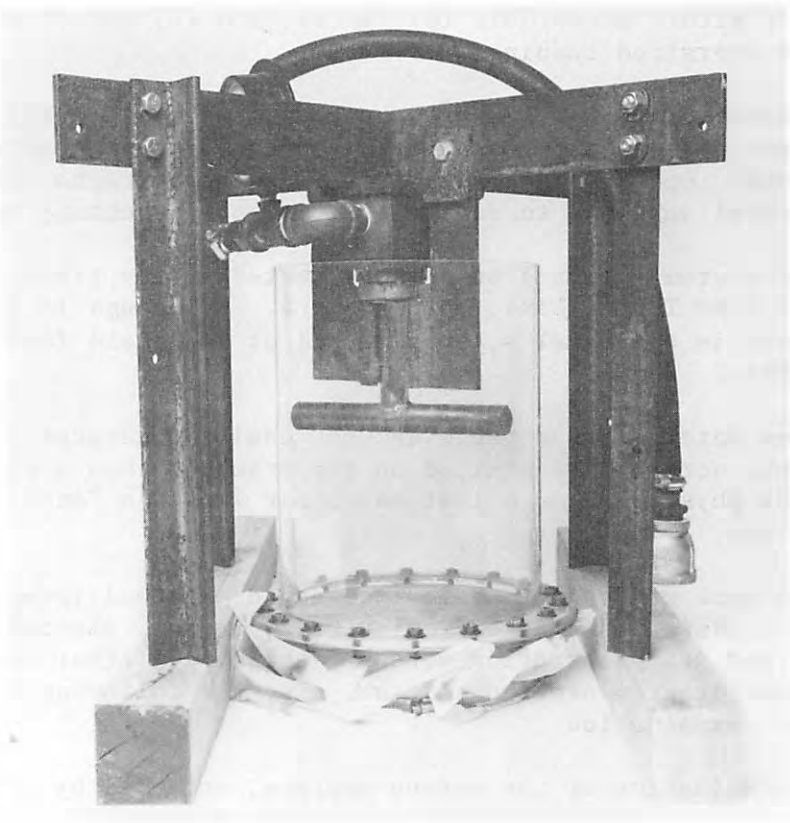
Testing in the sectional model involved defining the required nozzle type, diameter, spacing, angle, and pressure to remove algae and other debris from the screens effectively.

Laboratory results showed that No. 40 nozzles set perpendicular to the screen that created a flat fan-shaped spray, operating at 40 to 50 lb/in^2 with 40-degree divergence in the spray, and mounted 3-3/4 to 4 inches below the screen should be used for cleaning the upper screen. A similar arrangement cleans the lower screen from either the top or underside. The design was further investigated at the field test facility.

A spray-forced filtration apparatus was also constructed to evaluate the effect on eggs and larvae if a screen were cleaned from above. The device used a continuously rotating spray bar directed at a fixed 70-mesh screen to determine if spray cleaning action could push viable eggs and/or larvae through the screen. The device provided a continuous sweeping action of a fan spray across the screen surface.

The spray filtration apparatus was used during FY 1981, with 6 psi water pressure through the rotating spray system. The 6 psi water pressure was selected because it yielded the best operaton of the test device. Egg and larvae samples, which were very fragile, would have been disintegrated immediately if pressure ranges recommended for screen cleaning (40 to 50 psi) were used in the spray filtration apparatus.

This device was tested with both gizzard shad eggs and larvae. Two 45-minute tests were conducted using about 1,000 eggs (24 hours old) each. Within about 1 minute after introducing the eggs into the device, the rotating spray system distributed the eggs fairly uniformly over the 9-inch-diameter 70-mesh screen. Any material forced through the screen was collected in the plankton net below the screen. At the termination of the 45-minute test, this material was gently washed into a laboratory pan for examination for the presence of eggs or egg pieces.



SPRAY-FORCED FILTRATION APPARATUS USED TO FORCE EGGS AND LARVAE THROUGH A 70-MESH SCREEN

In the first 45-minute test, many pieces of eggs were observed in the plankton net. A count of egg pieces was begun, but was discontinued after 225 pieces were counted. Since the egg fragments were of various sizes, there was no way of determining how many eggs the pieces represented. The important point was that no whole, undamaged eggs were observed. All eggs were broken and damaged by passing through the 70-mesh screen. Many egg fragments were observed in the second test run on this device, but no count was made. Again, no whole, undamaged eggs were observed.

About 1,000 recently hatched (less than 12 hours) gizzard shad larvae were used in the seven 45-minute test runs on the spray device on May 29, 1981. For each test run, approximately 100 to 150 larvae were introduced into the spray device. Clumped larval fragments were observed in the plankton net after each test run. The yolk sac was broken off all larvae, and no whole, undamaged larvae appeared in the sample. In addition, larval fragments were also very battered.

Based on these tests, it was concluded that eggs or larvae would be damaged and could not survive if they were forced through a 70-mesh screen.

Verification of Screen Integrity

Methods were developed to (1) verify that screen openings, whether for new or used screens, were within acceptable tolerances, and (2) detect minor screen damage and locate oversized openings.

Examination of magnified photographs of screen was used to verify screen opening size. A system was developed to take before and after photographs of identical areas of the screen. Opening size data from these photographs are then subjected to statistical analysis to determine opening size change trends.

This photographic system was used on screens tested at the field test facility (described later) near Turtle Lake, North Dakota. No change in screen opening size was detectable in the monel screens tested at the field facility during 1979, 1980, and 1981.

The 70-mesh screen material is durable and not easily punctured if handled properly. When the screen is installed on the frame, it has a slick fabric-like appearance and any physical damage that may occur leaves a "dent" in the screen which is easy to see.

A long list of methods to check for minor screen damage and irregularities were investigated. Procedures such as optical-visual, tracer, electrical, sonic, surface tension, and jet penetration were investigated. After considerable discussion and some experimentation and analysis, the following methods were chosen for further examination:

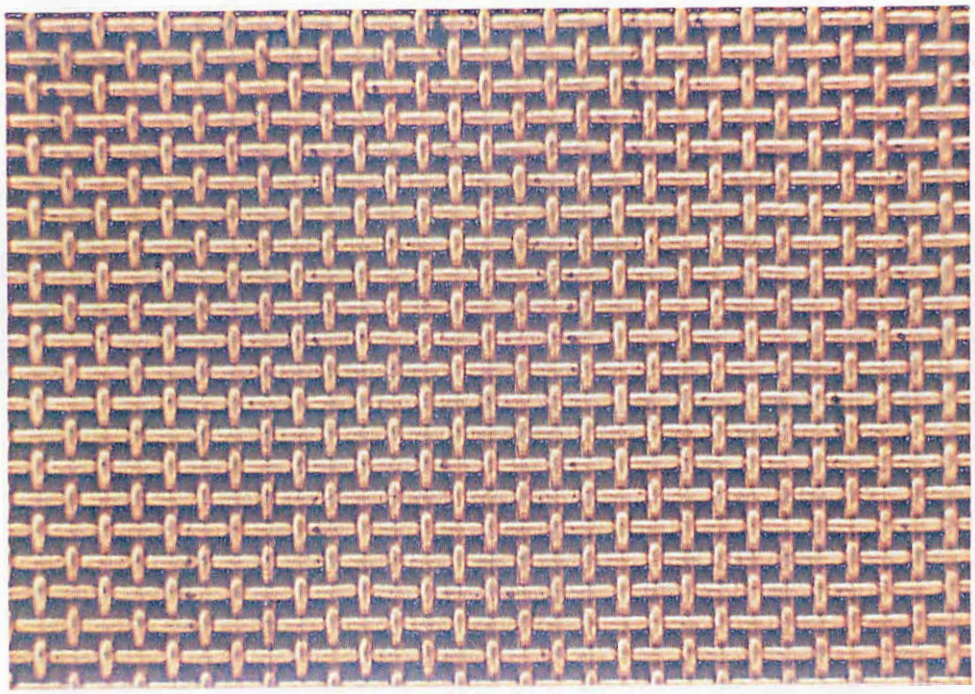
1. Visual examination of the screen surface, enhanced by oblique lighting

2. Videotaped scanning, with subsequent monitoring of the videotape

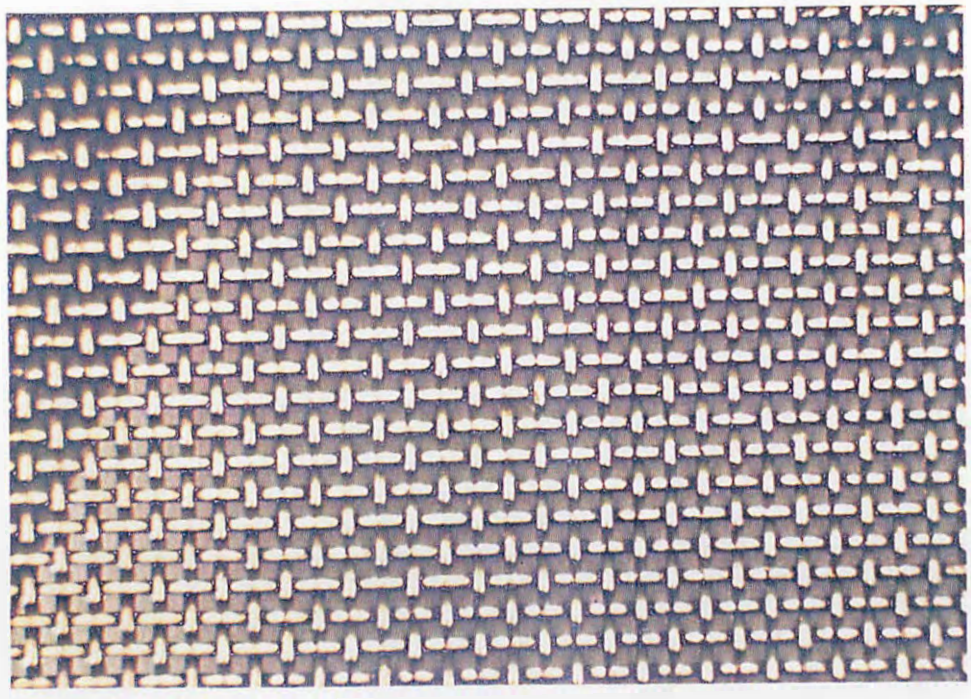
3. Using surface tension to detect irregularities in the screen material

The last method showed enough promise to warrant further investigation. A test tank was made to accommodate a full screen panel. Water was added to the reservoir below the screen in small increments to gradually increase the air pressure under the screen. Inconsistencies in the screen surface appeared as bubbles in a liquid film applied to the upper surface of the screen.

The procedure was modified to simply suspend the screen a few inches below the water surface. Air was introduced under the screen which accumulated and spread out over the underside. If there were any discontinuities in the screen, such as a broken wire, a puncture, or even a slightly enlarged screen opening, air would escape first through these larger openings.

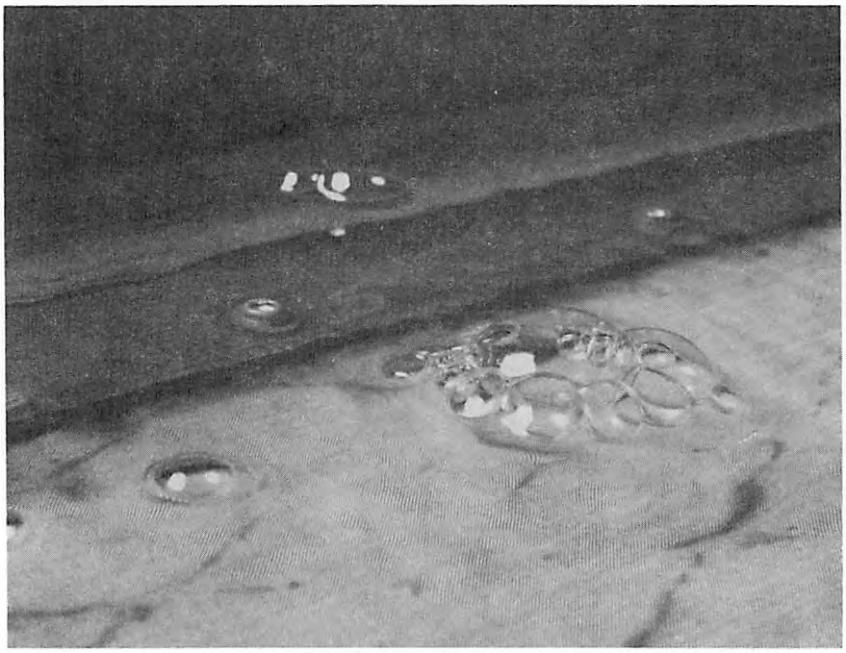


NEW SCREEN



SCREEN AFTER 3 MONTHS USE

MAGNIFIED PHOTOS OF 70-MESH PHOSPHOR BRONZE SCREEN
USED AT THE FIELD TEST FACILITY



AIR BUBBLES WHERE SCREEN WAS INTENTIONALLY DAMAGED

Screen Repair Methods

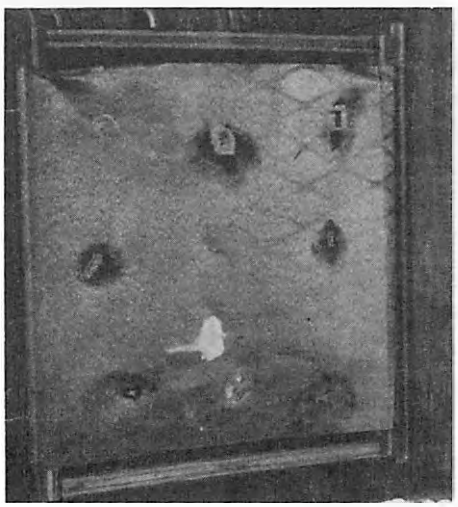
Several repair methods (epoxy, silver solder, and lead-tin solder) were investigated. To test the durability of the repaired screen, samples were placed in a test apparatus which subjected the patch to high velocity water sprays over long periods of time. The epoxy patch did not bond adequately to the screen material. Silver solder patches failed after approximately 400 hours exposure to high-veolocity jet sprays. The silver solder patch required high temperatures for application, which appeared to weaken the wire fabric.

Lead-tin solder patches do not have this problem and have remained viable after 1,000 hours of exposure to the sprays. Therefore, lead-tin solder was tentatively chosen as the screen repair method.

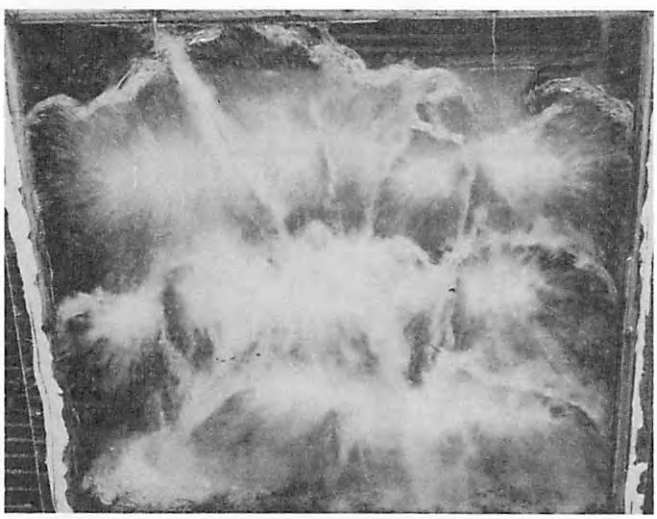
Screen Hold-down Methods

Several methods of attaching the screen fabric to the frame were examined. Initially, the screen was installed by pressing the screen into a square groove in the screen frame perimeter and keeping it in place with round monel rods pressed in the groove with machine screws 5 inches on center (refer back to detail in Figure 6). Other screen installation methods examined are shown on Figure 7.

SCREEN WITH TEST PATCHES



SPRAY NOZZLE ARRANGEMENT



TEST IN PROGRESS

APPARATUS TO EXPOSE SCREEN PATCHES TO HIGH-VELOCITY JETS

Figure 7

ALTERNATIVE RETENTION PLATE PLACEMENT

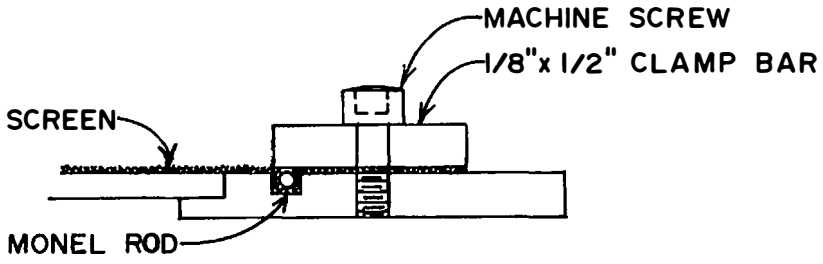


PLATE NO. 1

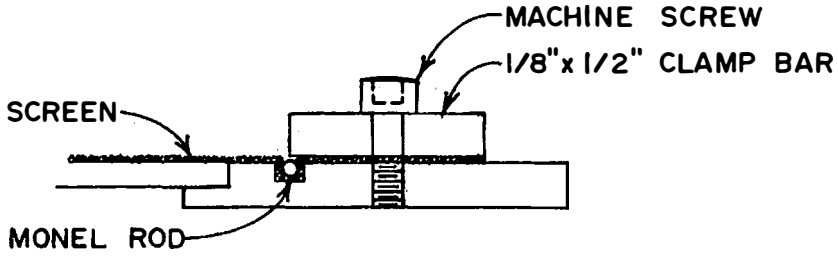


PLATE NO. 2

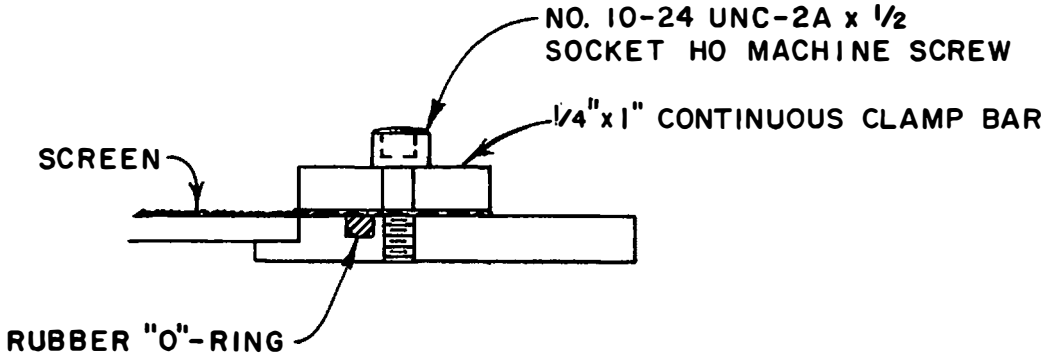
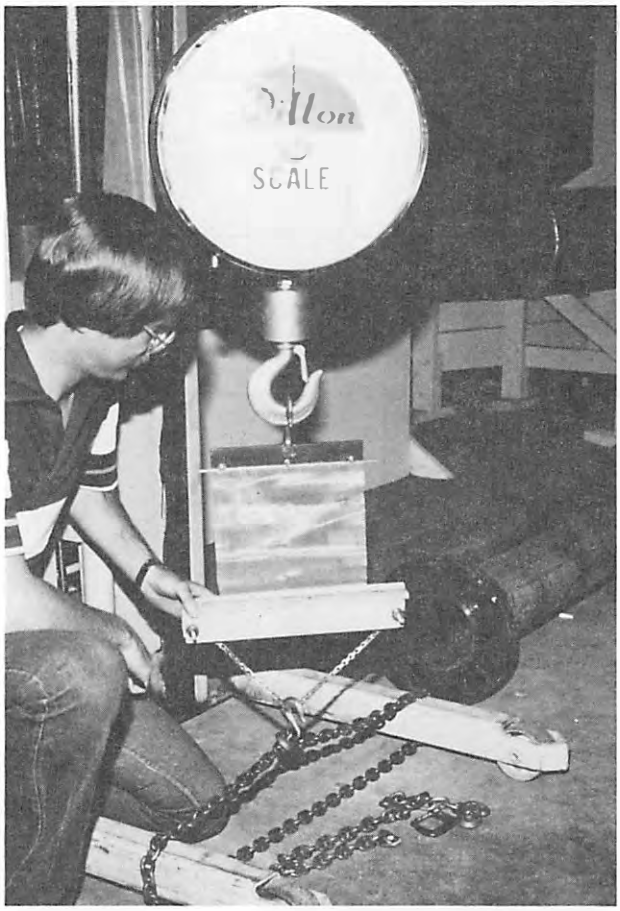


PLATE NO. 3

Observation of screen panels showed that the screen retention rods on the frame tended to bow out of the retaining groove with screw spacings greater than 5 inches on center, causing uncertainty about strength and adequacy of screen retention. Also, the screen tended to shear during installation when pressing it into the square groove.

A test apparatus was assembled to determine the pullout limits for various retention designs in both horizontal (parallel to the plane of the screen) and vertical (perpendicular to the plane of the screen) directions.

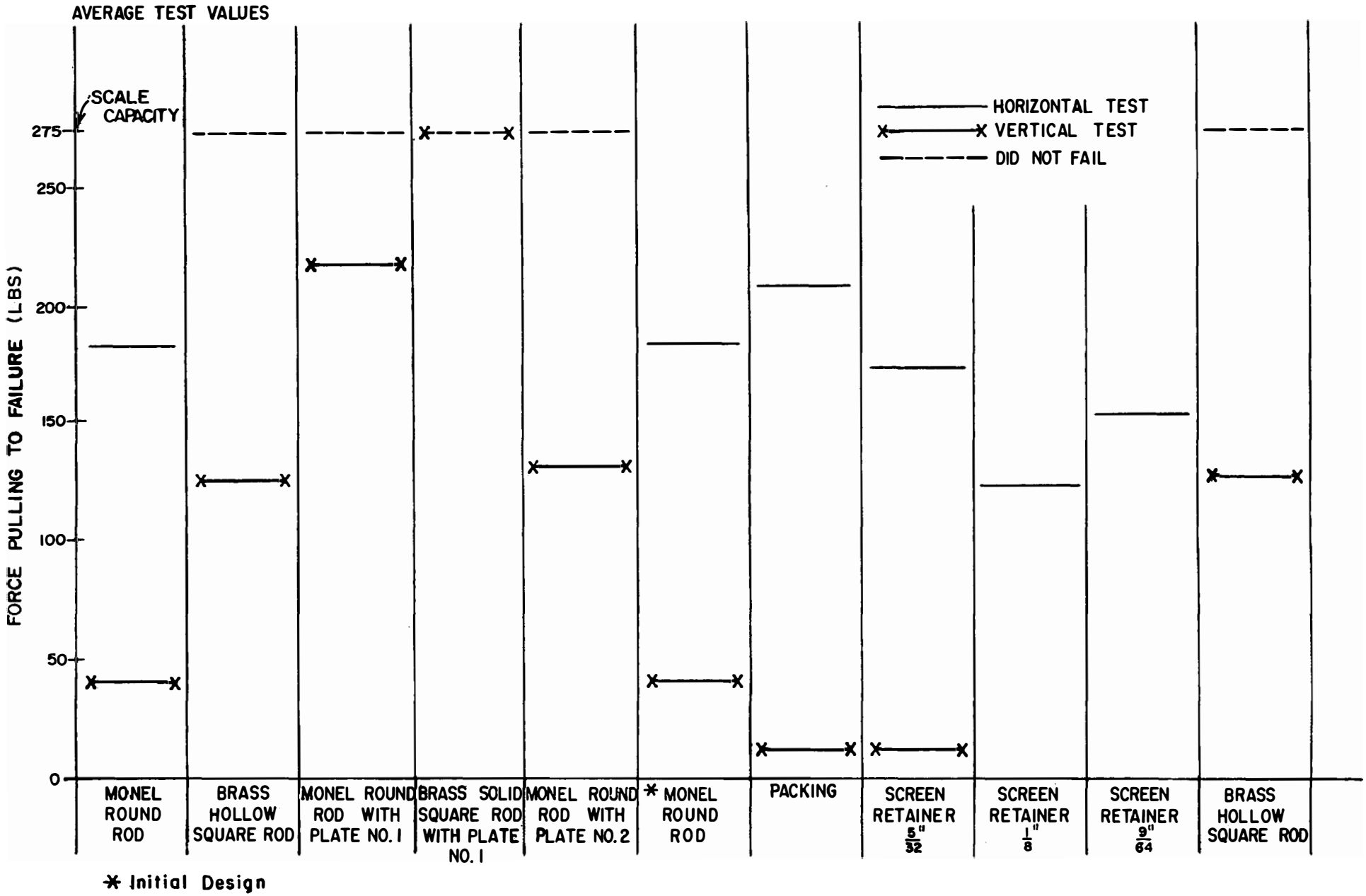


TEST APPARATUS TO DETERMINE PULLOUT LIMITS OF
VARIOUS HOLD-DOWN CONFIGURATIONS

Figure 8 summarizes the test results showing the forces required to pull free a 10-inch-wide piece of retained screen with various hold-down methods. Screen samples were loaded both horizontally and vertically. Horizontal loading is more representative of loading that would occur in full panels. Use of the circular monel rod with retaining screws spaced at approximately 5-inch centers was determined to yield adequate retention strength. Use of this design failed with

FIGURE 8

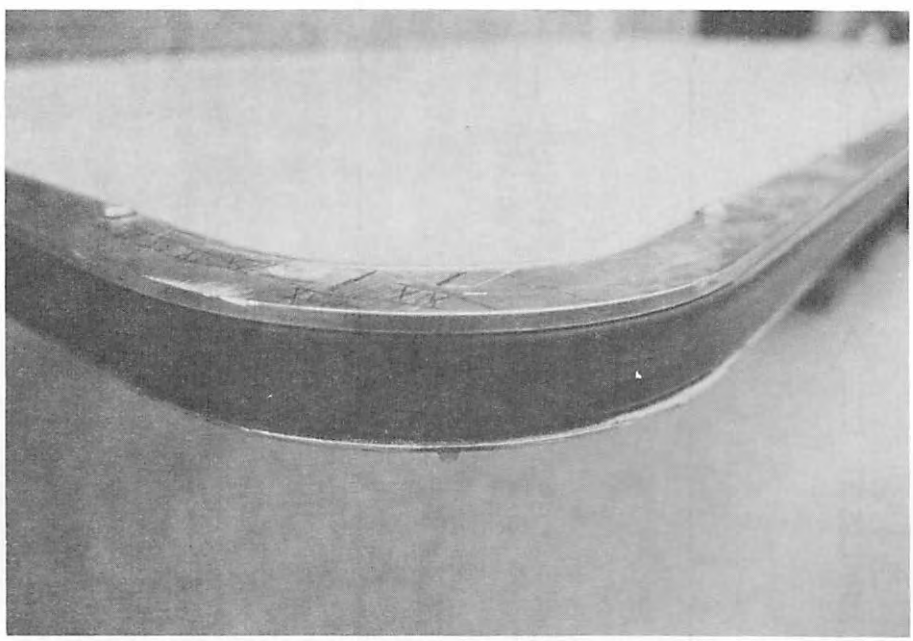
EVALUATION OF THE STRENGTH OF ALTERNATIVE SCREEN RETAINERS



approximately 200 pounds, which was within the acceptable limits with respect to pullout; however, screen installation was slow and difficult. Consequently, the retention configuration shown in plate No. 3 of Figure 7 was developed. This configuration provides a quick and sure way to install the screen and also insures adequate screen retention.

Pneumatic Seal Monitoring

Considerable effort was expended in developing a reliable seal monitoring and alarm system. As seen in the schematic of Figure 9, the system maintains seal pressure, either with compressor operation or with a compressed air tank reservoir, allowing line pressure even in the event of power loss or of compressor failure. Individual seals can be easily connected or disconnected from the air supply line with quick couplings. This allows for easy installation or removal of screen panels. The pressure regulator in the line inflates the seals to optimum pressure. The system would warn of excessive air loss through the entire seal system, and pressure switches would warn of excessive pressure loss at individual seals. Both the pressure and flow switches would activate visual and audible alarms. Pressure switches would function in the event of pressure loss due to either system failure or seal deflation for maintenance. The system includes pressure gages at each seal for monitoring ball and check valves at each seal to isolate individual seals. Though not shown in Figure 9, the top screen system is completely separate from the bottom screen system. In case of loss of pressure in either, the other would remain fully operational.



RECTANGULAR PNEUMATIC SEALS

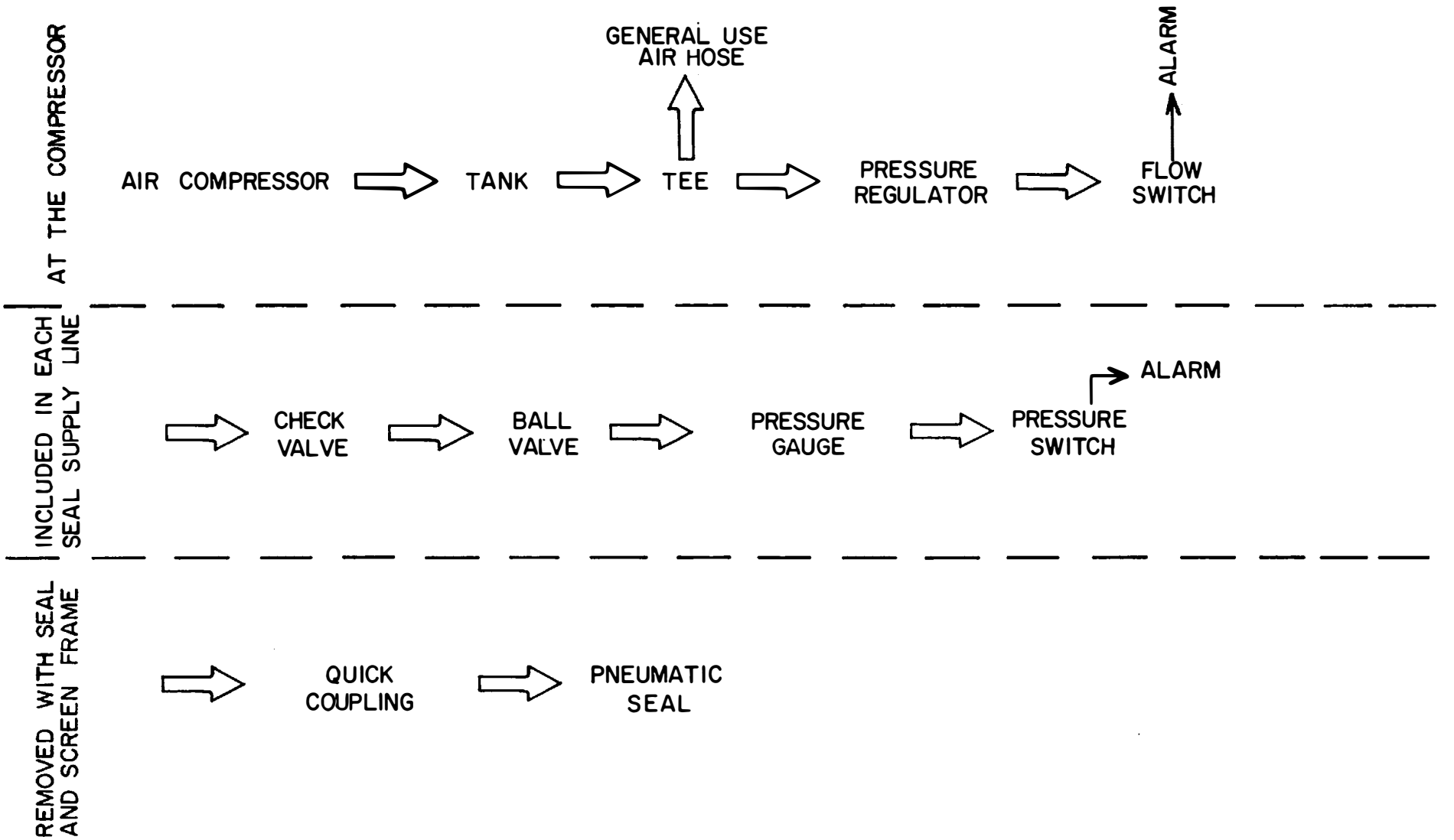
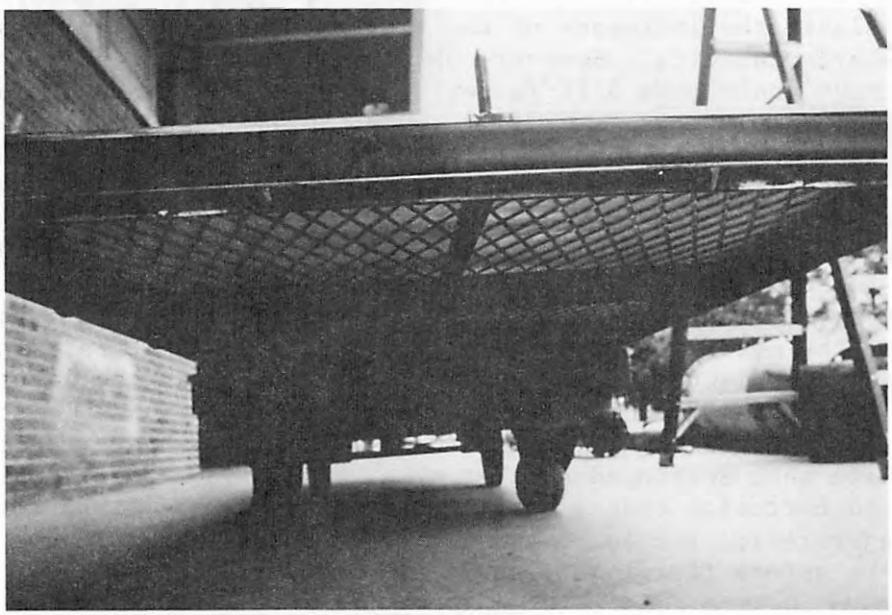


FIGURE 9 – SCHEMATIC DRAWING OF PNEUMATIC SEAL AIR SUPPLY LINE CONTROLS AND FITTINGS

Tests were conducted to determine the optimum seal inflation pressure. It was found that an adequate seal could be obtained at an inflation pressure of 12 psi. Another 10 psi was added to this to insure a positive seal. The pressure regulator in the system would thus be set to deliver 22 psi to the air supply line. It was decided that the pressure switches would be set to sound an alarm if the seal pressure dropped below 18 psi. This would be 4 psi less than the normal operating pressure, but 6 psi greater than the pressure required to yield an adequate seal. Thus, the alarm would sound well in advance of the loss of a positive seal.



70-MESH SCREEN WITH RECTANGULAR SEAL

Screen Flow Capacity

A sectional hydraulic model of the McClusky Canal fish screen that had been previously developed and tested with 40- and 80-mesh screens (Johnson 1975) was also used to collect capacity data on 70-mesh screens. The hydraulic model used a 20-inch wide screen panel with a 2-mesh support screen. Another identical screen panel was located 1 foot below the first. Sawdust was added to the test water to simulate anticipated field debris conditions.

When the hydraulic model was tested with 70 mesh in FY 1979 at the laboratory in Denver, the field test facility described later in this report was almost completed and ready for operation. The screens at the field test facility were

12.5-feet-long set at a -5° (below horizontal) slope. A design maximum unit discharge of 6 ft^3/s per lineal foot of weir was used for the field test facility.

Figure 10 summarizes FY 1979 test data on length of screen versus slope discharge. At a -5° slope, a screen length of 10.5 feet is required to pass the maximum unit discharge of 6 ft^3/s per foot. Laboratory tests also examined the effects of approach channel depth and backup screen configuration. Neither backup screen configuration nor approach channel depth were found to make a significant contribution to the capacity difference.

A 1.5-inch by #9-11 flattened expanded stainless steel sheet material was used in lieu of a 2-mesh support screen in the field test facility screen frames to support the 70-mesh screen. This material provided a more uniform support surface and made screen installation easier. Detailed capacity data were not collected to evaluate the influence of the flattened expanded metal support screens on discharge capacity. However, observations indicate that a 12-foot-long screen would pass 5 ft^3/s per foot of width in the laboratory.

After testing started at the field test facility, differences were noted between the field flow capacities and the laboratory flow capacities. An 80-mesh screen, with an open area nearly equivalent to the laboratory 70-mesh screen, was used in the field during 1979. Maximum capacity through the two 3-foot x 12.5-foot-long screens was 20 ft^3/s. For the two 3-foot-wide panels, this resulted in a unit discharge capacity of 3.33 ft^3/s per foot. On a long-term operating basis, the maximum capacity would be closer to 15 ft^3/s, or 2.50 ft^3/s per foot. These unit discharges are considerably lower than the laboratory unit discharge of 5.0 ft^3/s. Some of the difference may be attributable to differences in the discharge coefficients of the 70-mesh and 80-mesh apertures, although no conclusive data were developed at that time. There is a possibility that roughening due to corrosion causes a reduced capacity in the field test facility However, the major reason for lower capacity in the field than in the laboratory is believed to be screen clogging by algae and other plankton.

Fish Egg and Larvae Acquisition and Culturing

Providing the large number of fish eggs and larvae needed for the various laboratory testing programs previously described proved to be a challenging task. The four fish species used for study are not traditionally cultured in hatcheries; as a result, culture techniques had not been well established. In most cases, the critical sizes (smallest) were just after the eggs were spawned or the larvae hatched so timing and coordination with testing were important. Eggs used for testing were either collected in the field and transported to the laboratory or taken from adult specimens held in aquaria at the laboratory. Larvae were obtained from incubators that were kept in the laboratory. Egg and larvae acquisition and culturing during 1978 through 1981 are summarized in Tables 14, 15, 16, and 17.

Overview.--Rainbow smelt adults were obtained from commercial fishermen and state agencies in Minnesota, Michigan, North Dakota, and New York. Rainbow smelt eggs, spawned over burlap mats or moss, were obtained from Maine, New Hampshire, Vermont, and North Dakota, and placed in incubator trays at the lab until they hatched. Generally, the larvae that hatched during the night

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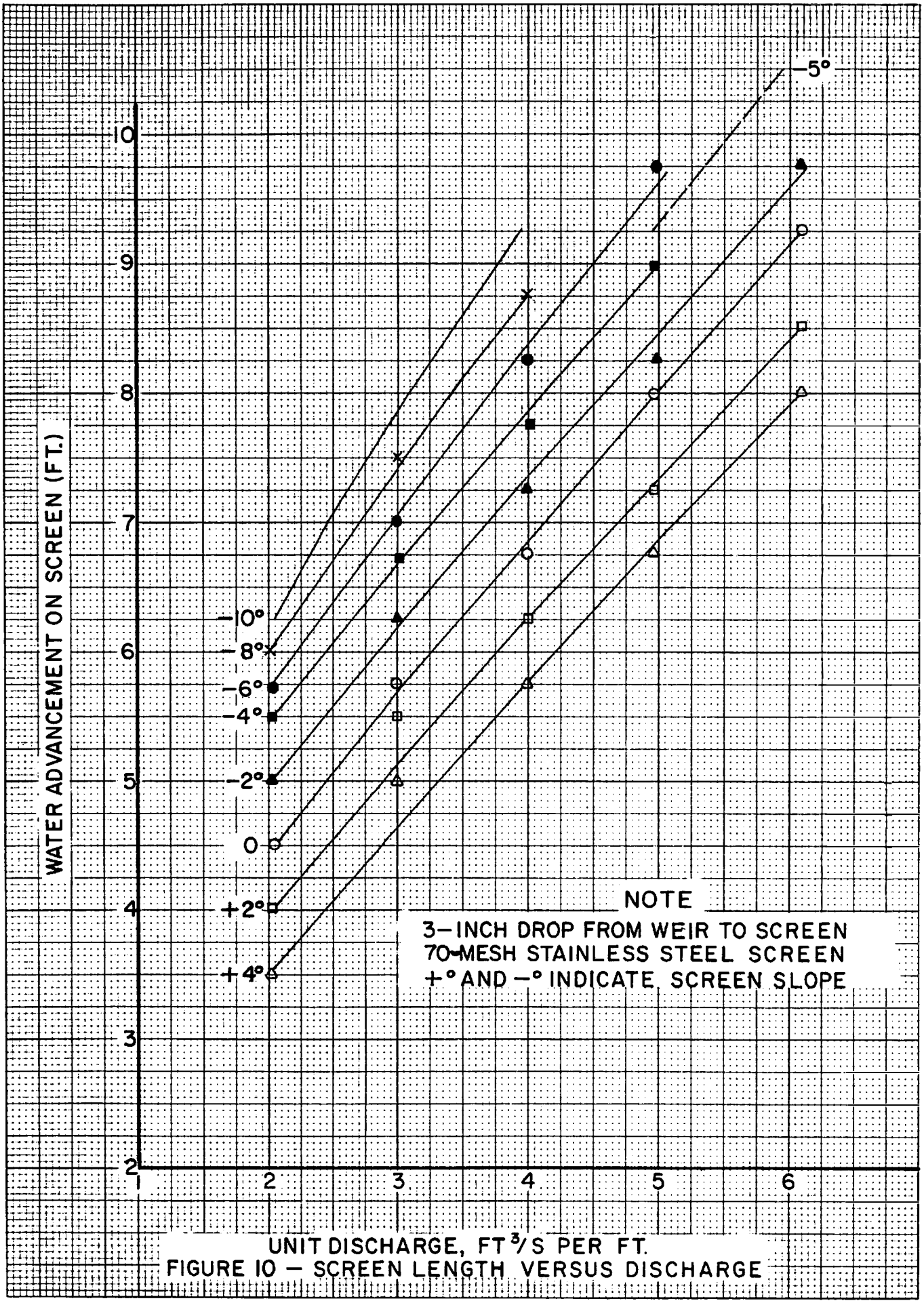
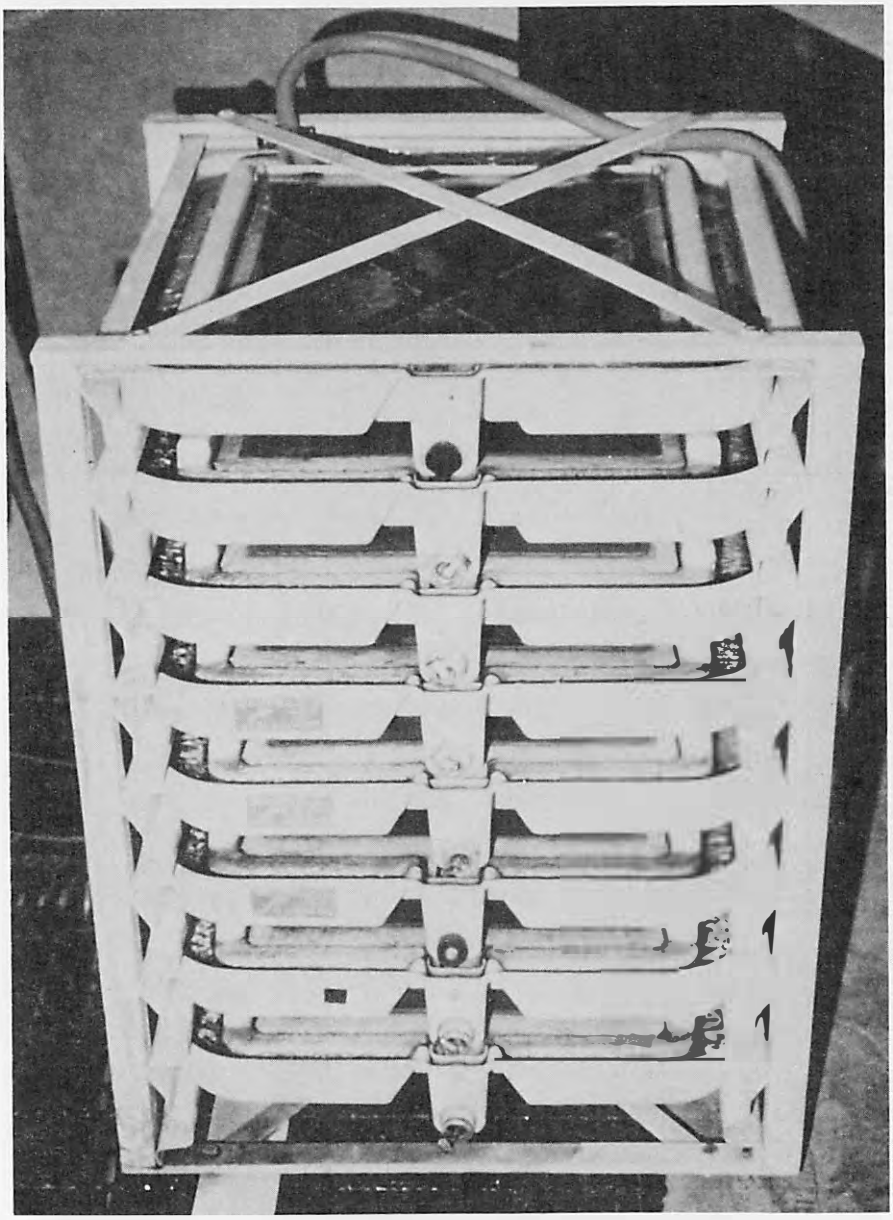


FIGURE 10 — SCREEN LENGTH VERSUS DISCHARGE



FLOW-THROUGH INCUBATORS

Table 14

RAINBOW SMELT ACQUISITION AND CULTURE (FISCAL YEARS 1978-1981)

Date/Number/Stage/Source	Mortality	Attempts	Success
(FY 1978)			
April 1978: 530 adults from French River Minnesota Hatchery, New Hampshire Fish and Game, Lake Sakakawea, North Dakota; 1.3 million fertilized and eyed eggs from New Hampshire Fish and Game and Cornell University.		Adults held in 300-gal., circular fiberglass flow-through tank at 52° F or in 180-gal., fiberglass flow-through tank at 61° F; eggs in 2 incubators with fine-mesh polyester trays, one at 52° F, the other at 61° F. Larvae held for testing in 180-gal. tank (61° F) and 170 gal. aquarium at 64° F, both with gentle aeration.	Eggs at 52° F hatched in 13 days; eggs at 61° F in 6 days
(FY 1979)			
March 12, 1979: 200 adults from George Johnson, commerical fisherman, Escanaba, Michigan, collected in pound nets set through the ice.	15-20% first day; few thereafter	About 100 placed in two aquaria at 33°-36° F; then 20 fish placed in a fiberglass spawning tank at 34°-35° F; the temperature gradually being raised to spawning temperature (55° F)	Sufficient eggs obtained for a test run, but very few hatched.
April 27, 1979: 80 adults from Cahill Fisheries, Oswego, New York	3 fish in shipping; few thereafter	Fish shipped in ice water, then placed in a hold tank at 36° F.	Eggs obtained, but no larvae hatched.
April 30, 1979: 600,000 eggs from New Hampshire Fish and Game, collected from burlap mats in a tributary of Lake Winnisquam.		Burlap mats placed in a plastic bag in a styrofoam container underneath a dome of oxygen. Put in Heath incubator in laboratory, collecting trap used to harvest.	Very high, enough larvae obtained, for 24 screen tests and 30 additional tests.
May 11, 1979: 140 Lake Superior adults collected on spawning run up French River (Minnesota)	6 fish in shipping; 14 thereafter	Shipped like eggs of 4/30/79; 15 put in spawning tank where temperature increased to spawning temperature. Attempt made to handstrip eggs when spawning not forthcoming.	Only one female in spawning tank (mostly males were collected). No eggs or larvae.
(FY 1980)			
March 18, 1980: 59 adults from Michigan Dept. of Nat. Resources, Escanaba, Michigan, collected in pound nets set through ice and drawn up from 50-foot depth.	50 within 2 days	Same as for March 12, 1979.	No spawn
March 25, 1980: Another 60 adults from same location as directly above.		Same as for March 12, 1979.	Enough eggs for 3 recovery runs 1 filtration run, no larvae.
April 11, 1980: 125 adults of 400 collected from Beaver Bay, North Dakota; other 275 adults put in Garrison Dam Nat'l Fish Hatchery	Good survival rate	Same as for March 12, 1979. 275 in concrete raceway at Garrison, fish spawned over burlap mats.	Egg production low, sufficent for 5 filtration runs.
April 15, 1980: Eggs (15 burlap mats) from adults in Garrison Dam Nat'l Fish Hatchery.		Mats put in Heath incubators, one at 40° F, the other at 48° F.	Eggs maintained at 48° F hatched in 18-21 days, larvae used for recovery and filtration tests; few eggs at 40° F hatched even when moved to 48° F.
April 24, 1980: 200 adults from Parshall Bay, Lake Sakakawea (North Dakota)		Same as for March 12, 1979.	Fish spawned, but none hatched.
April 24, 1980: Maine Dept. of Inland Fisheries and Wildlife shipped about 100,000 eggs on moss.		Same as for April 30, 1979.	Hatched in 12 days.
May 2, 1980: Vermont Fish and Game shipped several thousand eggs burlap mats		Same as for April 30, 1979.	Hatched in 14 days, providing larvae for recovery runs.
May 5, 1980: Adults from French River (Minnesota) Hatchery, collected during smelt spawning run.		Same as for March 12, 1979.	Most males; not enough eggs for tests.
May 5, 1980: Eggs on burlap mats from Garrison (North Dakota)	Almost complete mortality	Same as April 11, 1980 with temperature at 34°-37° F.	
(FY 1981)			
April 10, 1981: 44 adults from Beaver Bay, North Dakota		Placed in spawning tank with 55° F dechlorinated, aerated water flowing at 0.5 gal./min. Burlap mats placed in bottom. Eggs placed in a Heath incubator with 0.5 gal./min. dechlorinated water flow. Eggs eyed in 7 days, hatched in 10 to 11-1/2 days.	196 larvae.

Table 15

UTAH CHUB ACQUISITION AND CULTURE (FISCAL YEARS 1978-1981)

Date/Number/Stage/Source	Mortality	Attempts	Success
(FY 1978)			
Chub collected at Flaming Gorge Reservoir (Wyoming) and shipped by tank truck	Most died	Fish arrived in good condition and were within a few weeks of spawning.	Chub very sensitive to holding stresses.
(FY 1979)			
June 1979: Almost 500 adults collected in Flaming Gorge Reservoir using a New Hampshire-style fyke net	90% by arrival All dead in 10 days.	Chub shipped in 2% saline solution with aeration. Eggs stripped from recently dead chub and fertilized.	One larva hatched.
		Five adults later transplanted to a spawning tank with temperature slowly raised from 58° to 64° F to encourage spawning.	No eggs
		Nine adults placed in spawning tank maintained as above.	A few hundred eggs released, but no milt.
		Twenty adults placed in tank as above.	Many eggs, but no milt.
		Sixteen chub maintained as above.	Same as above.
		Eight chub injected with HCG and clomid to induce spawning	No eggs
August 7, 1979: 1,000 larvae air-freighted from University of Utah, Logan	90% by arrival	Twenty placed in aquarium and fed finely ground trout chow	
August 14, 1979: 200 adults caught either in Hebgen Lake or Flaming Gorge Reservoir obtained from Utah State University	Only 14 fish survived the trip	Two-percent saline solution used for shipping proved detrimental to chub	
1,000 larvae also transported on August 14	Arrived in good shape		
(FY 1980)			
May 12, 1980: 212 prespawning adults obtained from Flaming Gorge Reservoir by Wyoming Game and Fish Department and Utah Cooperative Fishery Unit.	None died in shipping	Transported chub in 0.2% saline solution and 2 mg/L quinaldine. Injections with carp pituitary and clomid induced in some fish.	Moderate success-several test runs from the eggs and larvae obtained.
(FY 1981)			
		Forty adult chub from May 12, 1980, shipment held in 300-gallon aquarium at 65° F. In October, temperature was decreased 2° F daily from 65° F to 55° F and was reduced from 13 hrs 45 min to 9 hrs. After 4 months at these conditions, temperature was increased to 65° F, and light was increased to 14.5 hrs. Chub were fed trout chow. Four males and four females were injected with carp pituitary and clomid on March 30, 1981, and two males and six females on March 31; the remaining were injected by April 3 (see text for incubation details).	Eggs spawned, eyed up in 96 hrs; larvae began hatching April 6

Table 16

COMMON CARP ACQUISITION AND CULTURE (FISCAL YEARS 1978-1981)

Date/Number/Stage/Source	Mortality	Attempts	Success
(FY 1978)			
None caught locally by beach seining.			
(FY 1979)			
June 28, 1979: 7 adults captured in gill net from lake in Lakewood, Colorado			
June 29, 1979: 20 adults captured in gill net in the same lake.	17 dead in 1 day	Eggs of one female preserved in formalin.	
July 2, 1979: 11 adults captured in morning, 5 adults in the night caught as above	All caught at night died in a short time	Eleven injected intramuscularly with 500 units of HCG and 0.6 mg/L clomid to induce spawning.	Less than 100 eggs and no milt produced.
		Fifteen injected interperitoneally with mixture as above; 5 reinjected.	No eggs
August 2, 1979: 3 adults caught as above		All sacrificed for milt and eggs	
September 13, 1979: 28 adults collected from Lakeside Park (Colorado)			
(FY 1980)			
June 1980: 43 adults from Marston Lake (Colorado) provided by the Colorado Div. of Wildlife	Died in holding pond	Mostly gravid females caught, but died in fishkill.	No eggs or larvae produced
June 27, 1980: 51 adults from Bear Lake (Colorado) provided by the Colorado Div. of Wildlife			

Table 17

GIZZARD SHAD ACQUISITION AND CULTURE (FISCAL YEARS 1979-1981)

Date/Number/Stage/Source	Mortality	Attempts	Success
(FY 1979)			
May 22, 1979: 10 adults from Longmont, Colorado, provided by Colorado Division of Wildlife	2 died within 4 days	One ripe male producing milt sacrificed to fertilize several hundred eggs.	All eggs died.
June 8, 1979: 9 adults from same source as above.			Fewer than 100 eggs produced.
September 11, 1979: 73 adults from same source.	3 died in shipment.	All fish died from accident in laboratory.	
(FY 1980)			
Received adult fish from 7 locations in 4 states.	Low	Most fish were ripe when collected.	Collected eggs, but larvae could not be obtained.
July & August, adult shad from Lake Mitchell, South Dakota.	None	Ripe females could not be collected.	None
Two shipments of eggs from Oak Ridge Nat'l Laboratory	N/A	The eggs were placed in incubators.	Eggs died; No larvae were produced.
(FY 1981)			
April & May: Collected and spawned several ripe shad from Fort Loudoun Reservoir, Tennessee.	N/A	Eggs and larvae were used for screen testing at TVA.	Both eggs and larvae were obtained.
May 27, 1981: Fertilized eggs from Reservoir, Colorado.	N/A	Eggs were spawned into incubator trays and shipped to the laboratory.	High success; most of the eggs hatched.

were used for testing the following day; therefore, they were less than 1 day old. Eggs obtained from the laboratory spawning were generally used for testing rather than incubation.

Prespawning Utah chub were obtained from Flaming Gorge Reservoir near Green River, Wyoming, and transported to Denver in an insulated hauling tank. Attempts to spawn chub using the dry method (eggs and milt in a container without water) in 1979 were unsuccessful. Several of these chub were retained in the laboratory for the 1980 season. Their reproductive cycle was decreased 3 months by manipulating the temperature and photoperiod. In March 1980, they were injected with a hormone. Spawning and hatching of the eggs provided larvae for several test runs. Chub were also collected from Flaming Gorge Reservoir in May 1980. Attempts to induce spawning using hormone injections were less than 50 percent successful. A few chub were spawned in 1981.

Common carp were obtained from ponds and reservoirs close to Denver and were held either in outdoor ponds or in a wet laboratory. In 1979, only a few carp eggs and no larvae were obtained. Imminent spawners in 1980 were held in a cage in an outdoor pond. The majority of these fish died suddenly, almost eliminating the source of carp eggs. Eggs obtained from surviving carp did not hatch. Additional carp collected locally did not provide sufficient eggs for hatching.

The Colorado Division of Wildlife (DOW) provided adult gizzard shad in 1979. Sufficient eggs could not be obtained from these fish to conduct tests. In 1980, adult shad were obtained from New Mexico, Kansas, Nebraska, Oklahoma, Colorado, and South Dakota. Generally, survival during transport from all locations was high. All shad eventually died while being held, most without providing any eggs. Oak Ridge National Laboratory provided some threadfin shad eggs spawned on cloth. These eggs did not hatch in the laboratory. Only a limited number of screen tests were conducted at the E&R Center with gizzard shad eggs. Because attempts to produce gizzard shad eggs and larvae during 1979 and 1980 were not successful, it was decided to conduct future testing at the TVA engineering laboratories in Norris, Tennessee. The Oak Ridge National Laboratory in Tennessee provided gizzard shad eggs and larvae to the TVA for testing.

FIELD TESTING

In 1979, a field test facility was constructed to test, under actual field conditions, the screening concepts that were developed in the laboratory and to determine and resolve operational problems that could occur at the McClusky Canal Fish Screen. Primary criteria used in selecting the site for these tests were that the site be within the Missouri River drainage and that conditions expected at the McClusky Canal Fish Screen could be closely simulated (Map 769-603-17746). The site selected was north of Turtle Lake, North Dakota, near Lakes Brekken and Holmes. In addition to meeting the above criteria, the Brekken-Holmes site had the following favorable characteristics: (1) the two lakes had adequate storage to contain test water, (2) lakes are in a closed basin and did not contain fish, (3) sufficient head was available between the McClusky Canal and the lakes to provide adequate water control, and (4) filling the lakes would accommodate future recreation development for which land had been acquired and additional right-of-way was not needed.

Other fish screen test sites considered included Audubon Lake, Turtle Creek, and Painted Woods Creek. Although these sites could have been used, none of them had all the advantages of the Lakes Brekken-Holmes site.

The Brekken-Holmes facility was operated continuously for 6 months in 1980 and for shorter periods in 1979 and 1981. Total operating time for the 3 years was about 4,800 hours.

The field test facility will be operated for another full season during 1982. Additional testing is needed to refine and test the control systems, conduct additional hydraulic capacity tests under varying algal conditions, complete traveling prescreen testing, and to collect additional data on equipment reliability and durability. Results of this testing were not available when this report was prepared, but will be recorded in an annual 1982 test facility operating report.

Field testing and research provided information used in the design of the screens, screen seals, and trash removal equipment and for developing initial operating procedures for the full-scale fish screen facility. The test facility was used to:

1. Verify the self-cleaning concept of the design

2. Determine the frequency and type of screen cleaning mechanisms required

3. Verify sensor design and placement for automatic backwash control

4. Determine the volume of debris removed by the screen

5. Determine the vulnerability of the screen to rapid, complete plugging

6. Determine the susceptibility of the screen to sustain growths, such as molds, algae, etc.

7. Check for leakage of panel joints and perimeter seals as a result of vibration, age, temperature cycling, etc.

8. Determine frequency and effectiveness of visual screen inspections

9. Determine flow hydraulics over and through screens

10. Determine susceptibility of various screen materials to corrosion, abrasion, fatigue, and physical damage

11. Verify the capability of the screen to prevent passage of fish eggs and larvae

12. Develop operating procedures for screen installation, removal, maintenance and repair, and detritus removal, etc.

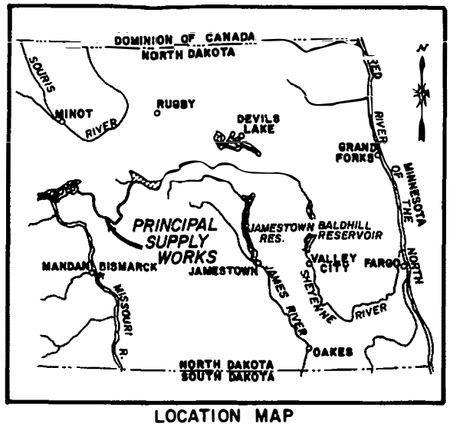
13. Determine if icing is a problem

14. Determine reliability and durability of equipment

Test Facility Description

During the field testing, equipment and control systems were modified as needed so all systems were eventually fully automated. Other than occassionally cleaning the stationary trashracks in the feeder canal, adjusting the flow regulating gates and conducting special tests, the role of the operator was to observe and monitor the screen operation.

FISH SCREEN TEST FACILITY LOOKING SOUTHWEST; LAKE BREKKEN IS IN FOREGROUND



LOCATION MAP

WARD COUNTY McHENRY COUNTY PIERCE COUNTY

SNAKE CREEK PUMPING PLANT

AUDUBON GAME MANAGEMENT AREA

AUDUBON LAKE

LAKE SAKAKAWEA

AUDUBON NAT. WILDLIFE REFUGE

AUDUBON GAME MANAGEMENT AREA (S.G.S.F.)

COLEHARBOR

UNDERWOOD

FALKIRK

LAKE NETTIE NAT. WILDLIFE REFUGE

CROOKED LAKE

LAKE NETTIE

MUD LAKE

Fish Screen Test Facility

McClusky Canal Fish Screen

COTTONWOOD LAKE

CHERRY LAKE

POSTEL LAKE

PELICAN LAKE

NELSON LAKE

KASPER SLOUGH

LAKE MARGARET

LAKE BERTHEN

LAKE HOLMES

BILLOWS LAKE

LAKE WILLIAMS

BLUE LAKE

BRUSH LAKE

HOWELLS LAKE

PROPHETS MOUNTAINS

TURTLE LAKE

CHERRY LAKE

LAKE ORDWAY

PETERSON LAKE

PELICAN LAKE

MERCER

PICKARDVILLE

McCLUSKY

EAST PARK LAKE

WEST PARK LAKE

HECKERS LAKE

NEW JOHNS LAKE

POP LAKE

SHERIDAN

BURLEIGH

McLEAN COUNTY

SHERIDAN COUNTY

WELLS COUNTY

OTIS LAKE

STRAWBERRY LAKE

CAMP LAKE

CAMP LAKE NAT. WILDLIFE REFUGE

LONG LAKE

CROOKED LAKE

SOO LINE

BENEDICT

RUSO

MAX

GARRISON – MINOT – RUGBY 115 KV. (U.S.B.R.)

STANTON – VOLTAIRE 230 KV. (U.P.)

GARRISON – VOLTAIRE 115 KV. (U.S.B.R.)

GARRISON – WASHBURN 230 KV. (U.S.B.R.)

JAMESTOWN 230 KV. (U.S.B.R.)

McCLUSKY CANAL

REACH 1 19.996 MI.

REACH 2 16.073 MI.

REACH 3A 15.366 MI.

REACH 3B 3.580 MI.

REACH 3C 2.259 MI.

REACH 4A 5.878 MI.

REACH 4B 4.986 MI.

REACH 4C 5.668 MI.

STA. 60+00

STA. 1113+50

STA. 1970+00

STA. 2785+00

STA. 2974+00

STA. 3091+00

STA. 3404+00

STA. 3662+00

STA. 3950+00 END PILOT CHANNEL

TOTAL MILES 73.61

WINTERING DAM

TO LINCOLN VALLEY IRRIGABLE AREA

LINCOLN VALLEY

SKOGMO LAKE

SHEYENNE RIVER

SHEYENNE LAKE NAT. WILDLIFE REFUGE

LONETREE

LONETREE DAM

LONETREE RESERVOIR

LONETREE LAKE

COAL MINE LAKE

TOP OF CONSERVATION POOL, ELEVATION 1540

JAMES RIVER DIKE

SANDY LAKE

SUYES LAKE

LAKE BITZ

MUD LAKE

WOLF LAKE

JOHNSON LAKE

HARVEY

MARTIN

BENTZ LAKE

WINDSCHI LAKE

FISH SCREEN & DROP

R.76W. R.75W. R.74W. R.73W.

R.85W. R.84W. R.83W. R.82W. R.81W. R.80W. R.79W. R.78W. R.77W.

T. 150 N. T. 149 N. T. 148 N. T. 147 N. T. 146 N. T. 145 N. T. 144 N.

47°45' 47°30' 47°15' 47°

EXPLANATION

- CANAL OR LATERAL
- HEADWORKS
- FISH SCREEN & DROP
- CHUTE
- BRIDGE
- CULVERT
- TUNNEL
- TRANSMISSION LINE (PROPOSED)
- TRANSMISSION LINE (EXISTING)
- SUBSTATION (PROPOSED)
- ROAD RELOCATION, PROPOSED
- EXISTING LAKE
- PROPOSED RESERVOIR OR LAKE
- PUMPING PLANT
- NATURAL DRAIN
- PROJECT DRAIN
- WILDLIFE REFUGE BOUNDARY

○ *Alternative sites considered for fish screen test facility.*

SCALE OF MILES 0 1 2 3 4 5 6

REFERENCE DRAWING

General Map------769-618-2700

603 D-W-R	REMOVED JOHNS LAKE
603 4-C-R	REMOVED PROPOSED WILDLIFE DEV. BOUNDARIES.
603 4-C-R	ADDED REACH 4 SUBREACHES.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION, GARRISON DIVERSION UNIT, N. DAK.

MC CLUSKY CANAL REACHES
ALTERNATIVE FISH SCREEN TEST SITES

DESIGNED: ____ SUBMITTED: M.W. McMORROW (SIGNED)
DRAWN: D.W. REDINGTON RECOMMENDED: ____
CHECKED: H.T. LEVI APPROVED: ____

BISMARCK, N.DAK. SEPT. 27, 1972

769-603-17746

The fish screen field test facility consists of a feeder canal from the McClusky Canal with two regulating structures, a traveling screen facility, a sloping screen facility, and a plankton net building (see Map 769-603-17566 and Figure 11). All water that passes through these facilities flows by gravity into Lake Brekken and Lake Holmes.

The unlined earth feeder canal, which connects the Fish Screen Test Facility to the McClusky Canal, is 3,300 feet long and has a 36 ft^3/s capacity. Flow into the canal is controlled by a regulating structure at the McClusky Canal turnout and a check structure near the screen facility. These structures are automated and can be controlled from the screen facility. Four high-water monitors at the pump sumps and trashracks automatically close the two regulating gates and prevent excessive flooding if unexpected operating problems occur and are not detected by the operation.

By comparison, the McClusky Canal has a 1,950 ft^3/s capacity and is essentially an unlined earth canal (about 12 percent of the canal length was lined with compacted earth lining to minimize seepage). The proposed McClusky Canal Fish Screen would be located about 64 canal miles from Audubon Lake and flow to the screen structure would be controlled by a regulating structure at Audubon Lake and three check structures in the canal.

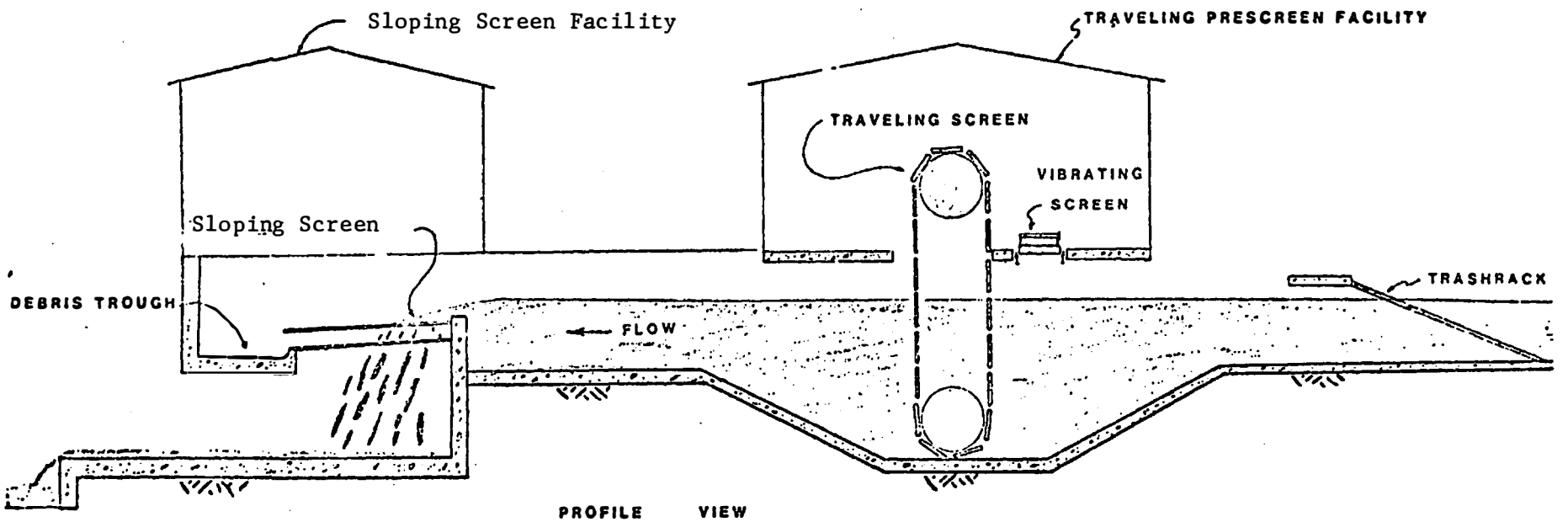
A traveling screen was installed in the spring of 1980 to determine if a prescreening facility would remove enough plankton from the water to allow greater flows through the sloping screens. The vertical traveling screen consists of nineteen 2-foot by 10-foot panels of 70-mesh screen installed in a continuous chain configuration. As the screen rotates out of the water, a spray system washes the screened material off the screens.

The traveling screeen is commercially available and commonly used to remove coarse debris from water intakes. Modifications of this screen for use at the test facility included bracing the screen frames to install and support 70-mesh screen material, placing rubber sealer strips between the screen frames, installing a debris retaining trough on each screen frame, and making general adjustments to reduce the amount of water by passing between the screens.

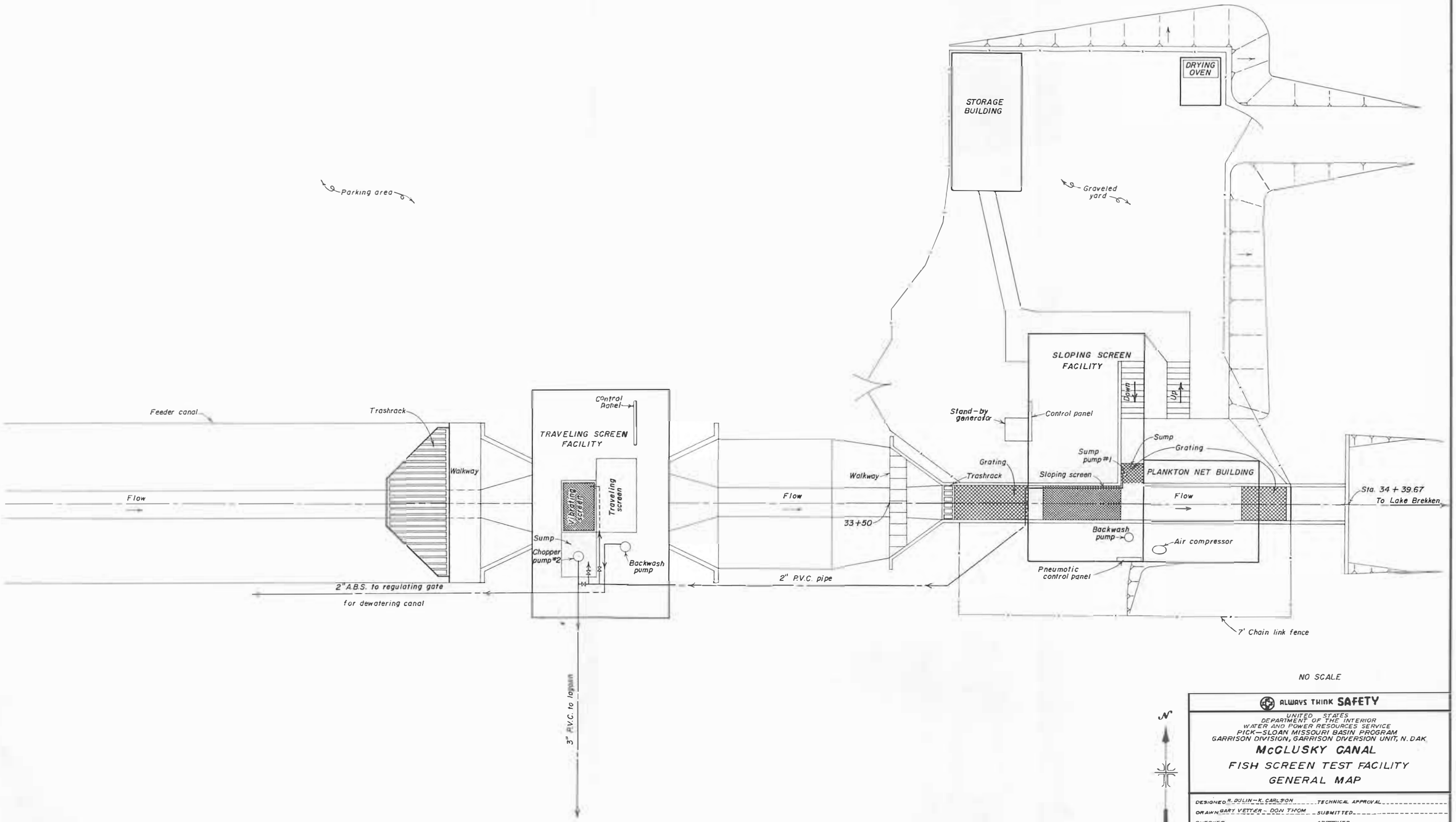
A vibrating screen, installed for the 1980 season, is a 4-foot by 8-foot, 80-mesh stainless steel screen attached to a spring suspended frame set at a 5° slope. The vibrating screen used a high speed elliptical vibration to remove excess water from material collected on the traveling and sloping screens. It was electrically interlocked with the sloping screen sump pump and the traveling screen backwash pump to cycle with these pumps. Vibration was adjusted by varying the angular position of the unbalanced shaft weights. Water passing through the screen dropped back into the feeder canal just upstream of the traveling screen while the plankton and other material moved to the end of the vibrating screen and was collected in a bucket, weighed, and dumped into a sump pit. A 125-gallon per minute (gpm) sump pump (Pump No. 2) was used to pump the screened, dewatered material to a lagoon.

The sloping (5° down from the horizontal) screen was designed to remove all fish, fish eggs, and larvae from the canal water. The screen installation contained four 70-mesh screens; two screens 3-foot by 12.5-foot mounted side by

Figure 11



FISH SCREEN TEST FACILITY



NO SCALE

N

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVERSION, GARRISON DIVERSION UNIT, N. DAK.

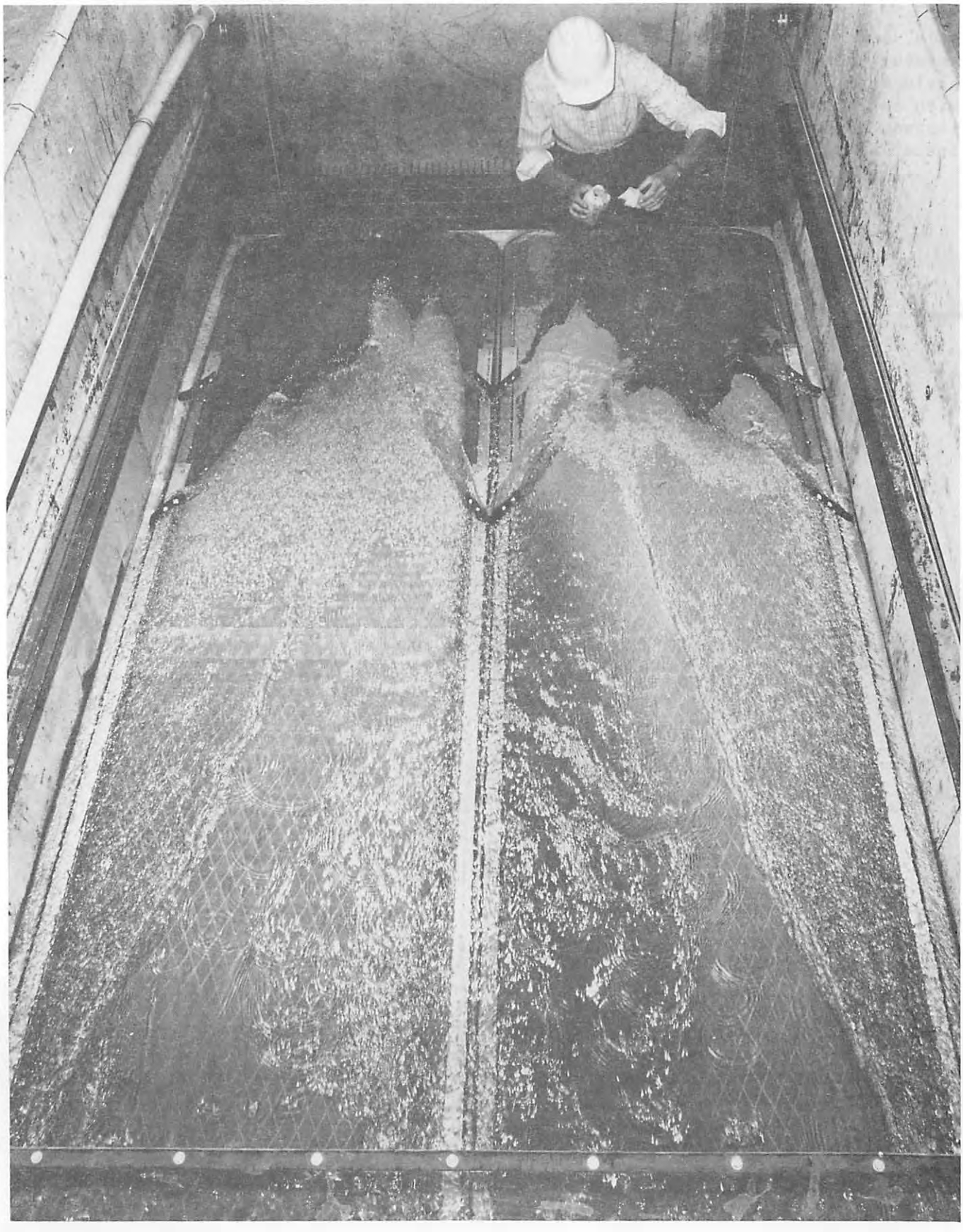
McCLUSKY CANAL

FISH SCREEN TEST FACILITY

GENERAL MAP

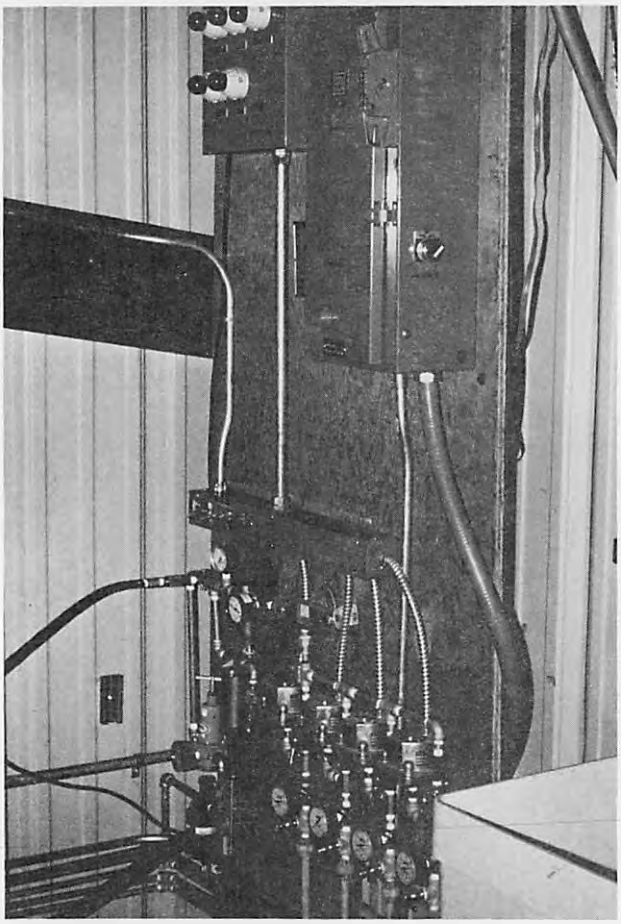
DESIGNED R. DULIN - K. CARLSON	TECHNICAL APPROVAL
DRAWN GARY VETTER - DON THOM	SUBMITTED
CHECKED	APPROVED

BISMARCK, N. DAK. MAY 5, 1981 | 769-603-17566



UPPER TWO SCREENS IN SLOPING SCREEN FACILITY-LOOKING DOWNSTREAM

side, and another pair of 3-foot by 12-foot screens mounted 1 foot below the top screens. This second set provided a back-up system in case the top screens or seals were damaged. The screen assemblies were sealed in the mounting frames with an inflated rectangular rubber seal (Figure 12), identical to the ones tested in the laboratory and operated at 22 psi. A monitoring system was installed for each seal to detect low pressures or slow leaks (Figure 13).



AUTOMATIC CONTROL ALARM SYSTEM FOR PNEUMATIC SCREEN SEALS

Three spray bars were used to clean the screens. One spray bar cleaned the top screen from below while the other two cleaned the lower screen either from above or below. The spray bars travelled on rollers set on a rail and were propelled, along with the water supply hoses and electric valve control cables, by an air cylinder connected by a system of pulleys and cables. Dislodged materials was washed toward the downstream end of the screen by the incoming water.

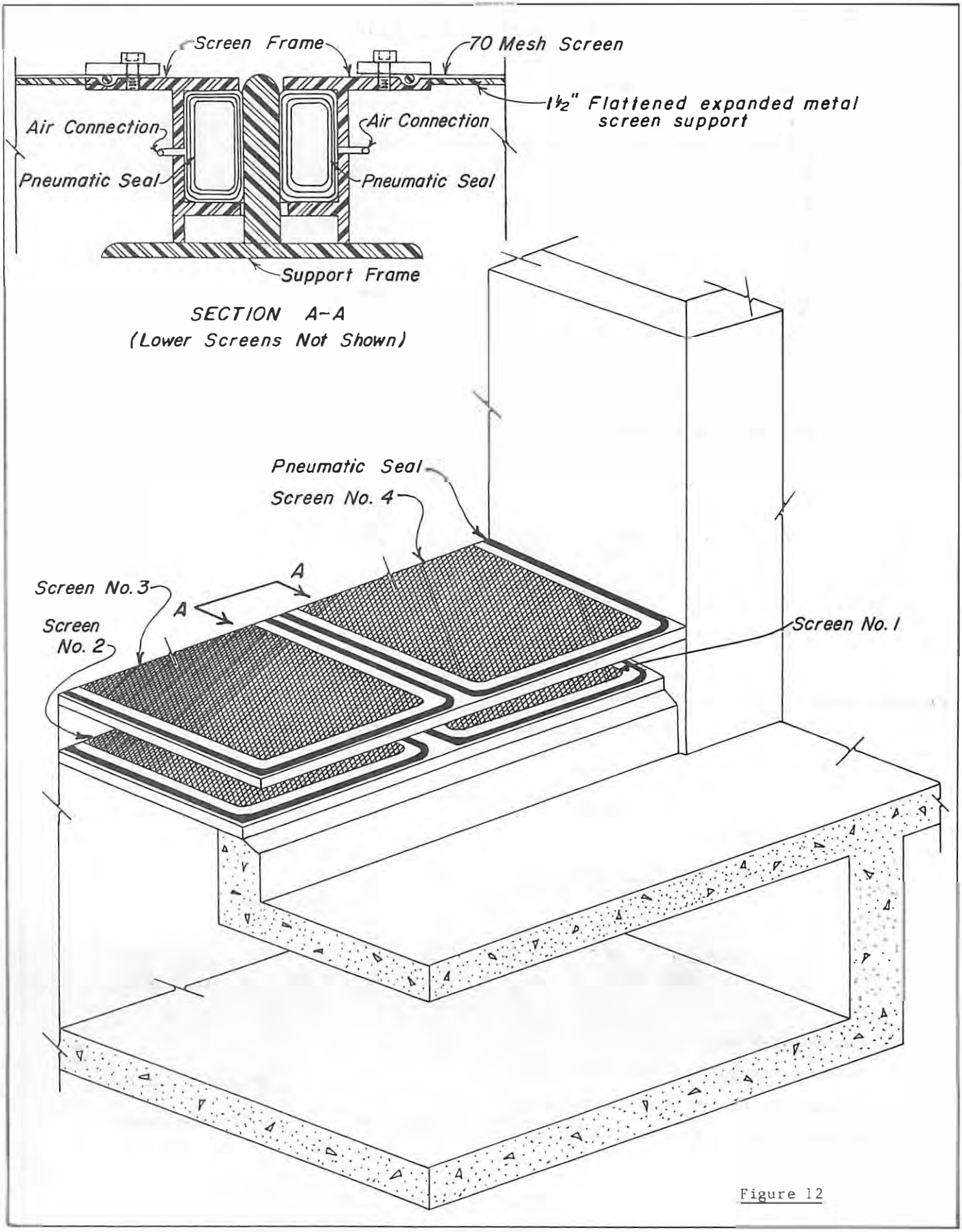

Screen Frame
70 Mesh Screen
1½" Flattened expanded metal screen support
Air Connection
Air Connection
Pneumatic Seal
Pneumatic Seal
Support Frame
SECTION A-A
(Lower Screens Not Shown)
Pneumatic Seal
Screen No. 4
A
A
Screen No. 3
Screen No. 2
Screen No. 1

Figure 12

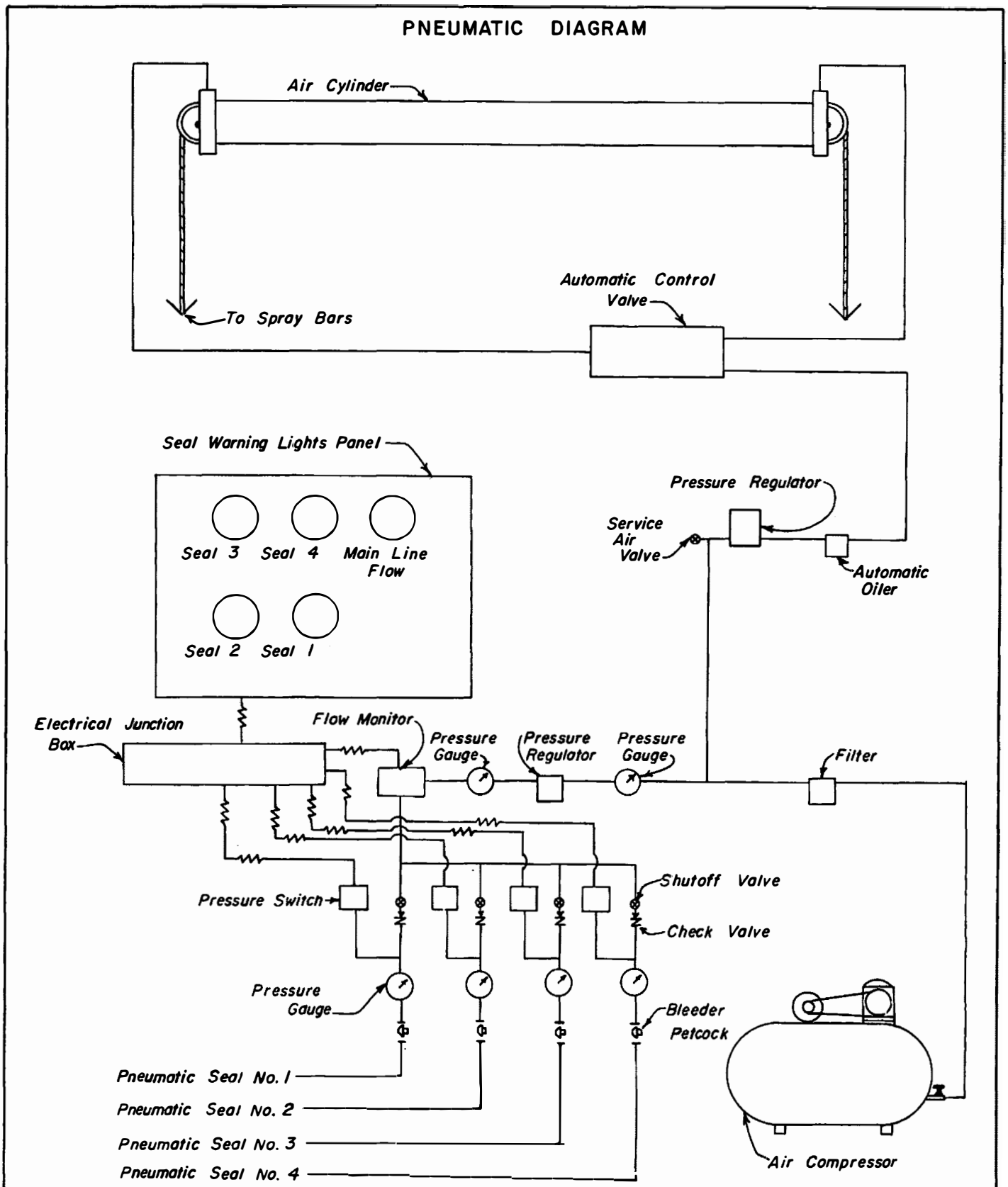
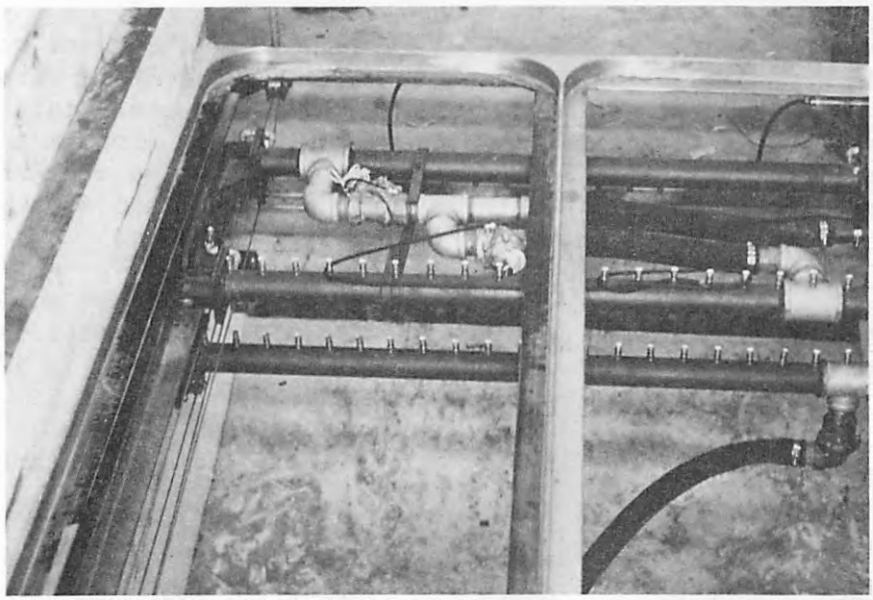

PNEUMATIC DIAGRAM
Air Cylinder
To Spray Bars
Automatic Control Valve
Seal Warning Lights Panel
Seal 3
Seal 4
Main Line Flow
Seal 2
Seal 1
Pressure Regulator
Service Air Valve
Automatic Oiler
Electrical Junction Box
Flow Monitor
Pressure Gauge
Pressure Regulator
Pressure Gauge
Filter
Pressure Switch
Shutoff Valve
Check Valve
Pressure Gauge
Bleeder Petcock
Pneumatic Seal No. 1
Pneumatic Seal No. 2
Pneumatic Seal No. 3
Pneumatic Seal No. 4
Air Compressor

Figure 13

A sump pit and pump located at the downstream end of the sloping screens collected all water, algae, and fish that reached the ends of the sloping screens. The sump pump (Pump No. 1) was equipped with a set of float controls to operate the pump. Screened material was then pumped back upstream to the vibrating screen.



SPRAY BAR SYSTEM USED TO CLEAN THE SLOPING SCREEN

The plankton net building was located immediately downstream from the screen facility. A large plankton net with 102-micron openings was designed to slide underneath the sloping screens and filter all water passing through the screens for short periods of time.

A two-cell lagoon system was used to store the screened material. The system included a 25,000 ft^3 primary cell and a 50,000 ft^3 finishing pond. Water could be pumped from the finishing pond back into the feeder canal. However, because the vibrating screen was more efficient than anticipated in removing water from the material, a minimal amount of water was pumped to the lagoon and the second cell was not used.

By mid-1980, all systems at the test facility had been automated. All pumps, backwash system, motorized control gates, and the vibrating screen were directly controlled by sensors or were electrically interlocked to operate with other

equipment. A standby generator, connected to the facility power supply, was available during extended power outages to operate lights and provide power to the control gates to shut the system down.

Operation

The testing program at the fish screen field test facility began on October 1, 1979. Testing continued during daylight hours through October 5. On October 9, 24-hour continuous testing began, continuing until October 19. On October 24, the facility operation was filmed. This initial operation was basically a shakedown to prepare for the 1980 operating season.

Continuous operation of the facility started on June 6, 1980, and continued uninterrupted (with the exception of a number of relatively short-duration shutdowns for maintenance, modification, repair, inspection, etc.) until December 1, 1980. During this testing season, downtime was kept to a minimum to simulate operation of the McClusky Canal Fish Screen and to determine the extent of aquatic growth on the equipment. Total system downtime was 134 hours, so the system was in operation approximately 97 percent of the time..

Operation in 1981 was intermittent on a 12-hour day, 5-day week schedule, with occasional 1-day operations for tour groups. Testing during this period primarily provided information on new control equipment installed in 1981 and screen hydraulic characteristics at different screen slopes.

The following tabulation shows flows at the facility during the three testing seasons.

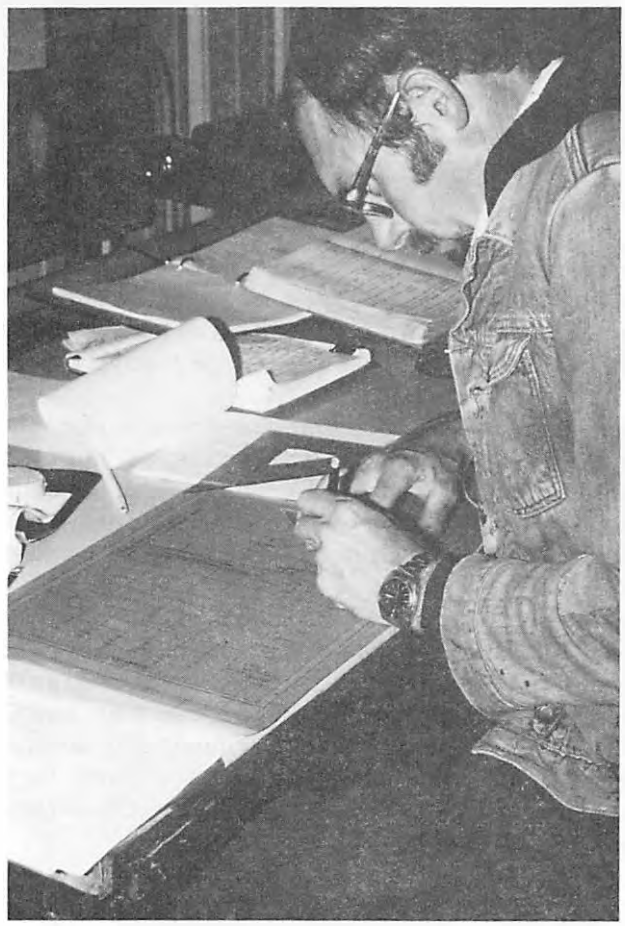
Year	Operating Period	Type of Operation	Approx. Hours Operated	Flow (ft^3/s) Max.	Min. 1/	Avg.	Total Water Screened (Acre-feet)
1979	October	Intermittent	280	19	10	15	340
1980	Jun-Dec	Continuous	4,300	21	4	12	4,150
1981	Aug-Nov	Intermittent	210	32	16	18	320

1/Minimum flow under normal operating situations.

Nearly 1,000 people toured the site, including the Manitoba Indian Brotherhood, a group of Manitoba farmers and city officials, the Manitoba Federation of Labor, the N.D. Farm Bureau Natural Resources Committee, the Garrison Diversion Conservancy District Directors, the N.D. Legislative Overview Committee, a group of Federal and State officials with the Assistant Secretary of Land and Water Resources, and the Commissioner of Reclamation.

In 1979 and 1980, two-person crews with biology and engineering backgrounds operated the test facility. The facility was run with one operator per shift in 1981. Operators were responsible for data collection, system operation, troubleshooting, maintenance, and visitor tours. Parameters that were closely monitored included water quality, plankton, climatological conditions, pumping rates, and backwash frequency. Various system tests were also conducted which

involved the operating capabilities of the facility and its components. Major components tested included the backwash system, traveling screen, vibrating screen, screen seals, screen cloth materials, automatic control systems, and the pumps and equipment for handling screened materials. The section below describes how the various units at the facility performed.



MUCH OF THE OPERATING DATA COLLECTED WAS PLOTTED AND ANALYZED AT THE SITE.

Sloping Screen Facility

Screens

The screens were initially set at a 5° angle from the horizontal sloping downstream. Two types of screen cloth were tested at the facility to determine

flow characteristics, resistance to corrosion, fouling characteristics, and durability.

In 1979, 80-mesh screen (.0055-inch diameter wire, .0070-inch-square opening) was used because 70-mesh screen was unavailable. Monel screen fabric was used on the upper and lower south screen panels and phosphor-bronze screen fabric was used on the other two panels. After testing in 1979, 70-mesh screen (.0065-inch diameter wire, .0078-inch-square opening) was used for all future tests.

The two lower screens were 3 feet by 12 feet, the two upper 3 feet by 12½ feet. This size differential allowed easier handling and installation of the lower screen frames. Cathodic protection was provided for the upper phosphor-bronze screen to prevent screen corrosion. To evaluate corrosion severity, the lower phosphor-bronze screen did not have cathodic protection. The upper phosphor-bronze screens were electrically isolated from the remainder of the model with insulating tape on the support frame.

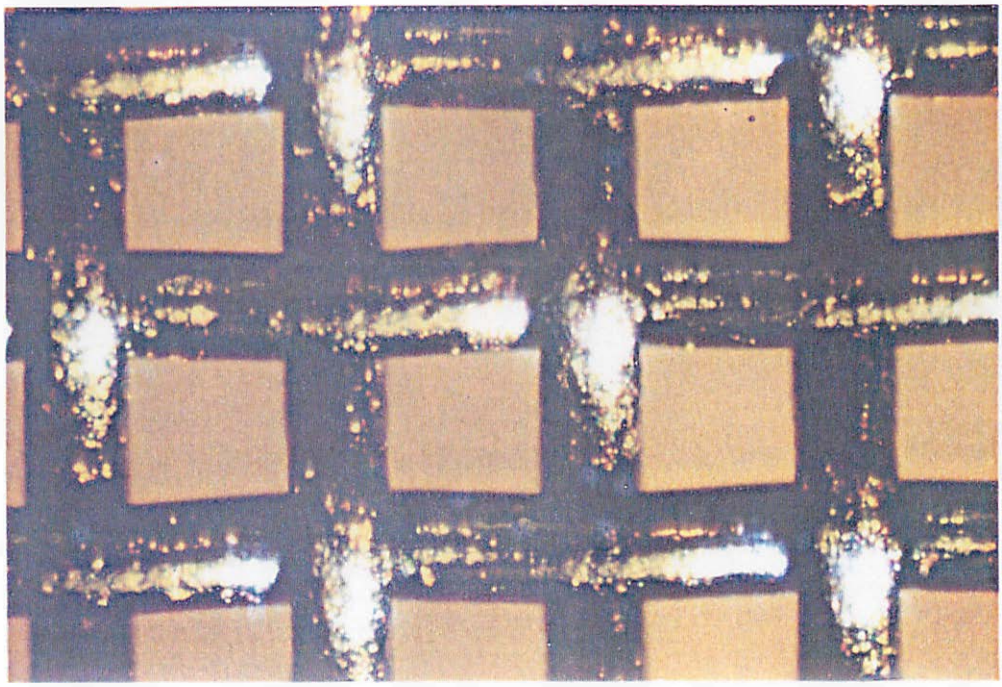
Three different phosphor-bronze screen panels were used on the top screen during the test period. When both phosphor-bronze and monel screens were new, they performed about the same. After a few days of use, hydraulic capacity of the phosphor-bronze screen was reduced by about 40 percent, however.

Cathodic protection used on the upper phosphor-bronze screen in 1979 was a sacrificial anode type later replaced by an impressed current type. Cathodic protection was only applied for a short period in 1980 because of problems with voltage drift. At one point, too much current was applied and both the upper phosphor-bronze and adjacent monel screens were damaged and had to be replaced.

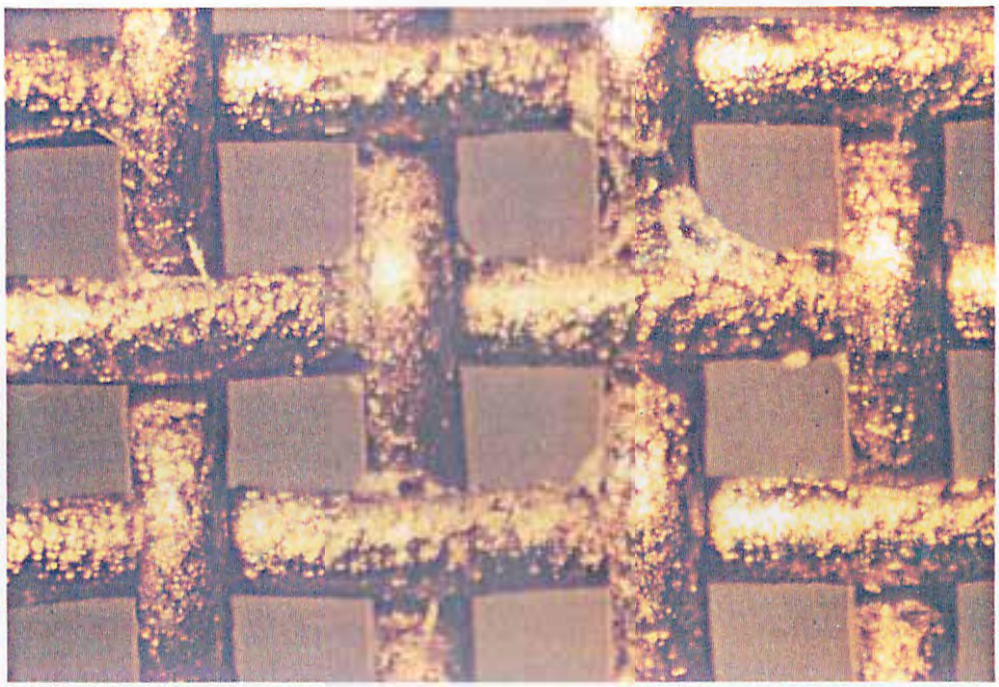
Initially, there was some concern that sediment might have been clogging the screen at the field test facility. However, sediment concentrations of particle sizes large enough to be retained by the screens was insignificant except during initial startup when some material was scoured from the supply canal. Analysis showed the maximum size of the sediment to be about 80-mesh, so clogging should be insignificant for a 70-mesh screen, unless the screen is partially plugged by algae. Sediment is comprised of abrasive minerals; therefore, with prolonged use, abrasion of the screen might be expected.

Testing of two types of screen material was discontinued in September 1980. The monel screen had consistently performed better than the phosphor-bronze screen.

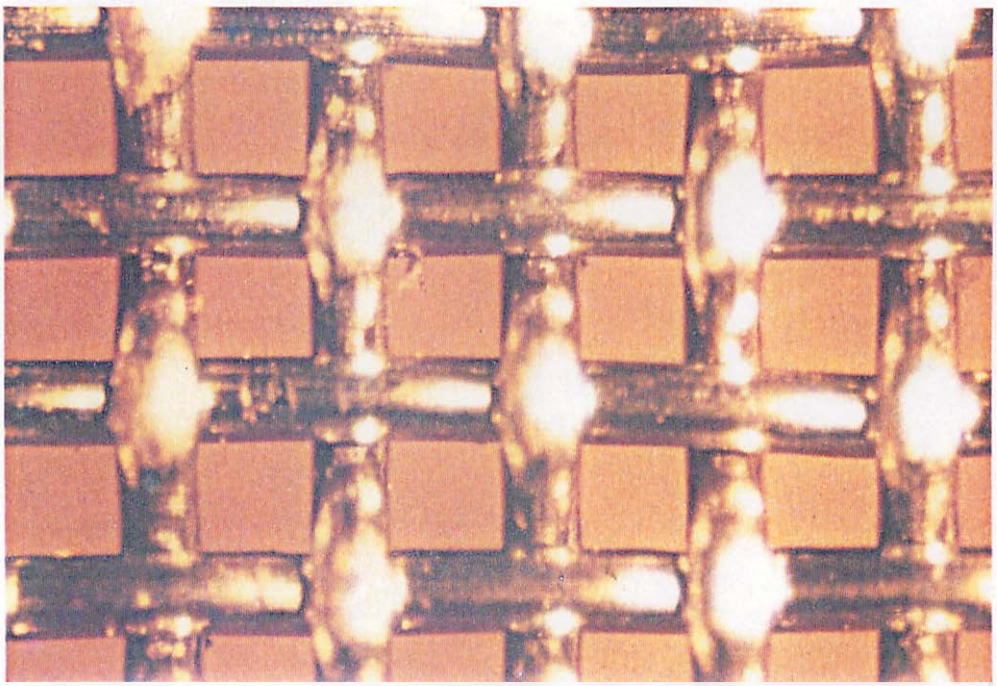
As discussed in the previous section, the screens were monitored for wear, corrosion, etc. In addition to periodic inspections during the season, magnified photographs were taken at 10 locations on each screen panel as it was installed and again when it was removed. On the phosphor-bronze screen, the wires became etched and corroded with use and also showed some wear from abrasion. The reduced hydraulic capacity of the phosphor-bronze screen was apparently caused by the deteriorated wire condition. No wear, corrosion, or fatigue were detected on any monel screen material, except for the one damaged by the cathodic protection system. Floating debris or loading from flooding did not cause any damage to the screen material; however, there were instances where a screen was damaged during handling or inspection. Physical damage to the screen cloth was easy to detect by casual visual inspection because there would



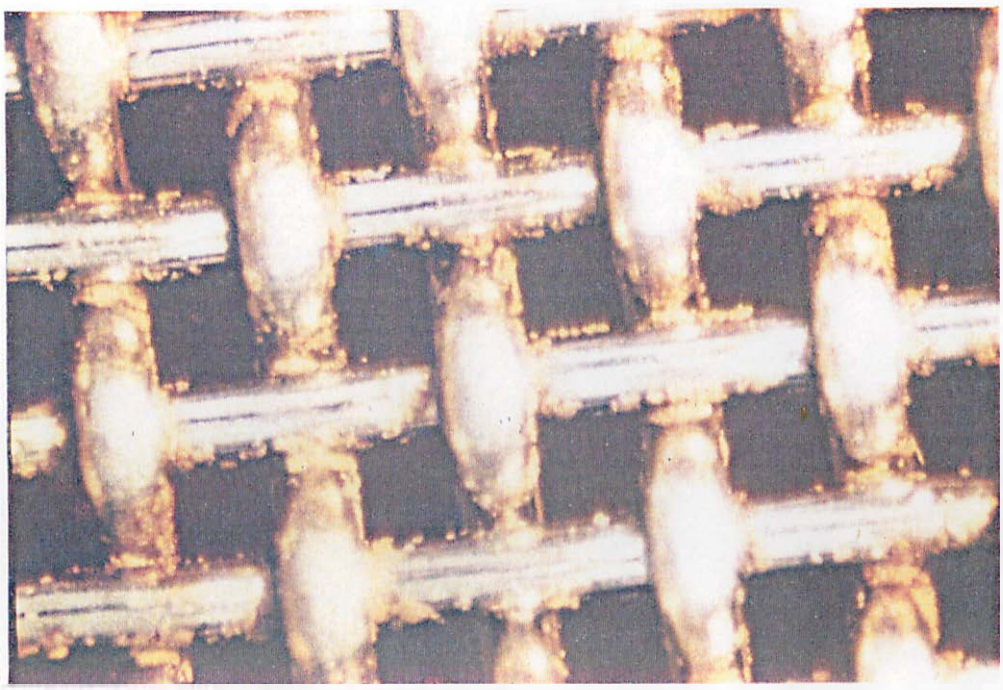
New Phosphor-Bronze



Used Phosphor-Bronze



New Monel



Used Monel

be a dent or other irregularity on the uniform, slick, almost mirror-like screen surface.

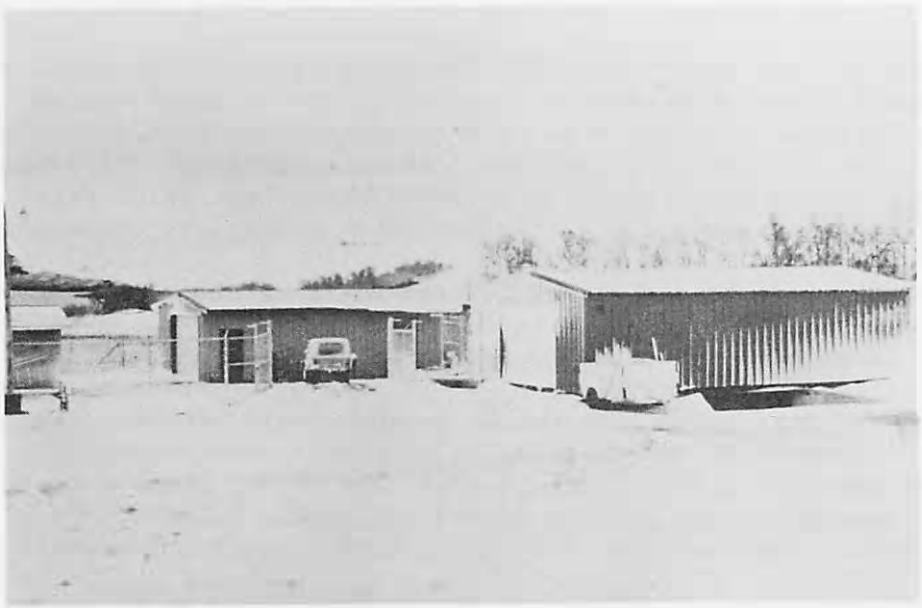
Aquatic growth did not occur on either the phosphor-bronze or monel screens except for small areas of screen not covered by the backwash system. Aquatic growth on the screens does not seem to be a significant problem. A heavy accumulation of black fly larvae (Simulidae) did develop beneath the screen panels and especially on the upper portions of the channel-side walls during the summer; but, these larvae did not interfere with the screen operation.

A number of deflectors to minimize water flowing down the screen frames and off the lower end of the screens were tested. At higher flow rates (15 to 20 ft^3/s), a large quantity of water could run down the screen frames and into the sump pit if deflectors were not used. It was also found that some deflectors directed too much water towards the center of the panels, causing premature runoff on both upper and lower panels. A deflector combination using single rubber strips placed 2.5 feet from the lower end of the screens on both outside edges of the screen frames, and two deflectors on the center divider between the two screen panels seemed to work best under a wide range of conditions.

Two flooding incidents caused by rapid 100-percent plugging of the screen occurred during the 1981 season. Both resulted in filling the screen bay to within 1 foot of the top edge of the wall. The first, on June 16, was caused by a heavy silt and algal load in the canal water (from pumping down a temporary holding pond) which overloaded the backwash system. On October 15, the second incident was caused by a control malfunction of the automatic-shutdown system which allowed flow to temporarily approach 50 ft^3/s. Flooding was rapid (less than 2 minutes) in both instances and the loading from the static water column bent the lower screen frame and panels. However, the screens and seals held in both instances and no unscreened water bypassed the system.

The lower frame was later reinforced and the system was intentionally plugged several times in 1981 without incident. After the screen bay was allowed to fill with water, the backwash for the lower screen was operated several times, cleaning the screen and allowing water to pass through the screen, and the system was back in operation in a matter of minutes.

The facility is not designed for winter operation, but it was operated until December 1, 1980, to determine the effect of cold weather and possible ice damage to the sloping screens. Snow and inclement weather were often experienced during the late fall and the miniumum temperature encountered was -4° F. The McClusky Canal and feeder canal remained ice free during this period. The sloping screens and seals were not affected by the cold temperatures. No icing or debris freezing was encountered on the sloping screens. The only icing problems were with water pipes located outside the structures that were inadequately insulated and with ice formation on the vibrating screen which is discussed later.



THE FACILITY WAS OPERATED WITHOUT INCIDENT DURING AN OCTOBER SNOWSTORM.

The screens were set at a 5° down slope based on laboratory tests which indicated this was the optimum angle for both self-cleaning action and hydraulic efficiency. As the screen slope increases, water velocity on the screen also increases, which improves self-cleaning characteristics, but also increases the length of screen required to pass the flow. After operating the test facility for several months over a wide range of algal loading conditions, it appeared that most of the flow was passing through the first 2 to 3 feet of screen where the water depth was greatest. Also, the screens usually required frequent backwashing which indicated that the self-cleaning characteristics by themselves were insufficient and that a backwash system was required. Based on these observations, it was felt that a 5° slope may not be the optimum angle under field conditions.

For 1981 testing, the top screens were made adjustable so the slope could be varied between 2 degrees and 5 degrees from the horizontal. With the light algal loading conditions experienced during the short 1981 operating season, hydraulic capacity of the screen was noticeably improved by decreasing the screen slope. With the flow set around 20 ft^3/s, backwash frequency was reduced by one-half when the screen angle was decreased from 5 degrees to 2 degrees. Additional testing is needed to determine if this improvement in screen function would occur with heavy algal loading.

Tests were conducted in 1981 with several types of material such as topsoil, sandy loam material, algae taken off the vibrating screen, fine sand collected from the parking area, and 1 pint of #10 motor oil to determine plugging effects on the sloping screens. Flow was set at 18 ft^3/s and the material was dumped

into the canal about 10 feet upstream from the screen weir. Except for the oil, about 3 gallons (dry) of each type of material were collected, mixed with 1 to 2 gallons of water, and then poured into the canal. The oil and inorganic soils had no plugging effect on the screens. A change in operating conditions could not be detected. However, the top screens plugged immediately when the algae was introduced. Two tests were conducted at different screen angles with similar results--with a 2-degree screen slope, the photo cells on the downstream end of the screens detected the plugging, backwashed the screens, and prevented the system from flooding out. At a 5-degree slope, flow off the end of the screen apparently had a higher tangential velocity and passed over the photo cell beam. The backwash system had to be manually activated to prevent flooding.

The original design for installing the 70-mesh screen fabric to the frame called for a hold-down system that would be nearly flush with the top of the frame. The hold-down system developed for attaching the screen material to the panels consisted of a monel rod held in a milled groove by machine screws and flat washers. It provided a positive, neat appearing connection, but it also required four experienced personnel and nearly 10 staff-hours to replace a screen. It was also easy to tear the screen material when "setting" the hold-down rod. At the test facility, where only four panels are used, the monel rod hold-down system was adequate, but at the McClusky Canal structure where hundreds of frames would be involved, much added labor would be required to replace the screens. It appears that a flush screen hold-down device is not needed because debris on the screens is easily washed off by the backwash system and water flowing on top of the screens.

For the 1981 testing season, continuous 1/4-inch by 1-inch stainless steel clamping bars were used on two screen frames. A neoprene "O"-ring gasket was placed in the milled groove originally designed for the monel rod. The screen was held against the "O"-ring and screen frame with the 1/4-inch clamping bar, which, in turn, was fastened to the frame using the same machine screw spacing as the monel rod hold-down. With this arrangement, installation is much easier and the screen is less susceptible to damage during installation since the screen does not have to be depressed and bent over a sharp 90-degree angle into the machined groove. The clamping bar on the top of the screen material did not affect the operation.

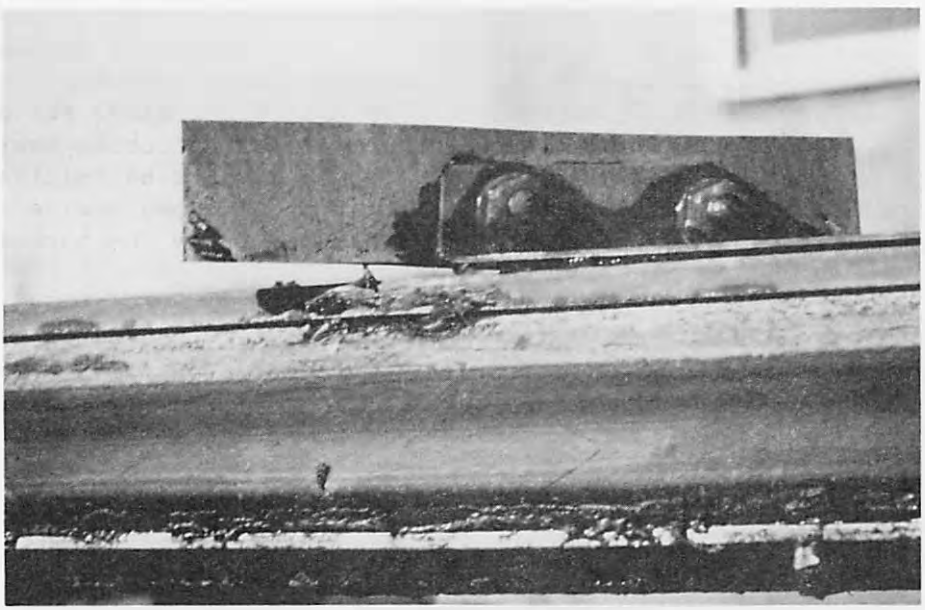
Seals

Pneumatic rubber tubes with a rectangular outside cross-section of 1-13/32 inch by 23/32 inch and a sidewall thickness of 1/8 inch (developed and tested in the laboratory) were used to seal the screen panels in the support frames.

During the 1979 testing season, the seals were manually inflated to 22 psi and sealed. Seal pressure was checked twice during the 3-week testing period. No pressure loss was noted.

For subsequent testing, the automatic inflating and monitoring system was installed. Features of this system are: individual low pressure indicator lights, air flow indicator, and pressure gages. The seals were operated at 22 psi with the low pressure alarm set at 18 psi. The only leak that has occurred was caused by a cracked steel elbow in one of the air supply lines and

was detected by the air flow indicator. The leak was repaired with no loss of seal pressure. During panel replacement, one of the rubber supply hoses was temporarily pinched off where the hose comes through the screen frame. The problem was corrected before operation. Rigid stems on the seals would eliminate this type of problem. During panel removal, there was no indication of leakage as indicated by an unbroken contact pattern where the seal met the frame. Even after severe lower frame distortions (approximately 6-inch deflection on center support frame caused by the flooding incident before the frame was reinforced), there was no indication of seal leakage. Overall, the inflatable seal system performed extremely well and does not require further modification other than using rigid stems.



SEAL ON LOWER SCREEN FRAME WHICH WAS BENT BY FLOODING INCIDENT. NOTE DISTINCT DEBRIS LINE WHERE SEAL CONTACTED SUPPORT FRAME

Screen Cleaning Systems

Although the screens had always been partially self-cleaning, they would plug with plankton impinged on the screen. Screen plugging was shown by the gradual advancement of the lower edge of the water flow line on the screen. The rate of plugging depended on flow rate and plankton abundance and composition in the water.

The self-cleaning action was adequate to prevent an accumulation of debris on top of the screen. Material contacting the screen would wash down and accumulate at the lower edge of the water flow line on the screen. This flow line would advance down as the screen gradually plugged with fine impinged debris. When the flow line approached the lower end of the screen, some of the debris would be washed off. Some debris would stack up at the lower end of the screen and then stabilize. This debris accumulation was minimal and did not interfere with the screen operation.

Several types of water-activated cleaning methods were tested at the site. Mechanical cleaners were not tried because of potential damage to the screen.

In 1979, four different cleaning methods were tried on the upper screens. The cleaning system originally designed for the facility was a track-mounted spray bar above the upper screen with nozzles oriented upstream, extending to within 1 inch of the screen. Individual nozzles with various orifice sizes were tested. A No. 20 elliptical orifice nozzle was the largest tested. Because of lack of water pressure, this system did not clean the screen adequately.

The next method tested was a carriage with two wheels on each side which rode on the lower screen frame and sprayed the upper screens from underneath. A single movable 1/8-inch diameter opening spray nozzle was mounted on the carriage assembly. A garden hose with 60 psi water pressure was connected to the nozzle. The carriage was moved up and down the screen by pushing with 3/4-inch pipes on each side of the carriage. The nozzle was traversed back and forth across the carriage system with a rope and pulleys. This system removed impinged plankton from the screen, but the system was too slow and cumbersome to be used to clean the upper screen. However, the system did demonstrate that spray cleaning the screen from below had potential.

A 1-inch horizontal pipe baffle was also installed near the weir directly over the top end of the screens to cause a turbulent roll in the water, thereby increasing the cleaning action of the water. Similar pipe baffle arrangements and a steel plate baffle were also tried, but none were effective.

The most effective cleaning method used in 1979 was hand spraying with a garden hose using 60 psi water pressure. The upper screens could be cleaned from above in 15 to 25 minutes by spraying with a standard hose nozzle set for solid stream held a few inches above the screen. The lower phosphor-bronze screen plugged once during the 1979 test. Flow through the screens was shut off and the screen was cleaned from below with the garden hose. The lower monel screen did not plug during this period.

Based on data collected during the October 1979 testing, a screen backwash system was designed and installed (Table 18 summarizes modifications to the backwash system as well as other changes made at the field test facility). The system included a pressure pump, an air cylinder, and traveling spray bars. The air cylinder propelled three spray bars by a system of cables and pulleys. Two bars are between the screens, one to clean the upper screen from below and the other to clean the lower screen from above. The other spray bar is below the lower screen and cleans the lower screen from below. The system is designed so all three bars travel together, but only one is in use at any one time.

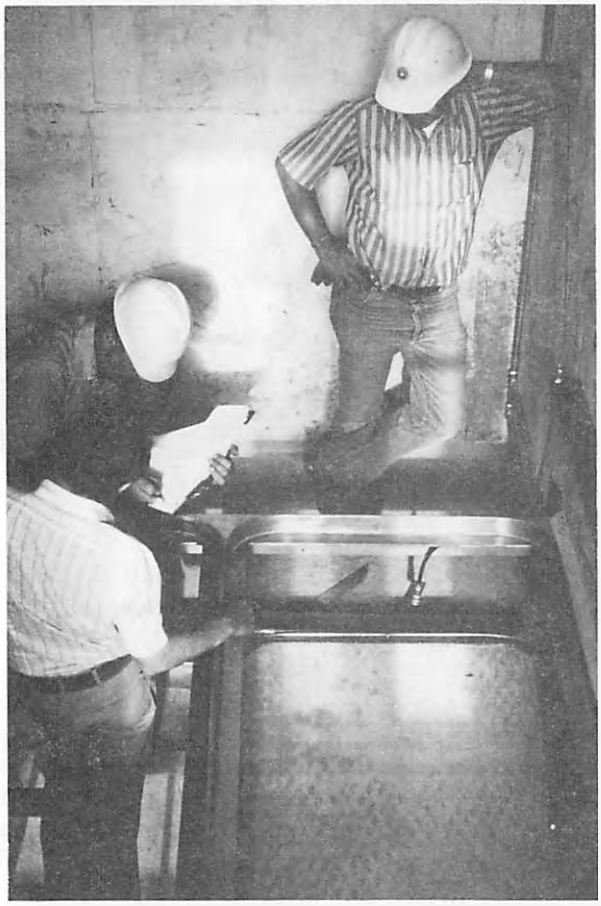
Table 18

SUMMARY OF SIGNIFICANT MODIFICATIONS AT THE TEST FACILITY

Date	Modification	Modification Reason	Results
	Sloping Screen Facility:		
Oct. 1979	Installed hand-propelled spray cleaning device to clean upper screen from below.	Plankton was plugging the top screen.	Demonstrated ability to remove impinged plankton from screen while in operation.
Feb. 1980*	Installed mechanically propelled spray bars to selectively clean either the upper or lower screens from below or the lower screen from above.	Existing spray cleaning device was inefficient.	Screens were easily cleaned by spray bars from below. Tests on cleaning lower screen from above were inconclusive.
Aug. 1980	Installed paddle switch at lower end of upper screen panel to detect screen plugging.	Convert backwash system from manual to automatic control.	The paddle switch worked, but occasionally "stuck" or hung-up with debris.
Feb. 1981	Installed photo-electric cell at lower end of upper screen plus electronic sequencers and timers for backwash control.	The paddle switch was not dependable. Demonstrate ability to control backwash via time and/or automatic detection systems.	Preliminary findings indicate the automatic control system will work, but more duration testing is needed to determine system reliability.
Aug. 1980	Replaced the sump pump with a 60-gpm submersible solids-handling pump that collected screened debris.	The shaft driven chopper pump being used was under-sized and the motor was susceptible to water damage.	60-gpm capacity was adequate. The pump occasionally became clogged with grass and other screened material.
Feb. 1981	Replaced the submersible pump with another 60-gpm submersible solids-handling pump that was designed to handle stringy material as well as solids.	Existing submersible pump was not dependable.	The pump was reliable and had adequate capacity.
Feb. 1980	Installed an automatic monitoring and alarm system for each pneumatic screen seal to continuously monitor seal pressure.	Needed a means of immediately detecting a pneumatic seal malfunction.	The detection system provided continuous individual screen seal monitoring.
Feb. 1980	Installed 70-mesh monel screen on two frames and 70-mesh phosphor-bronze screen on the other two screens.	80-mesh screen was used in 1979 because 70-mesh was not available in time for for the testing.	No change was noticeable in facility operation when the 70-mesh screen was installed.
Sept. 1980	Replaced 70-mesh phosphor-bronze with 70-mesh monel screen material.	Testing had conclusively demonstrated that monel screen had superior hydraulic characteristics and better durability.	The monel fabric continued to perform well.
Feb. 1981	Modified screen attachment system on two screen frames.	Existing attachment method was functional, but required about 10 man-hours/panel to install the screen cloth.	Screen cloth could be installed in one-third the time. Screen performance was not affected.
Feb. 1981	Changed upper screens from a fixed 5° slope to allow an adjustable slope from 5° to 2° from horizontal.	Under field conditions, a 5° screen slope may not be the optimum slope to achieve the best hydraulic characteristics.	When algal concentrations are light, screen hydraulic characteristics are improved by setting the screens at a 2° slope. The 2° slope has not been tested during periods of heavy algal loading.
	Other Facilities:		
Feb. 1980	Installed a 4x8-foot vibrating 80-mesh screen in the traveling screen facility.	To remove excess water and concentrated debris collected off both the sloping and traveling screens	By weight, the vibrating screen concentrated and reduced the algae and water collected off the sloping screens by 99%.
Aug. 1981	Installed and fitted the traveling prescreen with 70-mesh screens.	To determine if a prescreening structure would remove most algae from the water and increase the hydraulic capacity at sloping screens.	Preliminary findings indicate a prescreen structure does not appreciably increase capacity of sloping screens. Additional testing is neded during maximum algal concentrations.
Feb. 1980	Constructed two-cell lagoon near sloping and traveling screen facilities.	To provide a means of storing and containing material screened from the water.	Provided a very effective method of disposing of screened materials. Only one cell was needed.

*All modifications done during winter shutdown are listed as being completed in February.

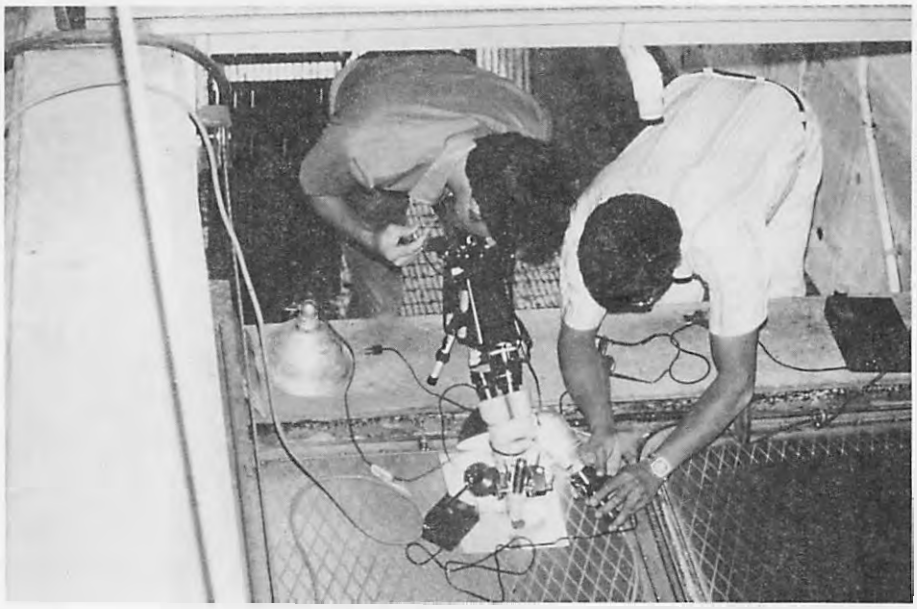
Testing of the spray cleaning system started with the 1980 testing season. Several spray nozzles, flow rates, and operating direction, were used on the upper screen. No. 40 nozzles were used early in the season and operated at a pump pressure of 30 psi with 65 gpm, and 50 psi with 78 gpm. These nozzles were later replaced with No. 30 nozzles, which required 53 gpm at 30 psi, and 64 gpm at 50 psi.



MUCH OF THE MODIFICATION WORK WAS ENGINEERED AND CONSTRUCTED AT THE FIELD SITE.

There appeared to be no difference in cleaning efficiency between the two nozzle sizes and 30 psi seemed to be as effective as 50 psi. In most cases, the material was relatively easy to clean from the screens. However, some of the more filamentous algaes, such as Aphanizomenon, had a tendency to wrap around

the wire strands and plug the screens faster than the more circular Microcystis algae. Although none of the material presented much of a problem for this backwash system, some had a tendency to plug the screens faster than others.



THE SCREENS WERE OCCASIONALLY EXAMINED TO DETERMINE EXACT CAUSE AND EXTENT OF PLUGGING.

Speed and directional tests were also conducted with the backwash system on the upper screens. It appeared most effective to operate the system starting at the inflow end of the screens and making a full pass down and back to the upper end. This was especially true at higher flow rates (15 to 20 ft^3/s). Starting at the bottom of the screens in this situation caused excessive quantities of backwash water to be carried over the ends of the screens.

Travel speed of the spray bar did not seem to affect cleaning efficiency. The most effective and economical operation may be to start the wash cycle from the upper end, shut off the water after the spray bar reached the lower end of the screen, and return the spray bar to the upper end of the screens.

During the season, flows were adjusted depending on the amount of algae in the water and were regulated so the upper screens required backwashing every 3 to 15 minutes. During one full cycle of the system, the spray bar traveled 22 feet, which averaged about 1 mile of travel per day (Table 19).

The lower screen did not require cleaning nearly as often as the upper screen, probably because most algae was removed from the water by the upper screen and any reaching the lower screen already had passed through a 70-mesh screen.

Table 19

SLOPING SCREEN OPERATION (1980)

Week Ending	Average Flow (ft^3/s)	Backwash Freq.[1] Avg. Times/Day	Sump Pump No. 1 (1,000 Gallons/Week)	Chopper Pump[3] No. 2 (Gallons/Week)	Screened Material[2] (Pounds/Week)
6/14	15	70	57	170	--
6/21	13	90	55	3,620	--
6/28	12	200	127	3,580	--
7/5	6	290	90	4,990	--
7/12	8	290	73	11,520	--
7/19	8	320	73	3,010	--
7/26	5	260	71	3,590	14,650
8/2	7	260	54	2,080	9,400
8/9	9	300	65	1,530	3,150
8/16	9	280	79	1,800	5,450
8/23	13	300	109	2,270	9,100
8/30	15	300	153	2,480	6,500
9/6	12	270	146	1,000	4,500
9/13	10	260	122	6,990	3,100
9/20	14	200	168	1,040	4,800
9/27	19	230	187	720	3,900
10/4	18	350	179	960	4,150
10/18	15	80	152	9,840	7,500
10/25	18	80	177	4,340	3,050
11/1	14	50	150	2,250	3,500
11/8	12	80	127	2,010	3,500
11/15	12	60	115	5,550	4,950
11/22	12	90	135	1,500	3,750
11/29	12	60	129	1,700	1,400

1/Data were not adjusted for equipment malfunction or special testing. Test of spray bar speed, direction, and automation equipment caused additional backwash that would not have been required for normal operation.

2/Water content in screened material was not always consistent because of water flowing off the vibrating screen if it was partially plugged or was being hosed off.

3/On August 12, a capacity test was conducted on the vibrating screen which added water to the sump. On October 10, the sump material solidified and the pump ran without pumping material.

Cleaning requirements for the lower screens varied from once every hour to once every several days, depending on the algal loading. The lower screen was easily cleaned from below.

Cleaning the lower screen from above was tried on three occasions in November 1980, but in each case, the screen plugged after a few hours. This may have been caused by improper nozzle alinement and plugged nozzles. In 1981, the lower screens were cleaned using the top spray bar, but the test was too short to demonstrate conclusively that the lower screen could be cleaned effectively from above.

Although the spray bar system under the lower screen seems to clean the screen more efficiently, that system could be eliminated from the design if the top spray bar could effectively clean the screen, assuming this procedure is acceptable biologically. The top spray bar is mounted on the same carriage assembly as the lower spray bar cleaning the upper screen from underneath. A spray bar to clean the lower screen from below would require an additional carriage and drive assembly under the lower screens where access for maintenance and repair would be very restricted.

Generally, the spray bar system performed very well. The system effectively cleaned the screens. Problems encountered with the spray bars in 1980 were generally mechanical or control difficulties.

The air-cylinder drive required no maintenance during the season, although a larger compressor was installed to keep up with high backwash frequencies. Frequent adjustments of the cable were necessary because of shrinkage. Sealed ball bearing, aircraft-type pulleys were used with the cable system since some, especially those used for the water supply hose retrieving system, were subjected to high loading. Those pulleys exposed to continuous moisture eventually failed and had to be replaced at least once during the 1980 season.

Two types of rollers were used on the traveling spray bar in 1980. Brass rollers were used earlier in the season, but all seized on the carbon steel axles shortly after being installed. These were replaced with plastic rollers which did not seize; however, some showed excessive wear on the axle-bearing surfaces, indicating a larger bearing surface or more compatible shaft material might be required.

After the 1980 season, all the cables, rollers, and pulleys that caused problems were replaced with different types. Testing in 1981, however, was insufficient to test durability of the new materials.

For the first part of the 1980 season, the backwash system was operated manually by starting the backwash pump, activating a forward and backward stroke on the air cylinder and then turning off the pump. The backwash system was fully automated by September using a collecting trough and paddle switch located at the lower end of the screen panels. When the paddle switch was tripped, it activated a series of electric timer controllers that would operate the air cylinder and backwash pump. This system worked, but was not very reliable because the paddle switch occasionally plugged with leaves, grass, twigs, etc.

The entire backwash control system was replaced prior to the 1981 testing season. A narrow beam photo electric cell with adjustable sensitivity was used at the end of the upper screens to replace the trough and paddle switch. The electric time controllers were replaced with electronic sequencers and timers. This system provided the following control capabilities:

1. Photo cell control to wash upper screen

2. Timer control to wash upper screen

3. Timer control with photo cell safety override to wash upper screen

4. Timer control to wash lower screen either from above or below

5. Manual override to operate any one of the three spray bars

This control system worked very well in 1981, with most of the testing done with photo cell control to wash the upper screen and the timer to wash the lower screen from above. However, the testing season was too short to demonstrate the control system's reliability and durability.

Lower Sump System

Water and screened material flowing off the end of the screens were collected in a sump located at the bottom end of the screens. Float switches were used for pump control and included a high-water limit switch that sounded an alarm and automatically shut the canal flow down in the event of high water in the sump.

Four different pumps were tried in this sump. In 1979, a standard duty 1/2-hp submersible sump pump was used, with the sump water water recirculated back into the feeder canal upstream from the screens. This pump was a temporary setup and would occasionally clog with debris.

Two pumps were used in 1980, a vertical turbine chopper-type and a submersible solids-handling sump pump. The chopper unit worked satisfactorily, but it was undersized (31 gpm), not designed for continuous duty, and subject to water damage to the motor when the sump flooded. The submersible trash pump had a higher capacity (68 gpm), but was susceptible to plugging, especially with twigs and grass, which sometimes jammed the impeller. With both pumps, leaves, grasses, salamanders, etc., had a tendency to float and accumulate on the sump water surface. A portable 5-hp gasoline powered standby pump was also connected into the sump, used primarily for evacuating excess water and material in the event of floods, electrical power losses, etc.

Flow off the screens into the sump generally averaged 760 gallons per hour in 1980, considerably more than anticipated when the facility was designed. Neither the sump pit nor pump provided the cushion necessary to accommodate minor changes in operating conditions. As a result, if the pump failed and it was not immediately detected by the operator, the sump would easily overfill and the high-water alarm system would automatically shut the system down.

For the 1981 testing season, another 70 gpm, 4-inch solids handling pump was installed in the sump with a 3-phase electric motor specifically designed to handle grass and other stringy material, as well as solids. The pump is submersible, mounted on guide rails and designed so it can easily be raised out of the pit for inspection without disconnecting any piping or electrical fittings. During 1981, this pump was used without incident, and it appears that pumping problems experienced with handling the sump material have been resolved. This pump is available in larger sizes and was used in the proposed designs for the McClusky Canal Fish Screen.

Plankton Net

The plankton net, similar to the one used in testing the laboratory sectional model, slides under the sloping screens while the facility is operating, and was first tested in 1979 and 1980. Initially, material passing the screen was to be collected in the net for 1 hour each day during operation. The plankton net would be positioned under the screen for a designated length of time after which the flow of water would be shut off, the net pulled out, and washed down to concentrate all collected material in the collection cup at the end of the net.

Attempts to use the plankton net were not successful. At normal flows of 12 to 16 ft^3/s, the plankton net quickly plugged with small debris, generally within 3 to 4 minutes after it was positioned under the screens. When the net plugged, the water force placed extreme strain on the net.

Traveling Screen

The traveling screen was tested at the facility to determine if prescreening would reduce the plankton load in the water and allow a greater flow through the sloping screens.

The traveling water screen was initially operated on July 28 and 29, 1980, continuously from August 4 to August 11, and intermittently from August 17 to September 12 on a 24-hour on-off cycle. The traveling screen was not tested in 1981.

Flow increased from 5 ft^3/s to about 8 ft^3/s, with the traveling screen in operation during July 28 and 29. During August 4-11, flows were increased from around 8 ft^3/s to 9-10 ft^3/s by operating the traveling screen. Loading consisted almost entirely of algae in July. Plankton loading was still heavy during the August 4 to 11 period.

Plankton was less abundant when the traveling screen was operated from August 17 through September 12. The flow averaged about 12 to 13 ft^3/s. The traveling screen allowed an increase in flow of about 6 percent.

Effectiveness of the traveling screen in increasing flow through the sloping screen during periods of heavy algae cannot be determined based on data collected in 1980 since the traveling screen was not operational until after the peak algal bloom. Two different types of screen material (monel and phosphor-bronze) were also being tested at the sloping screen facility at this time. The combination of testing sloping screen materials with different flow characteristics and the prescreen system at the same time made it difficult to assess

prescreening effectiveness. However, based on the testing that was done, the traveling prescreen did not remove enough algae to significantly affect capacities at the sloping screen facility and the cost of installing and operating prescreens does not appear to be justified. Also, the stationary trashrack (1-3/16 inch spacing between vertical bars) in the feeder canal was effective in preventing coarse debris from entering the system and potentially damaging the upper sloping screens so a traveling prescreen would not be needed for coarse debris removal.

Vibrating Screen

Except for brief periods when the vibrating screen needed repair or special tests were in progress, the water and debris coming off the sloping and traveling water screens was passed over the vibrating screen to remove excess water from the screened material.

The vibrating screen was installed on June 12, 1980; however, it did not operate properly until July 17. The first two 80-mesh stainless steel screen cloths installed on the vibrating screen tore after short periods. Apparently, the rubber support pads under the cloth were too hard. The third screen cloth, along with softer rubber support pads, was installed on July 17 and has lasted with no apparent wear or deterioration.

Material screened from the sloping screens was carried by large quantities of water. Most of the water in the sump came off the end of screens before backwashing, and from backwash when the spray bars were at the lower end of the screens. Generally, by weight, over 99 percent of the material and water collected in the sump below the sloping screens passed through the vibrating screen and returned to the feeder canal upstream of the traveling screen. The remainder of the screened material was pumped into the lagoon (Table 20).

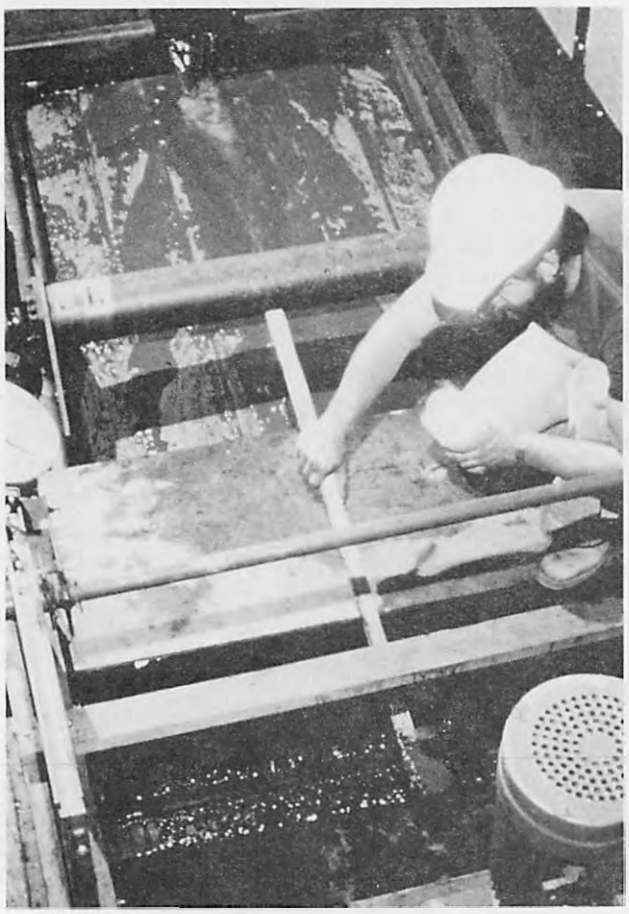
The water that passed through the vibrating screen did contain 20 to 40 percent plankton, but this material, which was finely broken, did not appear to affect the sloping screen operation.

On September 17, a test to determine maximum capacity of the vibrating screen was conducted by pumping canal water directly onto the screen. This was done to calculate the number of vibrating screens needed at the McClusky Canal structure and to explore using vibrating screens for prescreening canal water instead of the traveling screens. The following tabulation shows test results:

Vibrating Screen Slope	Capacity (ft^3/s)
5°	3.8
2-1/2°	5.1
0°	5.7

The vibrator motor was operated during the tests both clockwise and counterclockwise, as well as being stopped. Direction of rotation did not appear to affect screen capacity.

The vibrating screen proved to be an efficient, relatively maintenance-free mechanism for removing excess water from the screen debris. Except for late fall, material coming off the vibrating screen was still viscous enough to be pumped to the lagoon with the chopper pump. During the fall, screened material was mostly zooplankton and some water had to be added occasionally to the vibrating screen sump to maintain a pumpable fluid.



MATERIAL RECOVERED OFF VIBRATING SCREEN WAS
ROUTINELY WEIGHED AND SAMPLED

Debris freezing on the vibrating screen and some icing was encountered during cold weather because the screen bottom was exposed and pumping onto this screen was intermittent. Freezing on the screen was minimized with portable forced air heaters placed nearby. Enclosing the bottom of the screen would eliminate debris freezing on the vibrating screen.

Flow and Debris Quantities

Flow through the test facility was calculated with the broad-crested weir formula using head above the weir in front of the sloping screens. For much of the testing, flow was set at maximum capacity, limited by plugging (and therefore backwash frequency) of the upper sloping screen. In 1979, the screens were cleaned by hand with a garden hose so flows could have probably been higher if a more efficient cleaning method had been available.

For the first part of the 1980 season, flows were adjusted to maintain a 4- to 5-minute backwash frequency on the upper sloping screen. This was about the maximum acceptable. During October 1980, the flows were reduced to 12 ft^3/s to 14 ft^3/s because of limited storage capacity in Lake Brekken. Tables 19 and 20 and Figure 14 show flow and debris quantities for one testing period.

Several methods were explored to develop a consistently reliable way to quantify the amount of material removed at the sloping screens and traveling prescreen.

Baskets with 80-mesh screen were placed at the end downstream of the upper sloping screens in 1979. Material coming off the screens was collected, allowed to drain for a short time, weighed, and then disposed of in a earthen pit. This work was done by hand, and, although cumbersome, it worked satisfactorily.

For the 1980 season, the use of 80-mesh baskets to determine quantities of screened material was considered. However, in the spring of 1980, the plankton being screened were very small and did not allow the 80-mesh baskets to drain. A basket using plankton netting was also tried, but also it did not drain. The next method attempted was to determine the drained debris weight in samples collected from the sloping screen sump. Volume of material from the sump was to be recorded, a volume/debris weight relationship determined, and then the amount of debris screened was to be calculated. However, a method of concentrating the debris in the sample to a consistent dry weight could not be developed.

The method eventually used to determine the weight of screened material was to use an aluminum container at the end of the vibrating screen. All material coming off the vibrating screen was collected and weighed in the basket, dumped into the sump, and then pumped to the lagoon by chopper pump No. 2. This included material collected by the traveling screen as well.

The lagoon was an effective and easy method of disposing of screened material. Only one cell was used during the 1980 season. The cell has a bottom area of approximately 30 feet by 70 feet with 2:1 side slopes. Initially, about 1.5 feet of water was placed in the lagoon. After the system was in operation, water depth in the lagoon stabilized at around 2.5 feet. In the spring of 1981, the cell was drained into the adjacent deeper cell. The cell bottom contained about 1.5 feet of sludge. This material had a consistency similar to pudding and would not flow through a 3-inch gravity pipe leading to the second cell. Based on the consistency of the sludge, lagoon seepage should be negligible; however, with prolonged use, the cells would have to be periodically dried and cleaned.

Biological and Water Quality Monitoring

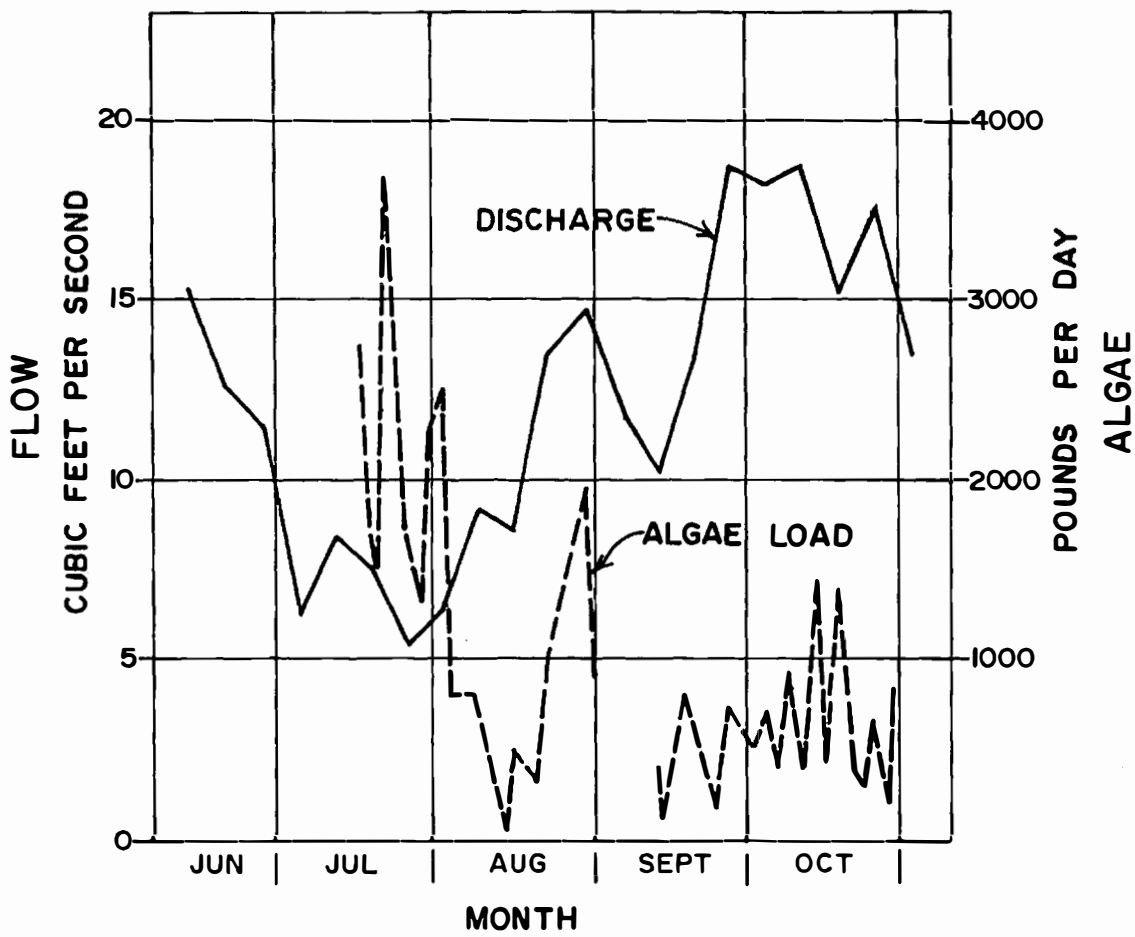
Trends in major physical, chemical, and biological parameters during the 3 years of field test facility operation are described in this section.

Table 20

SLOPING SCREEN OPERATION - 1979 AND 1981[1/]

Date	Flow (ft^3/s)	Screened Debris (Upper Screen) (lb)	Screened Debris (Upper Screen) (lb/hr)
09/28/79	2	--	--
10/01/79	10	--	--
10/02/79	10	125.1	18.8
10/03/79	15	236.8	28.4
10/04/79	18.6	226.5	30.9
10/05/79	15	172.8	32.4
10/09/79	15	356.7	25.5
10/10/79	15	838.1	34.1
10/11/79	15	844.7	35.2
10/12/79	15	851.1	35.5
10/13/79	15	817.4	37.2
10/14/79	15	750.1	31.2
10/15/79	15	793.4	39.3
10/16/79	15	798.1	34.0
10/17/79	15	670.0	27.9
10/18/79	15	610.9	25.4
10/19/79	15	249.5	27.7
10/24/79	15	288.0	36.0
08/04/81	19	--	--
08/05/81	20	--	--
08/06/81	19	--	--
08/07/81	20	--	--
08/10/81	20	--	--
08/11/81	23	--	--
08/12/81	19	--	--
08/13/81	17	--	--
08/14/81	18	--	--
08/19/81	17	--	--
08/20/81	20	--	--
08/21/81	22	--	--
09/02/81	20	--	--
09/04/81	17	--	--
10/10/81	14	--	--
10/14/81	18	--	--
11/02/81	22	--	--
11/04/81	20	--	--

1/In 1981, the facility was operated intermittently and usually tests were being conducted on various equipment. Therefore, meaningful backwash and debris data were not collected.



FLOW/ALGAE RELATIONSHIPS
FISH SCREEN TEST FACILITY
1980

Figure 14

Data were collected for three different operational periods in each of the 3 years, so a valid comparison of water quality and biological parameters among test years cannot be drawn. Long-term operation of the facility itself might affect physical, chemical, or biological parameters during some other subsequent operational period the same year. Different environmental or climatic conditions might also influence these parameters differently.

In 1979, water samples for complete chemistry, trace metal, and nutrient analyses were collected from the inlet canal five times. In 1980, water samples were usually collected from the canal twice a day, two days per week, except when sampling was reduced at certain sites based on preliminary data analyses and personnel considerations. In 1981, four samples were collected weekly or less frequently at mid-day. A complete analysis of the data collected for these years is contained in appendices to this report.

Complete Chemistry

Generally, pH increased over the 3-year period of operation, from an average of 8.24 in October 1979 to 8.68 in August 1981. Likewise, conductivity increased from 1,239 µS/cm to 1,320 µS/cm, and TDS increased from 798.3 to 929.0 mg/L (Table 21). Major cations and anions generally increased, but not consistently, with sodium predominating among the cations followed by magnesium, calcium, and potassium. Bicarbonate predominated among the anions, followed by sulfate, chloride, and carbonate. No statistical analysis of data among years was attempted since sampling procedures, times, locations (sites), and numbers of samples collected changed to reflect results of preliminary laboratory analyses and personnel limitations.

Hardness and alkalinity were both highest in 1981, being lower in 1980 than in 1979. Among the nutrients, orthophosphate and nitrate-nitrogen are the forms utilized biologically, so only these two will be discussed. Orthophosphate was higher in 1981 than in 1979 (Table 21); nitrate-nitrogen was higher in 1979 than in 1981. Nutrient analyses were done for 1980, but the results could not be used due to poor reporting of the data. Trace metals (copper, iron, zinc, manganese, and lead) were virtually absent in 1981; in only one sample was there a detectable level of a metal (zinc). In 1979 and 1980, levels of trace metals varied from nondetectable to exceptionally high, as when lead levels in July 1980 at Site 2 reached 1.274 mg/L, probably due to construction around the traveling water screen to prepare the screen for operation and testing.

Lake Brekken

Initially, Lake Brekken contained brine with TDS levels around 70,000 mg/L. During the 1978, 1979, and early 1980 seasons, the brine was intermittently pumped and flushed into Lake Holmes. The lake was essentially pumped dry prior to continous operation of the test facility in 1980.

Lake Brekken was sampled intermittently from May to September in the 1980 operation period. Average monthly values for some parameters in Lake Brekken are shown in Table 21. Of special interest are conductivity and TDS. Both parameters initially increased about 19 percent from May to June, then exhibited a steady decrease throughout the sampling period. Conductivity decreased about

Table 21

AVERAGE MONTHLY COMPLETE CHEMISTRY, NUTRIENT, AND TRACE METAL RESULTS FOR LAKE BREKKEN AND INLET CANAL SUPPLY WATER

Area/Date	pH	uS/cm Conduct.	TDS	Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO_4	Hard-ness	Alka-linity	NO_3	PO_4	Cu	Zn	Mn	Fe	Pb
Inlet Canal:																				
Oct. 1979	8.24	1,239.0	798.3	182.7	11.1	37.5	40.5	2.9	379.2	17.4	318.0	260.2	315.2	0.040	0.009	0.0080	--	0.008	0.044	0.015
Oct. 1980	8.39	1,247.9	826.7	185.7	10.5	34.5	38.1	6.3	366.2	18.2	350.3	242.9	310.6	--	--	0.0025	0.0023	ND	0.040	ND
Aug. 1980	8.57	1,229.0	804.5	195.6	10.6	30.4	42.0	13.2	344.5	18.2	326.7	248.5	304.5	--	--	--	--	--	--	--
Aug. 1981	8.68	1,320.0	929.0	201.0	14.0	37.2	48.1	27.0	345.3	23.8	345.5	290.9	328.0	0.011	0.045	ND	0.0050	ND	ND	ND
Lake Brekken:																				
May 1980	9.6	11,001.7	9,509.6	3,361.5	95.0	7.8	37.3	448.6	983.0	119.6	4,925.2	173.0	1,561.4	--	--	0.001	0.0016	0.0211	0.099	0.0016
June 1980	9.2	13,071.8	11,394.0	3,980.2	126.1	13.1	49.3	276.5	1,836.2	165.0	5,840.0	235.7	1,965.5	--	--	0.001	0.0200	0.2750	0.203	0.0133
July 1980	8.9	5,430.8	4,484.6	1,521.9	48.8	26.7	46.4	99.4	887.5	72.6	2,238.4	257.7	892.8	--	--	0.001	0.0108	0.0308	0.083	0.9094
Aug. 1980	8.8	4,412.7	3,274.4	1,006.0	38.9	24.1	37.0	59.0	756.6	56.7	1,609.7	211.9	718.3	--	--	--	--	--	--	--
Sept. 1980	9.0	3,596.0	2,582.3	798.3	30.1	25.0	40.7	45.6	622.4	44.0	1,296.8	229.8	586.4	--	--	--	--	--	--	--

67 percent to 3,596.0 µS/cm and TDS decreased about 37 percent to 2,582.3 mg/L in about 5 months.

Most cations and anions also increased initially then decreased steadily through September. The water flowing through the feeder canal from the McClusky Canal into Lake Brekken effectively converted Lake Brekken from a saline lake to a freshwater lake. In Lake Brekken, sodium predominated, followed by potassium, magnesium, and calcium. In canal water, sodium also predominated followed by magnesium, calcium, and potassium. While most cation concentrations decreased over the sampling season in Lake Brekken, calcium tended to increase, probably due to the low initial level in the lake coupled with relatively high levels in the inflowing canal water. This probably is also responsible for the apparent increase in hardness, which is calculated using the concentrations of calcium and magnesium in the water. Continued inflow of McClusky Canal water will probably dilute Lake Brekken even more.

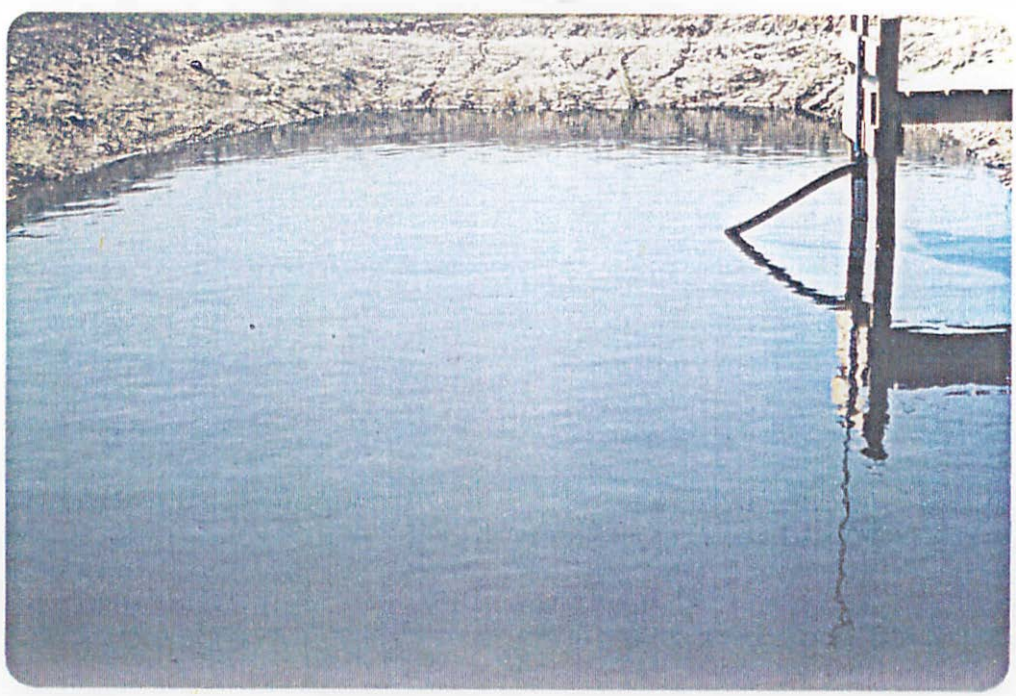
By the end of the 1980 operational season, Lake Brekken had reached its maximum storage capacity. Evaporation losses provided a small amount of storage capacity in Lake Brekken for limited testing in 1981. In 1981, no water quality or biological sampling were conducted on Lake Brekken. However, sampling conducted by the North Dakota Game and Fish Department indicated that there was good overwinter survival among about 25,000 rainbow trout (Salmo gairdneri) stocked in Lake Brekken in the fall of 1980.

Trace metal analyses for Lake Brekken were conducted only for May, June, and July. Copper levels were constant at 0.001 mg/L, while iron increased in June, then declined in July to 0.083 mg/L. Lead levels increased to 0.909 mg/L in July. At Lake Brekken Site 11, July lead levels rose to 1.860 mg/L concentrations with lead levels as high as 1.274 mg/L between the traveling water screen and the fixed sloping screens. Zinc increased from 0.002 mg/L in May to 0.011 mg/L in July, while manganese increased from 0.021 to 0.031 mg/L in the same period.

Nutrient data from Lake Brekken are not available.

Lagoon

Only one cell of the two-cell lagoon was needed to contain all screen debris collected at the facility. The lagoon was sampled periodically in 1980, but not in 1981. During most of the operational period in 1980, screen debris pumped to the lagoon was predominantly phytoplankton which changed to predominantly zooplankton in the fall. Breakdown of the predominant blue-green algae released various plant pigments, producing visible color changes, most noticeably red. Generally, only relatively dewatered, concentrated debris from the sump below the vibrating screen was pumped to the lagoon. No investigations to assess biological activity (aerobic or anaerobic bacteria, or living phytoplankton or zooplankton) were conducted. During the 1980 operating season, the level of the lagoon remained relatively stable, indicating a balance between incoming screen debris and evaporation of the small amount of water necessary to pump the slurry. Water quality sampling in the lagoon began on July 7, 1980, and continued through November.



Lagoon cell used to store screened debris. Note change in color from burgundy in July to almost gray in November.

Average monthly TDS increased from 1,462.8 mg/L in July to 2,034.5 mg/L in November. Conductivity likewise increased from 3,155.6 µS/cm in July to 5,870.0 µS/cm in November, while the pH dropped from 6.80 in July to 5.70 in August, then rose to 7.78 in November. Sodium predominated among minerals in the lagoon, followed by calcium, potassium, and magnesium. Sodium levels decreased from July through September, increased in October, then decreased again in November. Potassium decreased in August, increased through October, then decreased in November, while calcium increased in August, decreased through October, but increased in November. Magnesium increased in August, then decreased through November.

Since the pH of the lagoon was always less than 8.3, no carbonate was present. Bicarbonate increased through October, then decreased slightly in November. Chloride decreased through October, then increased slightly in November, while sulfate increased in August, decreased through October, then increased in November. Hardness also increased in August, then decreased through November. Alkalinity increased through October, then decreased slightly.

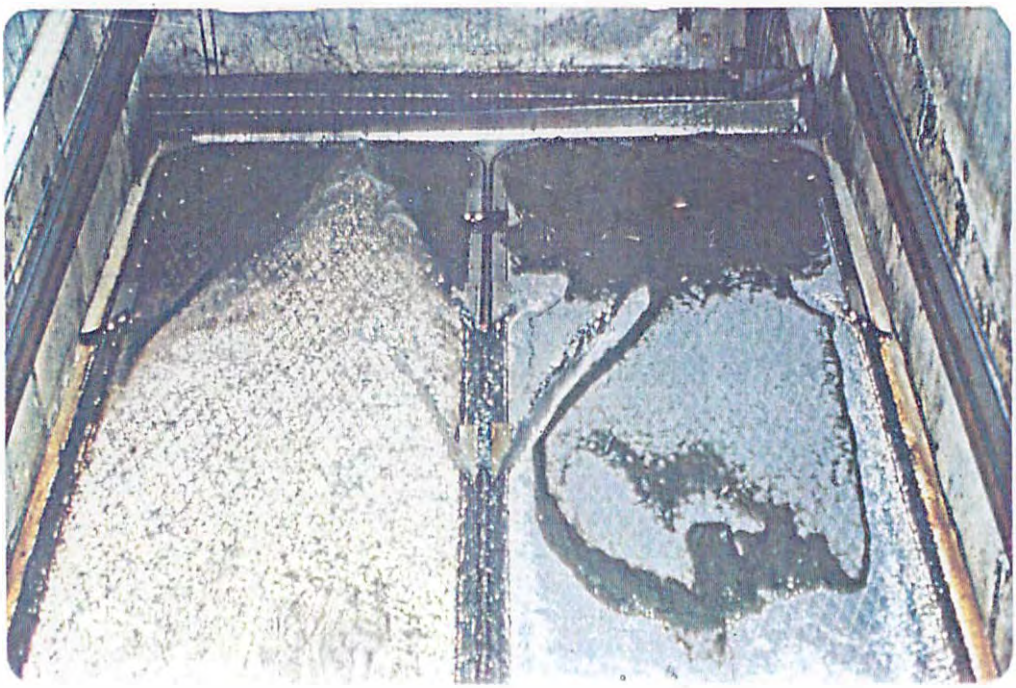
Plankton

Plankton in the canal water both above and below the screens was monitored in 1979, 1980, and 1981. Plankton samples were collected above the trashrack and below the sloping screens in the outlet channel, using either the collection cup from the large plankton net (with a 3.5-inch mouth) or a Wisconsin-type plankton net (with a 4-inch mouth). Samples were collected at the water surface just ahead of the trashrack in about 20 inches of water and in the outlet channel in about 6 inches of water twice a day for 2 minutes each.

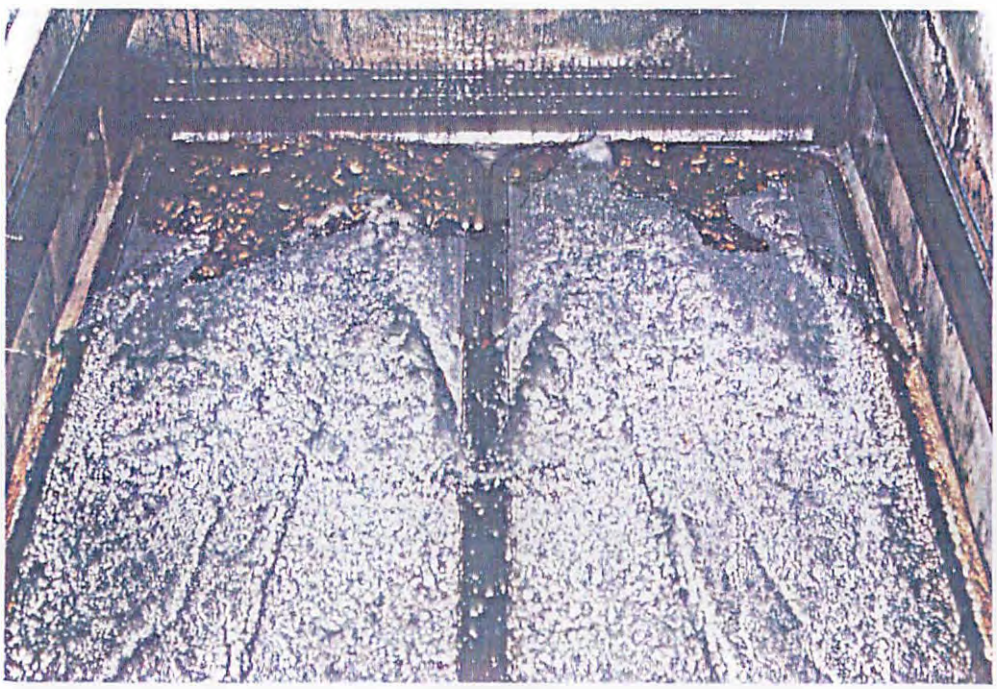
In 1980, a Wisconsin-type plankton net was used to sample the entire water column for 2 minutes at each of the three sampling sites on test days. This procedure was found unsatisfactory since plankton partially plugged the net during the 2-minute sampling period, thereby preventing an accurate determination of the volume of water actually being filtered through the net. This problem was overcome using a 2.5-liter horizontal Van Dorn sampling bottle was used to collect water samples. Sample volumes of 2.5 to 20 liters of water were collected, concentrated through the plankton net, and preservation preserved in formalin for later analysis. These same sampling procedures were followed in 1981. Toward the end of the operational period in 1981, the sampling frequency was reduced to once a week or less.

Generally, a greater number of organisms per liter occurred in samples collected above the trashrack than below the sloping screens, especially for larger zooplankton. Some of the same types of organisms were found below the screens as above. The screens effectively concentrated plankton in a windrow at the leading edge of water advancement and the continuous pressure exerted on the organisms may have forced some organisms through the screen apertures. Most organisms found below the screens were either small members of the same taxa found above the screens, or shells or cases resulting from physical damage to the organisms or from molting.

Zooplankton found in samples collected at the fish screen included copepods (Diaptomus and Cyclops), cladocerans (Bosmina and Daphnia), nauplii of copepods, and rotifers (Keratella and Asplanchna). Phytoplankton types found in canal



Heavy accumulations of Aphanizomenon were encountered in mid-summer. Phosphor-bronze screen is on the left. Monel screen is on the right.



During the fall, zooplankton were predominant. Note the leaves on the screen. Both screens are monel.

water in 1979 include Aphanizomenon, Microcystis, Anabaena, Oscillatoria, Dinobryon, and Pediastrum. Aphanizomenon was by far the most dominant phytoplankter. Microcystis and Dinobryon were present in fewer, but about equal numbers. The remaining species occurred sporadically. In 1980, Aphanizomenon predominated from June through August, with peak blooms occurring in early June and mid-July. Microcystis appeared in mid-August, peaked in late August, and was present for the remainder of the sampling season. Low numbers of Spirogyra and Oscillatoria also occurred infrequently. Only qualitative examination of phytoplankton samples was done in 1981; negligible quantities were found. Aphanizomenon, although present in small quantities, predominated over Microcystis. No other phytoplankton species were present.

Macroinvertebrates

In 1979 and 1980, aquatic macroinvertebrates were collected randomly from the screens with a small dip net. Organisms were preserved in 7 to 10 percent formalin for identification. No attempt was made to quantify them since the intent was to identify the types of macroinvertebrates in the canal.

In 1979, the following types of macroinvertebrates were identified from random collections off the screens:

Two species of water boatman (Trichorixa spp.)
Three species of diving beetles (Dytiscus spp. and Rhantus sp.)
Water scorpion (Ranatra fusca)
Giant water bug (Lethocerus americanus)
Back swimmer (Notonecta undulata)
Rat-tailed maggot (Syriphadae sp.)
Dragonfly naid (Libelludae sp.)
Horsehair worms (Gordius sp.)
Leeches

In 1980, the following macroinvertebrates were collected:

Giant waterbug (Lethocerus americanus)
Whirligig beetle (Gyrinius sp.)
Water scorpion (Ranatra fusca)
Blackfly (Simulium sp.)
Midges
Mosquito larvae
Horsehair worms

Blackfly larvae colonized the sloping screen, building both upstream of the sloping screens and in the outlet directly below the screens. The whole colony emerged and disappeared near the end of October. Blackfly larvae were the only macroinvertebrate species observed colonizing the structure.

In 1981, the following macroinvertebrates were collected:

Freshwater snails (Gyraulus sp., Lymnaea sp., and Physa sp.)
Midge larvae and adults (Chironomidae)
Blackfly larvae (Simuliidae)
Water boatman (Corixidae)
Diving beetles (Dytiscidae)
Horsehair worms (Goridiidae)
Mayflies (Ephemeroptera)

Fish

Fish were collected from the screen at random times during operation of the facility. In 1980, the McClusky Canal was also sampled to assess fish species composition and abundance. Fish were collected from the screens with a small dip net to obtain an estimate of the number of species in the feeder canal. It was impossible to estimate fish populations in the feeder canal from the number of fish collected on the screens because some fish, like bullheads, generally remain close to the bottom, while others, such as fathead minnows, generally swim throughout the water column. Behavioral characteristics might affect the fish's chance of getting onto the screens. Likewise, fish species composition and abundance in the feeder canal would not necessarily reflect composition and abundance in the McClusky Canal since some fish might avoid the feeder canal turnout.

In 1979, fathead minnows (Pimephales promelas) constituted about 77 percent of fish collected on the screens, followed by brook stickleback (Culaea inconstans), which made up about 21 percent of the fish. Six other species constituted 1 percent or less of the total numbers collected:

Black bullhead (Ictalurus melas)
Freshwater drum (Aplodinotus grunniens)
Black crappie (Poxomis nigromaculatus)
Carp (Cyprinus carpio)
Bigmouth buffalo (Ictiobus cyprinellus)
Orange-spotted sunfish (Lepomis humilis)

In 1980, 3,365 fish, representing nine species, were collected randomly or on a fixed schedule from the screens at the facility. Brook stickleback made up about 71 percent of the sample, followed by fathead minnows at 28 percent (very high numbers of brook stickleback in June collections contributed substantially to the overall high numbers of these fish). Sticklebacks were more abundant early in the season, then decreased with a steady increase in fathead minnow numbers. The following eight fish species constituted less than 0.2 percent of fish collected:

Black crappie (Pomoxis nigromaculatus)
Carp (Cyprinus carpio)
Freshwater drum (Aplodinotus grunniens)
Black bullhead (Ictalurus melas)
Yellow perch (Perca flavescens)
White sucker (Catostomus commersoni)
Walleye (Stizostedion vitreum)
Unknown

Species found in the McClusky Canal were essentially the same as those collected on the fish screen. In the canal, however, there was a greater occurrence of black bullhead, crappies, walleye, and carp than were collected on the screen. Generally, small individuals of a species occurred in the feeder canal, while the larger seemed to avoid the turnout. No rainbow smelt were collected at the screen facility or at any of the canal collection sites.

Fish were collected in 1981 only twice from the sloping screens; no sampling was done in the feeder canal or the McClusky Canal. On August 5, six fathead minnows were collected. On August 19, four fathead minnows, two brook sticklebacks, and one small carp were collected from the sloping screens.

McCLUSKY CANAL FISH SCREEN

When field and lab testing were partially complete and preliminary data became available, the task force evaluated the McClusky Canal Fish Screen to determine how much modification work would be needed on the structure. They concluded that it was not practical to modify the existing structure and that a new facility should be constructed in the canal at the same location. The previously made decision to adopt the 70-mesh screen significantly reduced the hydraulic capacity of the screens, requiring a much larger screen area than was available in the existing structure. In addition, the structure did not provide the necessary modular flow control, reserve screening capacity (standby), or access space needed for screen backwash equipment.

This chapter describes the new fish screen facility that the Bureau of Reclamation proposes to construct and operate in the McClusky Canal. The plans are at the feasibility level. Final design and operating plans for the facility would vary somewhat from these feasibility plans after additional test data and more detailed engineering designs are available. Testing to refine operating procedures and equipment would be a continuing process. The field test facility could be used for this purpose or a special isolated miniature sub-bay may be included in the facility for testing.

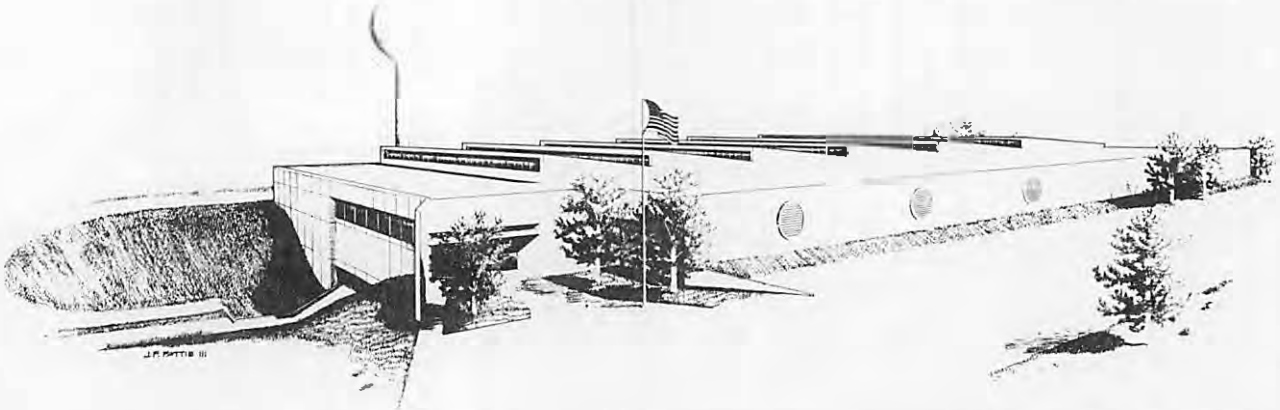
Facility Description

The facility would feature a modular-type design being divided into six bays (Drawings 769-D-1719 through -1724). Each bay would have 14 sub-bays and could be operated independently from the other bays. A sub-bay would contain four upper and four lower 3-foot by 12-foot, 70-mesh screen panels. Basically, a sub-bay would be almost identical to the fish screen test facility, except the sub-bay would be four panels wide. Each sub-bay would be equipped with a screen backwash system to clean both the upper and lower screens.

The facility would be initially designed for a 1,000-ft^3/s capability with four bays in operation and two standby bays. The design flow used to size the facility is 1.5 ft^3/s per lineal foot of screen panel width. This would equate to a 9-ft^3/s flow at the 6-foot wide field test facility. Under most conditions, the test facility can easily handle twice that flow, so the 1.5-ft^3/s design flow coupled with using one-third of the screen for standby, would probably prove to be a conservative design. Additional testing at the test facility may lead to the conclusion that the design flow should be increased.

The proposed facility would be large: the screen area would be about the size of two football fields placed side by side. Including the shop and personnel areas, the building would cover over 2.5 acres. In terms of screening capacity, the facility would be 168 times larger than the test facility, with 84 sub-bays (a total of 672 screen frames) set in the structure.

A trashrack would be placed at the entrance to the fish screen structure to strain all the water flowing through the intake to remove branches, logs, lumber, cans, bottles, tumbleweeds, and other coarse debris. A 1½-inch bar space opening would be used on the trashrack.



McCLUSKY FISH SCREEN STRUCTURE

ALWAYS THINK SAFETY

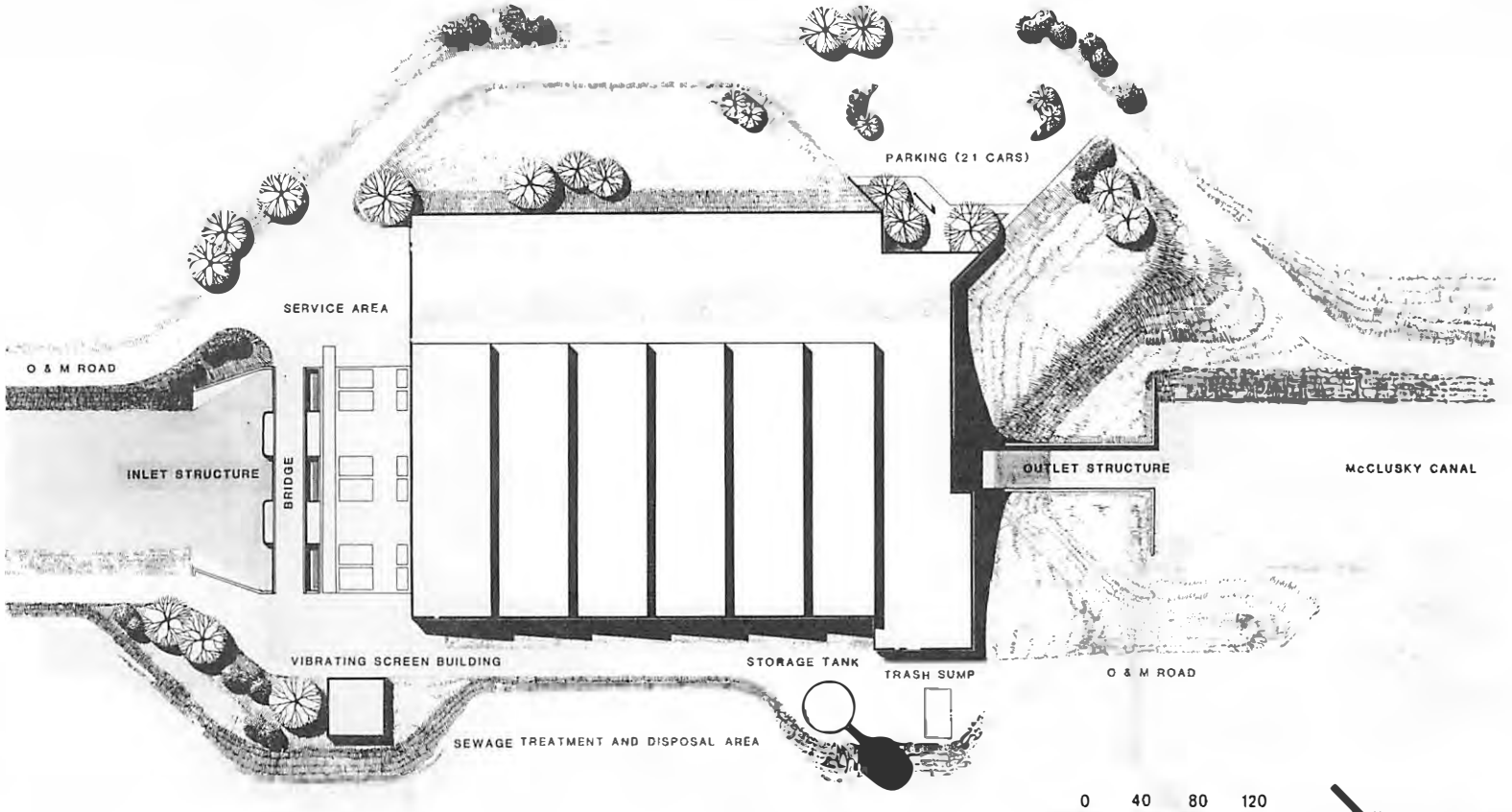
UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION: GARRISON DIVERSION UNIT N DAK

McCLUSKY CANAL
TRASH AND FISH SCREENING STRUCTURE
ARCHITECTURAL

FEASIBILITY DESIGN DRAWING
PERSPECTIVE

DESIGNED ... SUBMITTED K. E. Anderson
DRAWN J.P. PATTIE III RECOMMENDED James D. Crews
CHECKED ... APPROVED ...
DENVER, COLORADO FEB 22 '68

759-D-1719



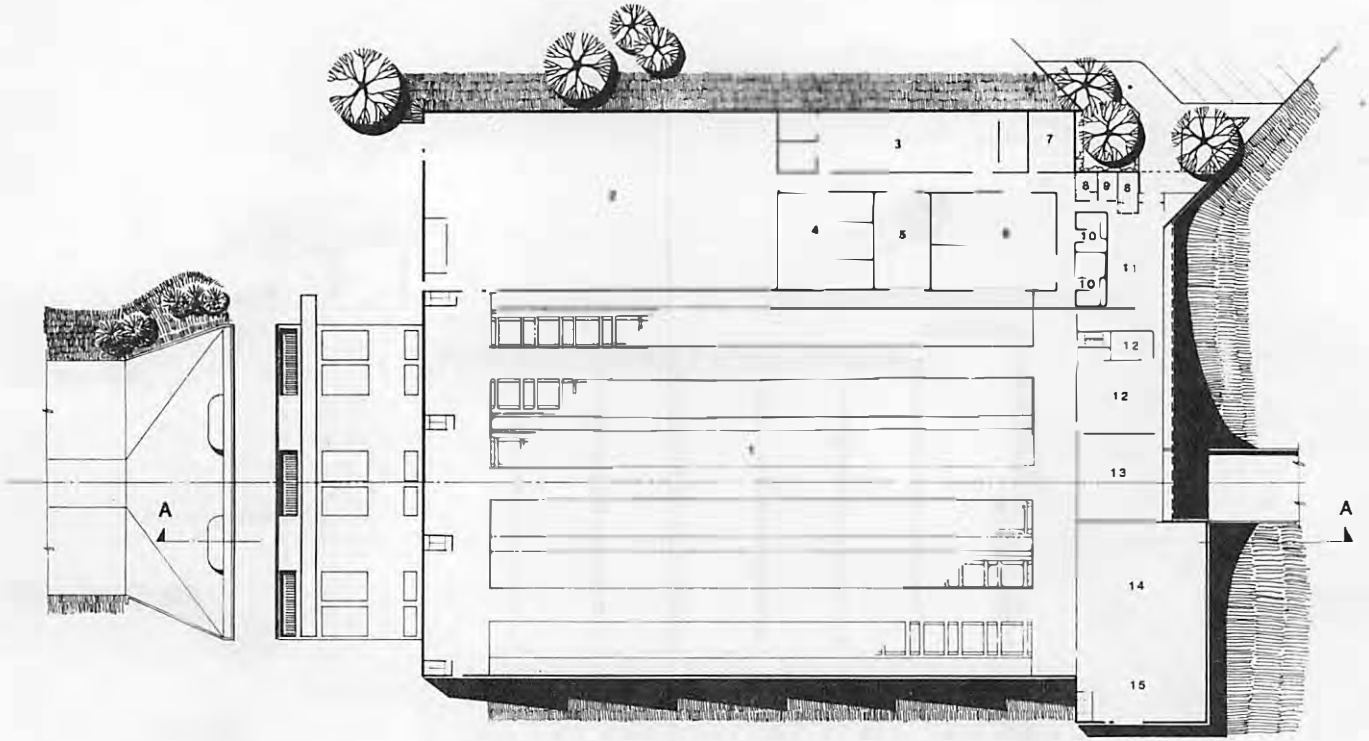
SITE PLAN

ALWAYS THINK SAFETY

McCLUSKY CANAL
TRASH AND FISH SCREENING STRUCTURE

FEASIBILITY DESIGN DRAWING
SITE PLAN

769-D-1720



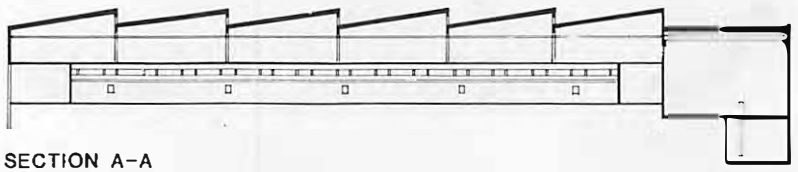
1. SCREEN BAYS
2. SCREEN STORAGE
3. SHOP
4. SCREEN INSPECTION
5. WASH
6. SCREEN MAINTENANCE
7. MECHANICAL
8. TOILET
9. UTILITY
10. LOCKER ROOM
11. VISITOR CENTER
12. OFFICE
13. CONTROL ROOM
14. PUMP ROOM
15. SERVICE AREA

FLOOR PLAN

0 30 60 90

SCALE OF FEET

N



SECTION A-A

THINK SAFETY

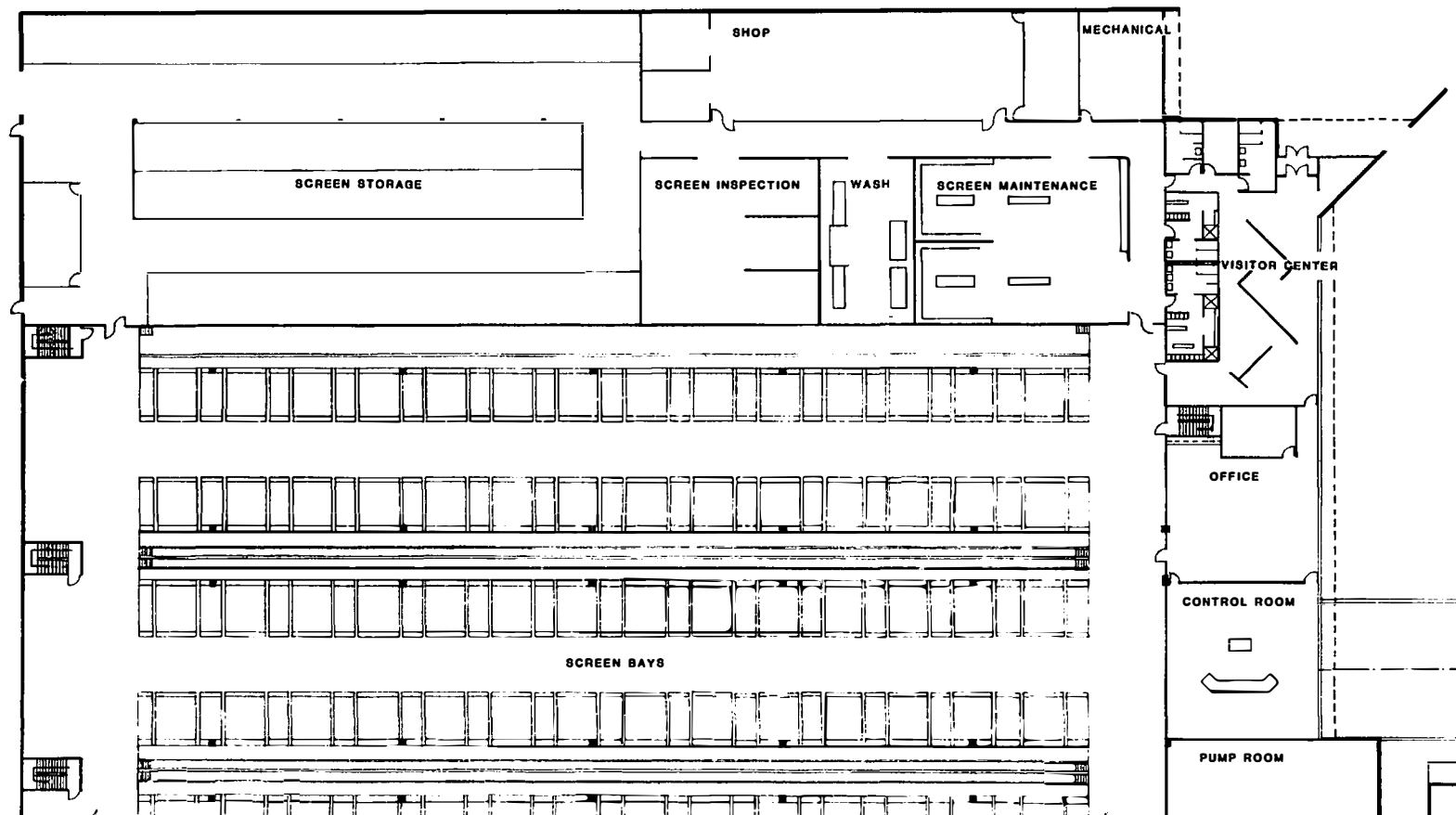
UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION, GARRISON DIVERSION UNIT, N. DAK.

McCLUSKY CANAL
TRASH AND FISH SCREENING STRUCTURE
ARCHITECTURAL

FEASIBILITY DESIGN DRAWING
PLAN AND SECTION

DESIGNED Shaw Thomas SUBMITTED R. R. Peabody
DRAWN Shaw Thomas RECOMMENDED Garney L. Lee
CHECKED ... APPROVED ...
ASST. CHIEF, ENGINEERING AND RESEARCH

DENVER, COLORADO FEB. 20, 1976 769-D-1721



PARTIAL PLAN

0 16 32 48

SCALE OF FEET

N

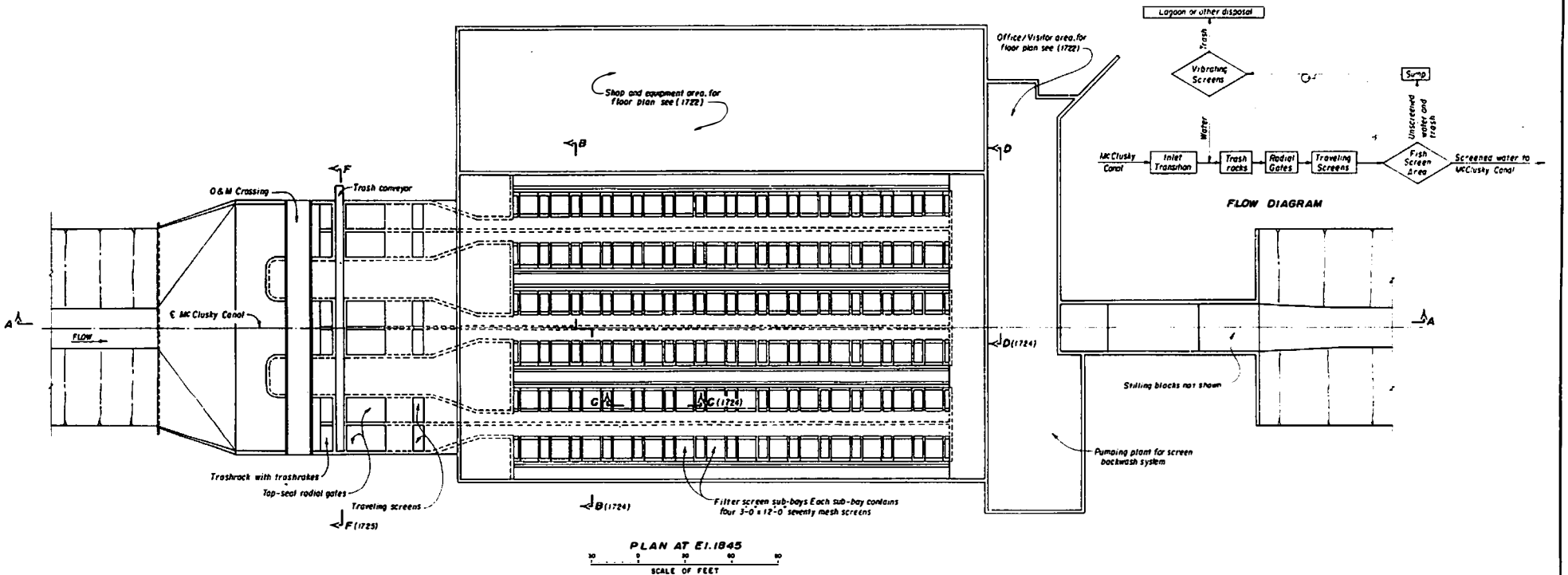
GIVING THEM SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION, GARRISON DIVERSION UNIT, N DAK

McCLUSKY CANAL
TRASH AND FISH SCREENING STRUCTURE
ARCHITECTURAL

FEASIBILITY DESIGN DRAWING
PARTIAL PLAN

DESIGNED Ross Hanson SUBMITTED T. R. Johnson
DRAWN Ross Hanson RECOMMENDED Donald D. Dunn
CHECKED [illegible] APPROVED [illegible]
DENVER, COLORADO 80225 769-D-1722



NOTES

For perspective drawing, see 769-D-1719
For site plan, see 769-D-1720
For information on screen sections and strut manifolds, see 769-D-1726

ALWAYS THINK SAFETY

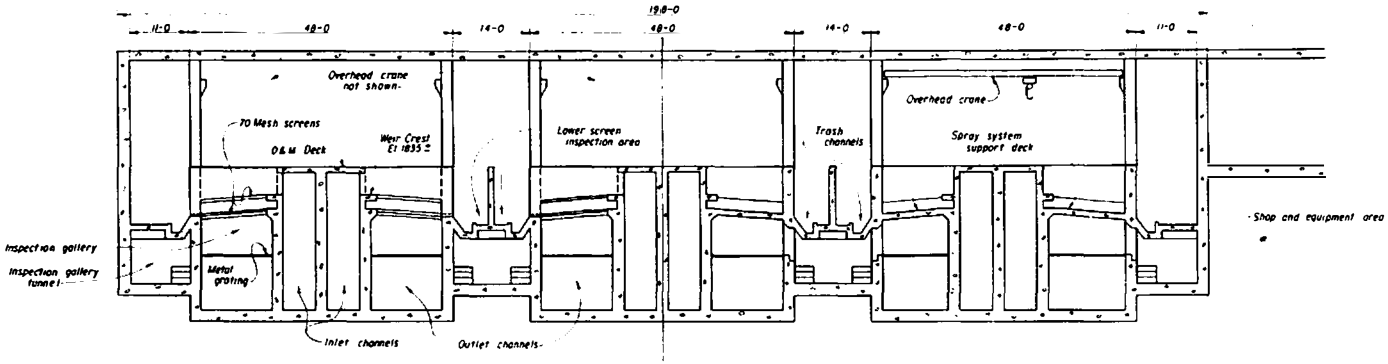
UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION, GARRISON DIVERSION UNIT, N. DAK.

Mc CLUSKY CANAL
TRASH AND FISH SCREENING STRUCTURE
FEASIBILITY DESIGN DRAWING
PLAN AND SECTION

DESIGNED ... DRAWN ... CHECKED ... SUBMITTED ... RECOMMENDED ... APPROVED ...
ASST. CHIEF-ENGINEERING AND RESEARCH

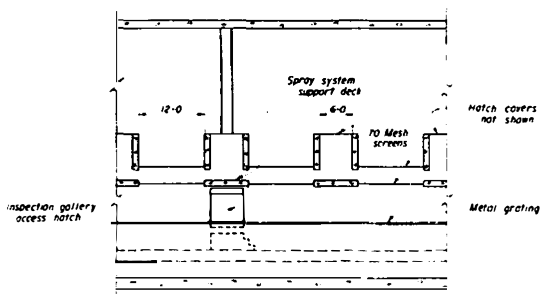
DENVER, COLORADO MARCH 6, 1981 SHEET 1 OF 3

769-D-1723



SECTION B—B (1723)

SCALE OF FEET



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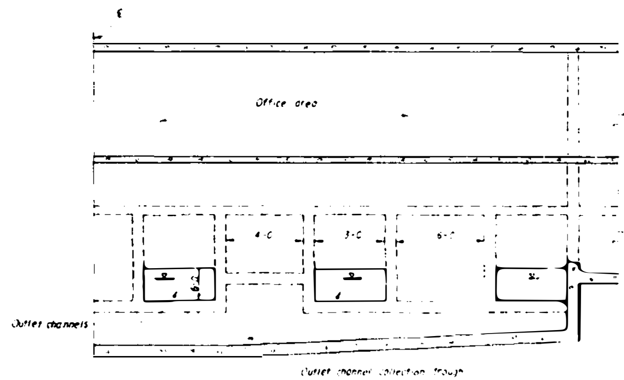

SECTION D—D (1723)

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
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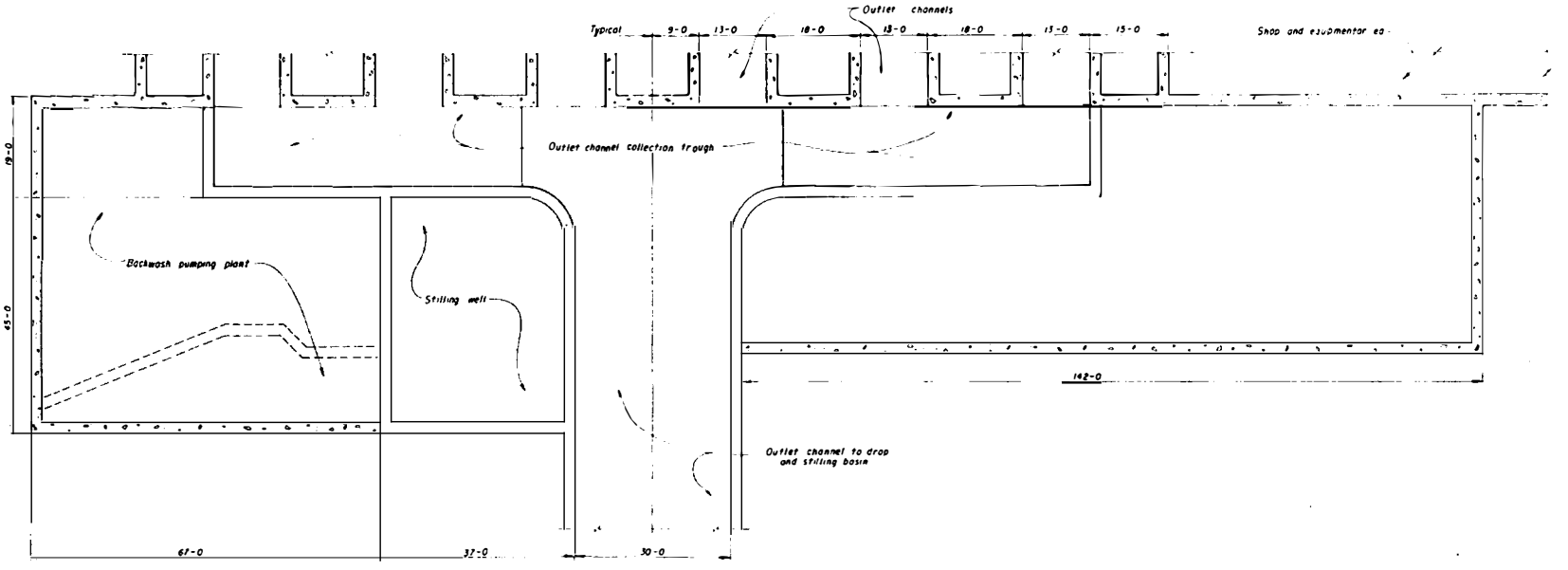
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION, GARRISON DIVERSION UNIT, N. DAK.

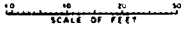
McCLUSKY CANAL
TRASH AND FISH SCREENING STRUCTURE
FEASIBILITY DESIGN DRAWING
SECTIONS

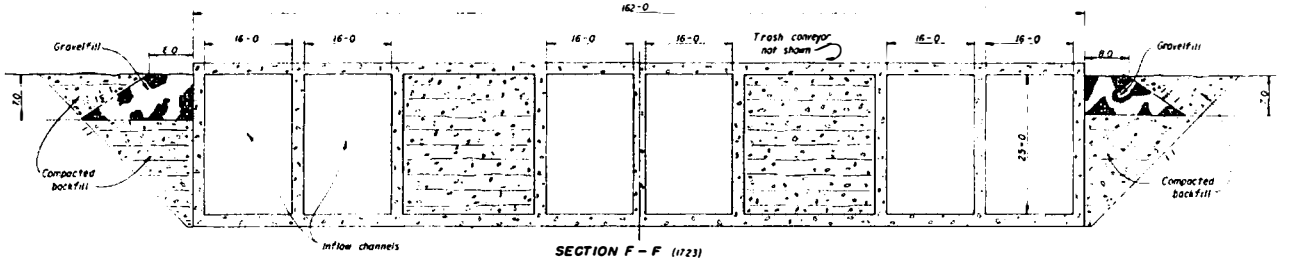
DESIGNED .... SUBMITTED ....
DRAWN .... RECOMMENDED ....
CHECKED .... APPROVED ....

DENVER, COLORADO — MARCH 8, 1981 — SHEET 2 OF 3 — 769-D-1724



SECTION E - E (1723)





SECTION F - F (1723)

UNITED STATES DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION, GARRISON DIVERSION UNIT, N DAK

Mc CLUSKY CANAL

TRASH AND FISH SCREENING STRUCTURE

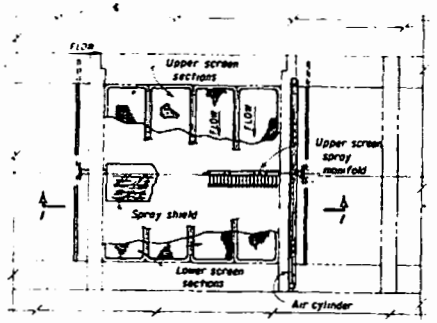
FEASIBILITY DESIGN DRAWING

SECTIONS

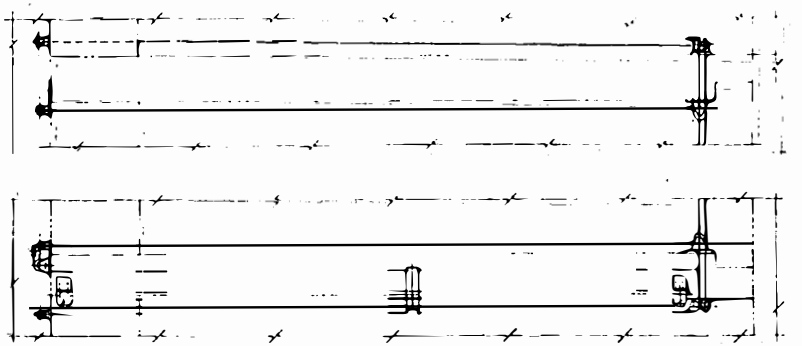
DESIGNED ... SUBMITTED ...
DRAWN ... RECOMMENDED ...
CHECKED ... APPROVED ...
CHIEF, COMMITTEE ON RESEARCH

DENVER, COLORADO — MARCH 6, 1961 — SHEET 1 OF 1

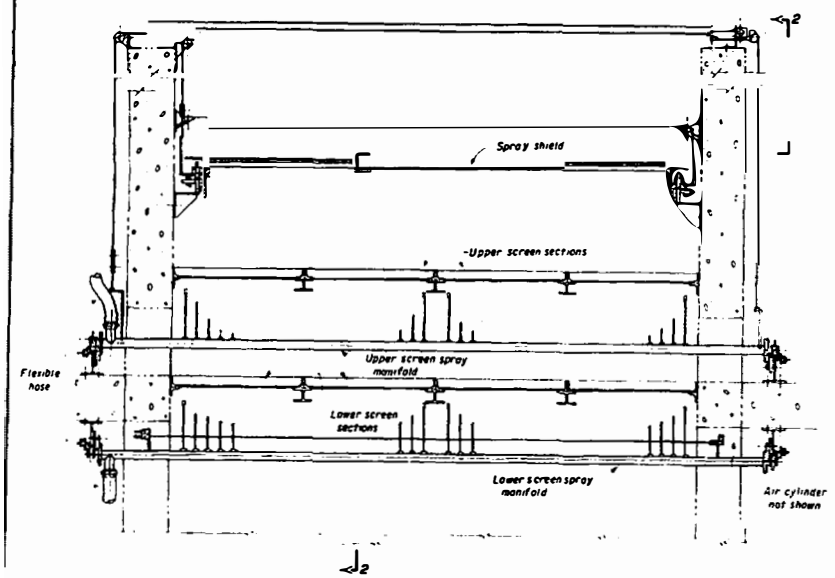
769 - D - 1725



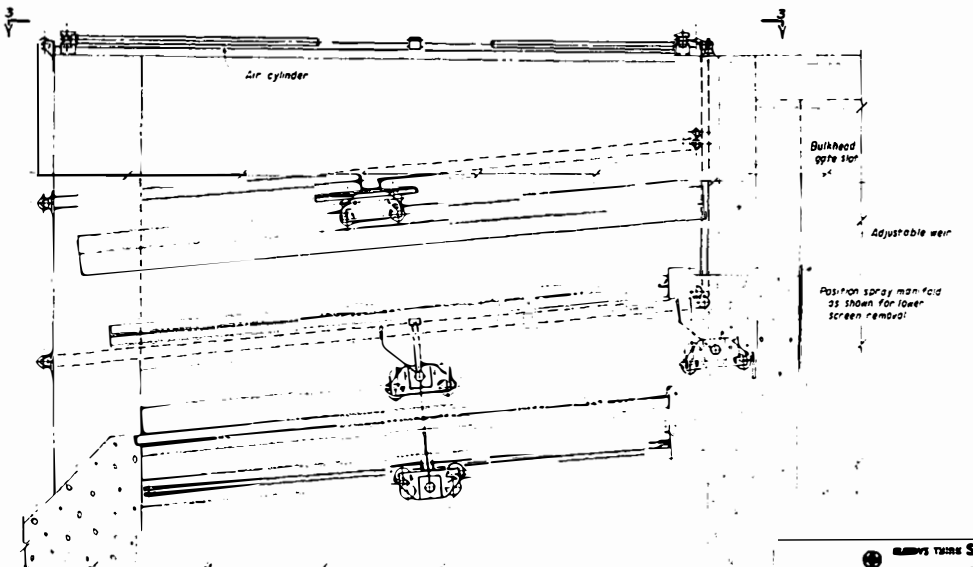
PARTIAL PLAN
(TYPICAL FOR ALL SUB BAYS)



VIEW 3-3
(SCREENS AND SPRAY MANIFOLDS NOT SHOWN)



SECTION 1-1



SECTION 2-2

REFERENCE DRAWINGS

FEASIBILITY DESIGN DRAWING	
SITE PLAN	769-D-1720
PLAN AND SECTION	769-D-1723
SECTIONS	769-D-1724
SECTIONS	769-D-1725

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
PICK-SLOAN MISSOURI BASIN PROGRAM
GARRISON DIVISION-GARRISON DIVERSION UNIT-N DAKOTA

Mc CLUSKY CANAL

TRASH AND FISH SCREENING STRUCTURE

FEASIBILITY DESIGN DRAWING

INSTALLATION-SECTIONS

DESIGNED ..... SUBMITTED .....
DRAWN ..... RECOMMENDED .....
CHECKED ..... APPROVED .....

DENVER, COLORADO APRIL 1, 1971

769-D-1726

Debris would be lifted from the trashrack by a trash rake and removed by a trash conveyor to a disposal bin. The conveyor and disposal system would be designed so lighter debris such as tumbleweeds would not be blown away by strong winds.

The trash rakes and conveyor would have both manual and automatic controls. During automatic operation, each trash rake would operate by a differential water level control device, adjustable between 0 to 6 inches of water level differential.

When the differential is reached, both the trash rake and conveyor would be energized. A time-delay controller would be used on the conveyor so it runs long enough after the trash rake has shut off to clear debris off the conveyor.

These feasibility designs would include concrete receptacles for six traveling screen structures downstream from the radial gates. Preliminary results at the test facility indicated traveling prescreens are not needed, but if operations of the facility indicated they are necessary, provisions have been made for installation. They have not been included in this design or cost estimate.

Flow into each bay would be controlled by a top sealing radial gate, adjustable so flow rates into individual bays could be controlled. The gates would be rapid-closing type so, if necessary, flow into one or all bays could be stopped in less than 60 seconds. Each bay would be equipped with a 3,000-gpm pump which would dewater the bay by pumping the water back above the radial gate. A bay could be dewatered in less than 2 hours with the 3,000-gpm pump. Figures 15 and 16 show water and debris routing through the structure.

Flow rate into each sub-bay would be controlled by an adjustable blade weir at each bay. Stoplog guides would also be provided at each sub-bay so stoplogs could be placed at the head end of each sub-bay to shut off flow into the bay.

Most of the flow entering the sub-bay would pass through both sets of screens and into the outlet channels located underneath the screens. Debris and some water ($\pm$0.2 percent of the inflow) would flow off the ends of the upper and lower screens into a debris trough for each bay, being collected in another trough, running perpendicular across the end of the bays, to be stored in a 3,100-ft^3 (about 23,000-gallon) sump. Material in this sump would be pumped back upstream to the vibrating screen building. The sump would be equipped with two active pumps and one spare pump of 3,000-gpm capacity of the same type as the six pumps used for dewatering the bays so that they would be interchangeable.

During normal operations, the two sump pumps would be operated on a lead-lag system: the elevation for the sensor of the lead pump would be slightly below the elevation of the lag pump so the lead pump would activate first. Under normal conditions, the lead pump would handle the inflow and the lag pump would not be used. If the lead pump could not handle the inflow, the lag pump would also be activated and the operator would be alerted that one or more sub-bays in the structure were not functioning properly.

Debris from the 3,100-ft^3 sump would be pumped to the vibrating screen buildings at a rate of 3,000 or 5,000 gpm depending whether one or both pumps are

MCCLUSKY CANAL FISH SCREENING STRUCTURE

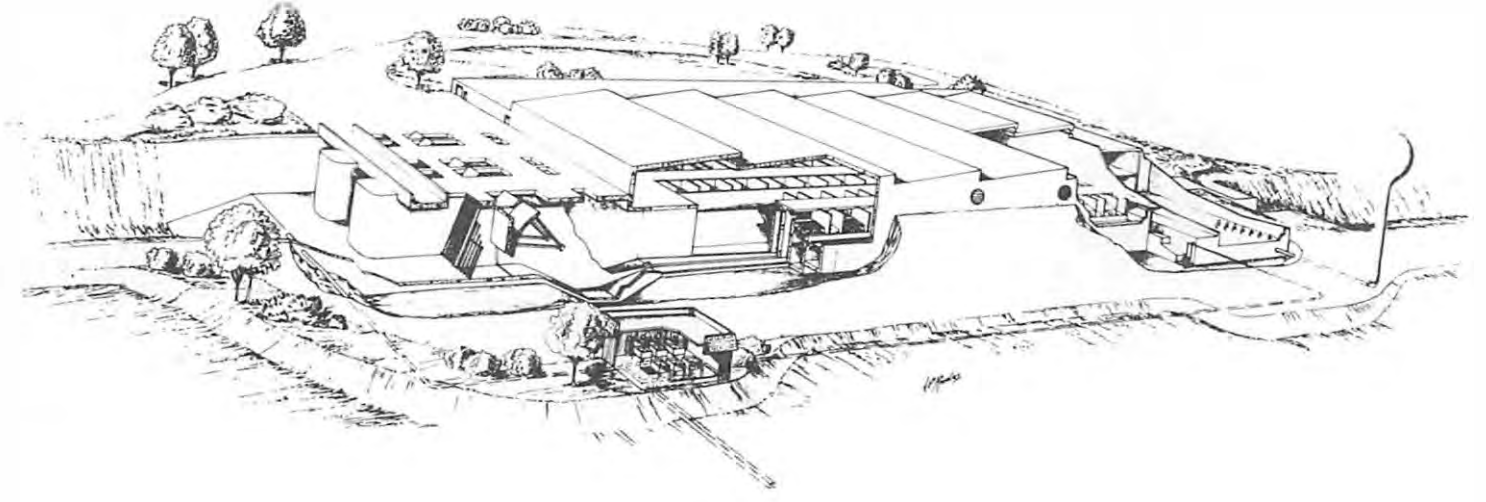
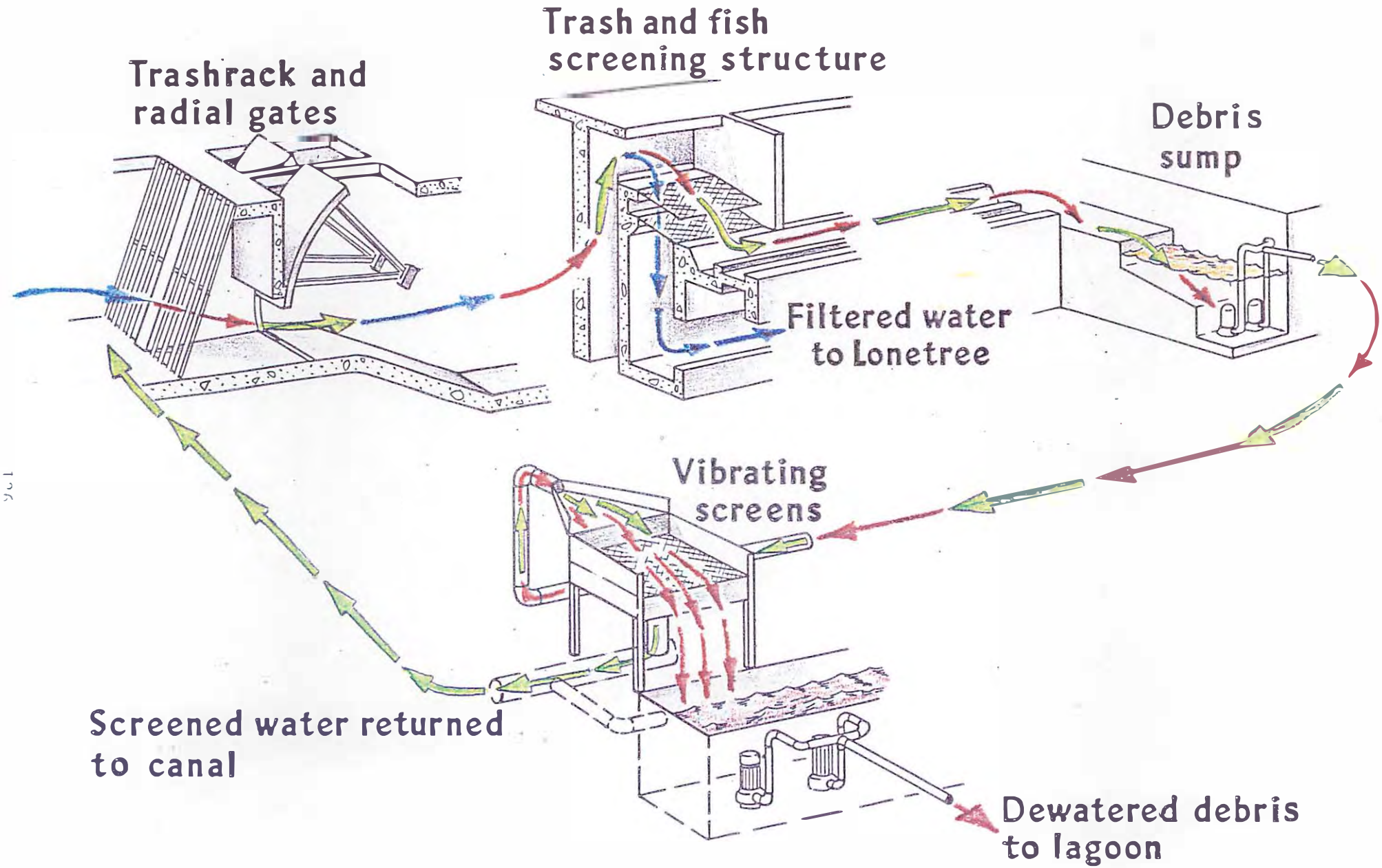


FIGURE 15

Figure 16



McCLUSKY CANAL
Trash and fish screening structure
Flow diagram

operating. Eight 4-foot by 8-foot vibrating screens (with 80-mesh screens) would be used to remove excess water from the debris, each screen having a 1,000 gpm capability; therefore, under normal operating conditions, three screens would be used. If the second sump pump activated, five of the eight screens could handle the inflow.

Water passing the vibrating screen would flow by gravity back into the canal upstream of the radial gates. Material would flow into a 425-ft^3 (3,100-gallon) sump where two 450-gpm pumps (plus a spare) would pump the debris to a disposal site. Under normal conditions, only one pump would be used with a lead-lag system. The second pump would come on only if there was excess water flowing off the vibrating screens. The vibrating screen sump would have an overflow outlet; if this sump flooded, water and debris would be re-circulated back into the canal upstream of the screen structure.

A lagoon disposal system would be used at the facility to handle the debris removed by the screens. The lagoons were not designed for the feasibility estimate; however, a multicell lagoon system would be used with a sufficient number of cells to allow periodic drying and sludge removal. Total lagoon area would probably be around 30 to 40 acres. At the field test facility, the waste material in the lagoon was rancid and had a crust after the first test season. No waterfowl were observed using the lagooon. Conditions at these larger lagoons should be similar and wildlife will probably not use the lagoon area. However, the lagoons will be monitored and if wildlife did use the area and were a potential source for fish transfer, appropriate measures would be taken to protect the system.

Other pumps used in the facility would include eight 2,250-gpm pumps to provide water for screen backwash systems and other nondomestic use in the facility. Screened water would be drawn from the outlet channel and pumped to a 150,000-gallon elevated water storage tank.

Equipment handling systems would also be designed into the facility to provide safe, efficient handling of screen frames and equipment; overhead traveling cranes would be provided to handle pumps, screen panels, etc. Motorized carts and wagons would be used to store and transport screen frames.

An engine generator set would provide emergency standby power for the facility, to operate the facility during brief power outages and to shut the facility down if the power outage were extended. Standby power would not operate the eight 2,250-gpm pumps that supply screen backwash water. Reserve capacities in the elevated water storage tank would be used during a brief power outage to backwash the screens.

The facility would be connected to a primary power distribution system so power outages would not be expected to occur frequently. For additional power reliability, the possibility of connecting the facility to two separate electrical distribution systems is being investigated.

The screen facility structures would be of concrete construction, heated, and ventilated. Fire hose reels would be provided throughout the facility in addition to sprinkler systems in the shop areas.

The facility would be designed and operated to restrict access by unauthorized personnel, but an enclosed viewing areas would be provided for visitors. Unauthorized visitor access to the screen area would not be allowed when the facility is operating.

Construction and Operating Costs

Construction costs (1981) of the facility would be approximately $40,000,000. The breakdown is as follows:

Remove existing structure	900,000
Electrical	1,200,000
Structure	18,500,000
Piping and Equipment	12,400,000
Subtotal	33,000,000
Design Cost and Overhead	7,000,000
Total	40,000,000

As many as thirty full-time employees might be needed to operate the facility (see Figure 17). With no similar facilities to compare to, it is difficult to determine personnel requirements. The organization used for the feasibility estimate includes five, four-person crews to conduct the actual 24-hour operation, plus 10 management, scientific, and maintenance personnel.

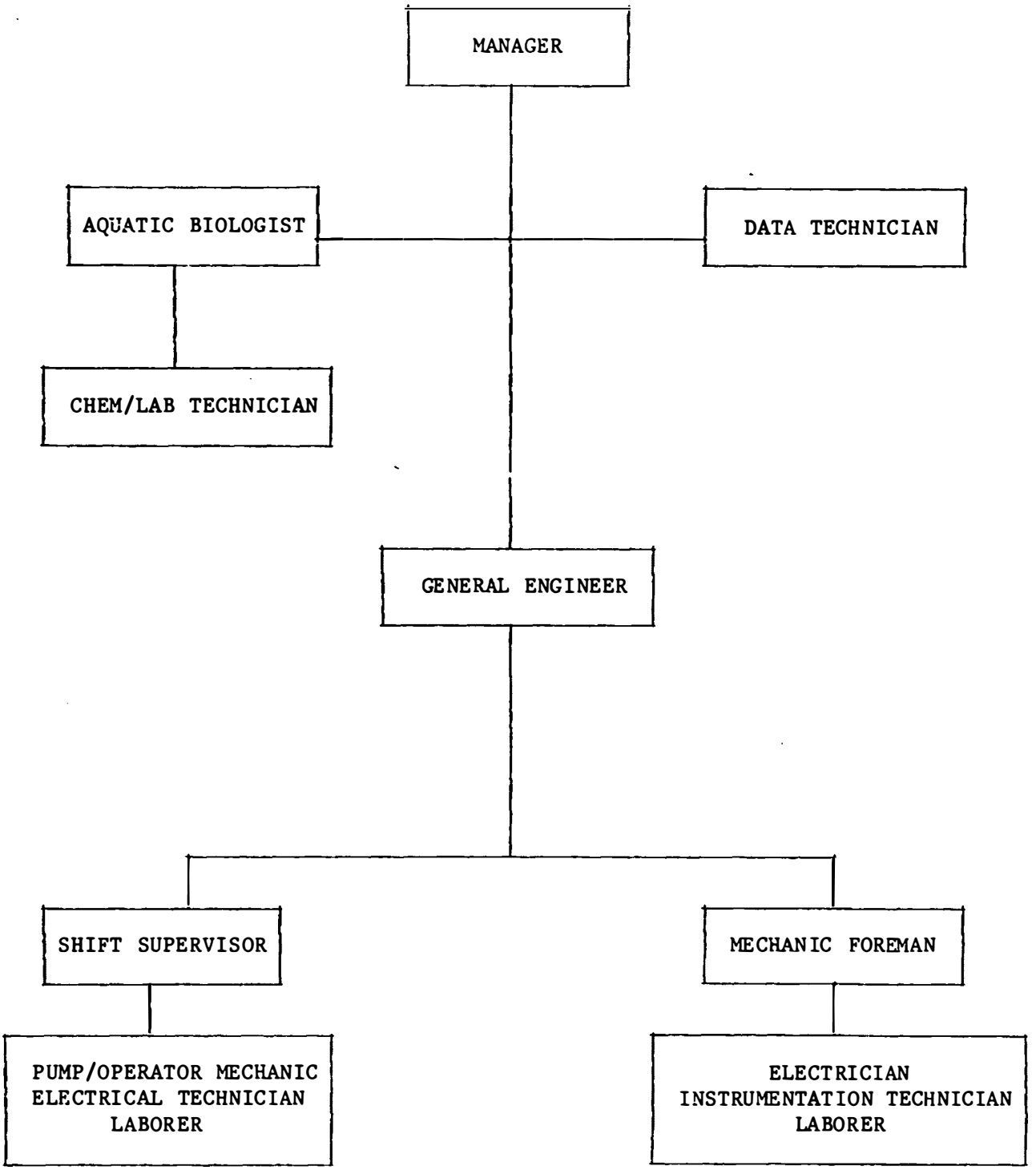
Operating personnel requirements would not be known until after the first season of operation and facility shakedown is complete. Another factor which would dictate personnel requirements is the extent of chemical and biological monitoring which might be dictated to satisfy international obligations. The estimated 30 employees is considered conservative on the high side and includes personnel for intensive monitoring requirements.

The annual operating cost (1981) would be about $1.3 million per year. The breakdown is as follows:

Personnel	$ 630,000
Supplies	330,000
Equipment	47,000
Subtotal	$1,007,000
Administration & General Expense	94,000
Major Replacements	144,000
Electrical Power	28,500
Special Items (Contingencies)	26,500
Total Annual Costs	$1,300,000

Figure 17

McCLUSKY CANAL FISH SCREEN ORGANIZATION CHART[1/]
(TENTATIVE)



Fish Screen Operation

The objective would be to operate the facility in a manner to insure that no fish, fish eggs, or fish larvae could bypass the screening structure. Under no circumstances would this objective be compromised to meet other project goals.

The fish screen would be operated during March through December to maintain a project water supply in the Lonetree Reservoir. Depending on demand at Lonetree Reservoir, operation could be intermittent or continuous during the season. When there is a demand for water, operation would be continuous until Lonetree Reservoir is filled (elevation 1640). Lonetree Reservoir would also be filled to elevation 1640 msl at the end of each operating season. This program might be modified slightly to optimize benefits of other project purposes, such as recreation and fish and wildlife enhancement, providing water delivery requirements oculd be maintained. The seasonal shut-down periods would be used to conduct scheduled screen inspections, screen replacements, and general equipment repair and replacement.

The following criteria are preliminary and will be modified and expanded after final designs are completed for the fish screen structure. It is also probable that the criteria would be further modified to optimize efficiency and reliability as experience is gained during the first few years of operation. During the first years of operation, the operation will be periodically reviewed by an independent quality assurance team to insure the highest standard of performance.

McClusky Canal Operation

The canal has a design capacity of 1,950 ft^3/s with a normal depth of 17.3 feet and 6 feet of freeboard, sufficient capacity to provide water to the 250,000-acre authorized project. Initially, the fish screen facility would be designed to pass a flow of 1,000 ft^3/s with provisions for future enlargement. The 1,000 ft^3/s would be sufficient capacity to serve in excess of 100,000 acres with a full water supply.

The present fish screen is 64 miles from the canal headworks. There are three check structures located in the canal between these two facilities. The headworks and canal checks would be remotely monitored and controlled from the fish screen, operating at flows of 1,000 ft^3/s or less initially. When operating at less than design capacity, the canal would be checked. The fish screen gates and check gates would be controlled so that the canal water depth is checked up to the normal depth (17.3 feet) for design capacity. Changes in flow in the canal would be accomplished automatically by a preprogramed minicomputer located at the fish screen controlling gate openings at the fish screen, check structures, and at the headworks.

Under normal conditions, changes in flow conditions would be controlled to limit changes in canal water surface elevations to less than 1 foot per 24 hours and to avoid excessive surge wave action in the canal. At high flow rates (in excess of 1,000 ft^3/s), rapid changes in flow conditions could damage the canal banks.

For canal flows of 1,000 ft^3/s or less, flows might be varied at will, including instantaneous stoppage of the canal, with no fear of damaging or overtopping the canal banks (instantaneous is defined as stopping the flow in the canal in the quickest manner the existing radial and slide gate motors will permit, which is approximately 20 minutes). This would include the radial gates at the screen structure which would be capable of closing in 1 minute. For flows in excess of 1,000 ft^3/s, the headworks and check structure gates would have to be carefully controlled to prevent excessive drops in canal water levels and the inevitable bank sloughing this would cause. In the event of an emergency requiring instantaneous closure of all canal control gates, the flow could be stopped in the canal with some damage resulting to the canal, but no spillage of canal water would result. The following tabulation indicates the time required to stop all flow in the canal if no damage is permitted to occur.

Flow (ft^3/s)		
From[1/]	To	Time
1,950	0	2.5 days
1,950	1,500	1.0 day
1,500	1,000	1.0 day
1,000	0	20 min.

1/Indicates initial steady state condition.

Initially, the canal and fish screening facility would be operated at flows of 1,000 ft^3/s or less. If the experience gained during this operation indicates that rapid shutdown of the canal is necessary for flows above 1,000 ft^3/s, additional checks would be constructed in the canal to permit this type of operation without damage.

Flow Through the Screen Structure

Flow into each operating bay would be controlled by radial gates, while the flow over each of the 14 sub-bays in each bay could be balanced with the adjustable blade weirs at each sub-bay.

Individually controlled screen backwash systems would be used in each sub-bay to clean the screens when they became plugged. A photo cell/timer combination would be used to control the backwash system for the upper screen panels. The lower screen would be controlled with a timer/counter combination so it could be cleaned on a time basis or on the cleaning frequency of the upper screens (e.g., the counter could be set to operate the lower backwash system once for every 10 backwashes on the upper screens).

The frequency in which the screens would require cleaning depends on two elements: (1) flow into each bay/sub-bay, and (2) algal types and densities in the water. Generally, to provide the operator sufficient time to react to any unpredictable operating problems that might develop, flow into a bay should be

set so most of the backwash systems for the upper screens were operating not more than 10 to 12 times per hour. Flow through the structure would be adjusted based on algal loading in the water. It is possible that if a very heavy algal bloom occurred in the canal, the structure may not be capable of screening at 1,000 ft^3/s and flows would have to be reduced accordingly.

There are two possible modes of operation that could be followed for any given flow rate.

1. At a given flow (say 1,000 ft^3/s), two to four bays could be used, depending on algal loading, to handle the flow. Backwash frequency in the bays being operated would be 10 to 12 times per hour; two to four bays would not be in use and would be available for standby. In the event one of the operating bays developed a mechanical or control problem, the gate to that bay could be closed and the gate to a standby bay opened with no disruption in canal flow.

2. The other option would be to distribute the 1,000 ft^3/s through all six bays, assuming all were in operating condition. Under these conditions, backwash frequencies might be only once every hour or longer. In the event one of the bays developed a mechanical or control problem, the gate to that bay would be closed and the other five bays could pick up the "slack" without disrupting total canal flow.

Either condition would provide the necessary capacity to be able to shut down one or two bays without disruption. At this point, it is not known which method would provide optimum operation.

Bay Shutdown

During the operating season, a bay could be shut down for two reasons: (1) the bay is used for standby, or (2) one or more screen sections have been removed from a sub-bay.

When a bay is being used for standby, the bay would not be dewatered and special precautions regarding radial gate operation would not be necessary. Flow into the bay would be controlled from the control center as necessary.

When a bay is down because one or more screen sections in the bay were not serviceable, procedures would be developed to insure the following:

1. The bay would be dewatered.

2. The control gate could not be inadvertently opened. This would include manually disconnecting power to the gate control motor and "red tagging" appropriate control devices.

3. Stoplogs would be placed at the end of the bay debris trough.

4. The gate would not be rendered operable until specific check-off procedures had been completed which insured all screens were serviceable and the bay was ready for operation.

Sub-bay Shutdown

Sub-bay shutdown might occasionally be required to perform maintenance on the spray bar system. Flow would be stopped by placing stoplogs at the sub-bay weir. These would not be designed to be 100 percent watertight so the screens and screen seals would have to remain serviceable during a sub-bay shutdown. As previously discussed, if a screen is not serviceable, the entire bay would have to be shut down and dewatered.

Screen Removal and Installation

Specific step-by-step procedures will be developed and followed for removing one or more screens during the operating season. These procedures would be documented (i.e., check-off sheets) and certified by an inspection team prior to screen removal. The procedures would include:

1. Proper bay shutdown and dewatering.

2. Wash down of entire bay debris trough.

3. Placing stoplogs at end of debris trough to prevent water from backing up into the trough in the event of a flood-out caused by other operating bays.

4. Proper decontamination of sub-bay in which screens were to be removed.

5. After the screens had been replaced, but prior to removal of stoplogs and returning gate control to the operator, the inspection team would also certify that the screens had been properly serviced and installed and the bay suitable for operation.

Control Room Operation

The shift supervisors would be able to monitor and control all critical facility operations from the control room. They would be able to perform the following functions from the control room:

1. Control flow in the McClusky Canal from headworks to the screen structure. This would include both automatic or manual emergency shutdown control.

2. Via closed circuit TV, view screen sub-bays, trashracks, vibrating screens, and radial gates at the facility.

3. Control flow in each of the six bays.

4. Over-ride automatic backwash systems.

5. Communicate with other shift workers in the area.

6. Monitor and/or record performance of critical items such as: air pressure in the screen seals (each set of four upper and lower pneumatic seals in each sub-bay would be individually monitored), water pressure for backwash systems, pumps, vibrating screens, trashracks, power supply, weather conditions,

total flow, flow into each bay, flow level in each bay debris trough, total flow to sump pumps, flow to lagoon, and flow from vibrating screens back into canal. Most recording would be accomplished with automated data gathering equipment.

Emergency Sensing Equipment

Automated sensing equipment to activate audio and visual alarms would be used extensively in the system to alert the operator if a problem were developing.

Sensing would be used for the following applications:

1. Monitoring air flow and seal pressure to the 168 pneumatic seal sets (of four).

2. Detect if the standby pump in either the debris sump in the screen structure or vibrating screen building is activated.

3. Detect emergency high water level in all debris trough and sump pumps.

4. Detect low water levels in the elevated water storage tank.

5. Detect a high water elevation "flood" situation in the screen structure in order to automatically activate a shutdown procedure.

6. Detect a control structure malfunction at each control structure in the canal using water elevation sensors.

Critical Operating Situations

Based on experience at the field test facility, if a problem did develop during operation, it would likely be screen plugging caused by a malfunction of one or more screen backwash systems. A backwash system malfunction would probably be caused by a failure in the spray bar drive mechanism or the automatic control system.

As described previously, during operation the debris and some water will flow off the end of the screen panels into a debris trough in each bay. These debris troughs drain into a main debris trough that runs perpendicular across the ends of the bays. This main trough connects into the debris sump. Debris would be pumped from the sump with two pumps controlled on a lead-lag system.

Under normal operating conditions, the inflow rate at the sump would be around 1,000 gpm (2.2 ft^3/s). This would require the lead pump to be operating 25 percent of the time. Under these conditions, the lag pump would not operate and only one-half of the sump capacity would be used, while the upper half would be available for emergency storage.

The following situations, while not necessarily realistic, show the operator reaction time that would be available under different screen plugging conditions.

In all situations, the operator's primary concern would be to stop the flow of water to the plugged screens. Once the plugged screen or screens were isolated, the "critical" function would be completed and the cause of the screen plugging could be identified and corrected.

Situation A.--If a backwash system failed and one sub-bay became totally plugged an 18-ft^3/s flow could be flowing off the end of the screens. The lead pump would not be able to keep up, so the lag pump would automatically activate and the emergency storage capacity in the sump would be used.

If the screen plugging was not observed by the operator, he/she would be alerted by the alarm system that activates with the lag pump. Operating personnel would then take one of the following stops:

1. Correct the backwash system malfunction if it could be done quickly (e.g., backwash by manual control it it was a control malfunction).

2. Place stop logs in the sub-bay weir to stop flow into sub-bay.

3. Close the radial gate for that bay.

If no corrective action was taken by operating personnel, the sump would be filled in about 3 minutes, at which point a second alarm system would be activated and water would begin backing up into the main debris trough. This second alarm would not activate any equipment, but would alert operating personnel that the debris sump was full. After 7 minutes, the main debris trough would be full and water would begin backing up into the debris trough in each bay. After a total of about 18 minutes, the debris troughs in the bays would be partially full and a third alarm system would activate. This third alarm would automatically close all radial gates to the bays. The radial gates would be closed 1 minute after the third alarm was activated and the water ponded in the structure would be about 1.4 feet below the elevation of the lower screens. In addition to closing the radial gates at the structure, the third alarm system would activate a pre-programmed process which would start an automatic shut-down procedure of the canal headworks and all check structures in the canal.

Situation B.--If several screens all plugged simultaneously and a 100 ft^3/s surge were flowing into the sump, the sump would be filled in less than one-half of a minute and both the first and second alarms would be activated. Based on experiences at the test facility, it is highly unlikely that this situation could ever develop. Loss of water pressure for the backwash system would eventually lead to this type of situation. However, the water pressure is also automatically monitored and operating personnel would be aware of the condition at least 10 minutes before the screens became plugged.

In any case, if a 100 ft^3/s surge did occur, after three-quarters of a minute, the main collection trough would be full and water would begin to backup into the bay debris troughs. After 3 minutes had elapsed, and if no

collective action were taken, water levels would reach the third alarm system and the radial gates would automatically close. To avoid the automatic shutdown, operating personnel would have about 2 minutes to locate which bay or bays were causing the 100 ft^3/s flow into the debris troughs and to start closing the radial gates for those bays. If water levels did reach the third alarm system, the gates would automatically close in 1 minute and ponded water in the structure would be 1.1 feet below the elevation of the lower screens.

Situation C.--If all screens instantanesouly plugged with a 1,000-ft^3/s inflow, flow into the sump would also be 1,000 ft^3/s. If this situation occurred where the system instantly changed from a normal operating condition to 100 percent screen plugging, there would be no time for the operator to react. At a 1,000 ft^3/s flow to the debris sump, the debris troughs would be filled and the water levels would reach the third alarm system in about 14 seconds. The radial gates would close in 1 minute and the water in the structure would be ponded at the elevation of the lower screen.

Situation D.--If the same situation as in "C" occurred, but the radial gates malfunctioned and did not close, the water would submerge the screens and pond to the elevation of the weir within 2 minutes. After another 2.5 minutes, the ponded water surface elevation would be 3 feet above the weir elevation. All openings in the screen structure (doorways, windows, etc.) would be set with a minimum elevation of 1844.3 feet (the same as canal bank, which has 6 feet of freeboard) to prevent high-water spillage from the structure. The ponded water surface elevation would continue to rise at a rate of 0.2 foot/hour, until the gates at the structure were closed or the last set of control gates 9.5 miles upstream from the structure were closed.

Scheduled Maintenance

The screens and pneumatic seals would be periodically removed, inspected, and replaced. Frequency of this work has not been established; however, if the screens were used for any length of time during the season, they would probably be removed and inspected at the end of the season. The screen cloth would probably be replaced after one or two seasons of use. A replacement schedule has not been developed for the rubber pneumatic seals, but they should remain serviceable for several years. Screen and seal replacement frequency will be established during initial shakedown period. Testing to date has shown both to be very durable.

A preventive maintenance program would be developed for most operating equipment in the facility. Operating time would be monitored and equipment replacement/overhaul would be scheduled on the basis of use to enhance equipment reliability.

Recordkeeping and Reporting

Check-off lists and automatic data recording equipment would be used extensively to document that operating procedures were being followed and that critical equipment was functioning properly. Annual operating reports would be published.

Monitoring Programs

Monitoring programs would be implemented at the McClusky Canal Fish Screen. These programs would provide a general understanding of pertinent water quality, biological and climatic parameters systemwide; and the affect these parameters have on operation of the facility. Although the monitoring program described herein is somewhat specific, it is tentative and should not be construed as a commitment on the part of the BR to conduct the program as described. Additional planning and coordination with other agencies would be necessary prior to developing and implementing a monitoring program.

Monitoring in this area would provide data to describe pre- and post-operational conditions of the system; determine how the system responds to changes such as pumping Lake Sakakawea water into Audubon Lake; provide background information about the system for possible troubleshooting for the system; show, and possibly predict, long-term trends; develop short-term predictive capabilities; and monitor the potential for filtration problems developing at the fish screen.

Fish

The Bureau of Reclamation has made commitments in impact statements and other documents to do most of the work described in this section. When this program is implemented, it would be in conjunction with appropriate State, Federal, and Canadian agencies to maximize program viability and eliminate duplication.

Utah Chub.--The Missouri River would be monitored to document any downstream movement of chub beyond their currently documented locations (Hauser Lake and Lake Helena, about 2 miles downstream from Canyon Ferry Reservoir). Monitoring would begin concurrently with start-up of fish screen operation and be conducted every third year thereafter. If chub did migrate to Audubon Lake and the fish screen, monitoring would be discontinued.

Smelt.--Concurrent with beginning of operation of the fish screen, Audubon Lake would be surveyed three times a year for the presence of: (1) spawning populations of smelt, (2) larval smelt, and (3) young-of-the-year.

The Audubon Lake survey should be conducted for 3 consecutive years, after which the study would be evaluated and effort increased, reduced, or redirected as appropriate.

McClusky Canal Above and Below Fish Screen.--The canal would be sampled for fish at sites to be determined in conjunction with the N.D. Game and Fish Department and U.S. Fish and Wildlife Service. Monitoring would determine the presence of smelt and describe the canal fishery in general. The information might also be of value to the N.D. Game and Fish Department for management of in-canal lakes. The canal should be surveyed intensely for 3 years, then the study reevaluated and efforts increased, reduced, or redirected as appropriate.

Lonetree Reservoir.--General fishery surveys would be conducted in the area after the reservoir filled. A long-term monitoring program might be maintained, but at a reduced level. Lonetree Reservoir would function as a monitoring point to determine the presence of undesirable fish downstream of the fish screen.

Rainy River (Hudson Bay Drainage).--Contact with appropriate fishery officials in Minnesota would be maintained regarding documented collections of smelt in the Rainy River system. Literature would be monitored as necessary and intense surveys for smelt in Minnesota would be encouraged. Communication with Ontario fishery biologists should also be opened regarding distribution and movement of smelt in western Ontario.

James River.--Limited monitoring in the James River would be conducted to document distribution and movement of shad in South Dakota. The Missouri River would also be surveyed for upstream movement of smelt from the Missouri River into the James to keep aware of reports of smelt movement throughout the Midwest. This program would be adjusted accordingly if there was any overlap with monitoring for the Oakes Test Area.

Plankton and Macrophytes

Plankton and aquatic macrophytes would be sampled at one station each in Lake Sakakawea and Audubon Lake and in the McClusky Canal at sites near fish sampling sites during the operating season. These surveys could be conducted weekly for the first year and then changed accordingly in subsequent years based on data evaluation. This would identify material being screened and would provide information about filtration problems.

Screened Material

Grab samples of debris on the top screen would be collected daily at 10 random sites per day to determine the general nature of collected debris, and during the spawning season, to look for fish eggs and later, larvae. The number and size range of fish collecting on the screens should give a general idea of prey fish, rough fish, or game fish disposed of (killed) at the structure.

Water Quality

Complete chemistry, heavy metals, and nutrients would be sampled every 2 weeks during the first year of operation, and monthly thereafter in Lake Sakakawea and Audubon Lake, at the canal headworks and upstream and downstream of the fish screen. This monitoring would develop a data-based correlation to any premature corrosion that might develop on water-handling equipment. After the water quality in Audubon Lake stabilized as a result of flushing from Lake Sakakawea, monitoring at Lake Sakakawea would be discontinued.

Temperature, DO, pH, and conductivity would be collected at the above sites bi-weekly or monthly, except daily or continuously (with automatic data collecting equipment) at the fish screen.

Climate

Wind speed and direction, air temperature, precipitation, relative humidity, and solar radiation would be collected at the Snake Creek Pumping Plant and the fish screen for possible troubleshooting of problems at the fish screen or to develop a mathematical model for prediction of system response (i.e., biological productivity of canal water).

Quality Control

The quality control program would be carried out by personnel assigned to the fish screen. The general engineer and aquatic biologist would essentially make up the quality control team, being involved in surveillance work during normal operation and helping to certify that certain operations and/or procedures outlined in this section were followed. However, all employees at the facility would be well versed on the significance of maintaining screen integrity, and would be required to report any operating procedures or event that might potentially affect screen integrity.

In addition to the in-house quality control, an audit or inspection of operation and maintenance practices by an outside or independent group would be conducted. These inspections would be conducted on a systematic basis, probably annually. If possible, representatives from the Canadian government should participate in these inspections. Such a review would help insure continuing effective operation and maintenance practices.

Normal Operation

Once each week, the quality control team would conduct a formal walk-through general inspection of all aspects of the facility. This inspection would include a review of the operations records.

Bay Shutdown for Screen Removal

The bay would be dewatered as previously described when one or more screen panels in a sub-bay need to be removed. The sub-bay of concern and entire debris trough would be washed down with water. The sub-bay and adjacent debris trough would be decontaminated (decontamination methods have not been developed, but it would probably be with hot water, steam, or chemicals). Before screen removal, the biologist would certify that all potential contaminating material had been removed or properly decontaminated. The team would certify that the bay has been properly shutdown and the radial gate control system is properly secured.

Before the screens are installed, the team would inspect the screen panels as well as the support frames and general sub-bay area. After the screens are installed, the sub-bay would be reinspected and certified as operable before startup.

Spring Start-up and Fall Shutdown

General maintenance and inspection procedures would be followed as described above for screen removal.

Emergency Shutdown (Floodout Condition)

If a floodout condition ever occurs to a degree that floodwater elevation reaches the lower screen elevation, the quality control team would be involved in problem analysis to help determine the cause of the floodout, recommend corrective action, and certify that the facility is operational.

Structural Exam

An annual inspection would be conducted by a team of experts in appropriate disciplines to check for structural deterioration that could potentially lead to filtration failure. Areas to be examined would include: (1) cracks in concrete, (2) connection between support frames and concrete sidewalls, and (3) expansion joints (if used), etc.

Other Types of Inspection

1. Both new and used woven screen would be checked by photographic or optical inspection to verify compliance with specifications and to identify if a used screen shows any wear or deterioration.

2. Automated monitoring equipment (alarms, warning lights, pressure switches, etc.) should be examined and tested for proper operation regularly, both by staff personnel and the quality control team.

Other Items

1. Future project development or water use (canal-side irrigation upstream of structures) would be controlled so that there was no bypass of the screening structure.

2. It would be necessary to insure that waste disposal is not in the Hudson Bay drainage.

3. Smelt eggs are at their smallest diameter immediately after they are spawned and increase in size during incubation. Smelt eggs are also very adhesive; therefore, it is not likely the screens would be exposed to numerous smelt eggs unless spawning populations established immediately upstream of the structure and ripe females landed on the screens. Although the screens would prevent passage of smelt eggs and larvae, the absence of spawning smelt populations immediately upstream of the structure could be considered another built-in safety factor.

LITERATURE CITED

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