Value Engineering

Final Report

Grand Valley Irrigation Company
Fish Screens

(A30-1745-2311-001-93-0-0 (4) and GJ029)

February 28, 2000

Conducted for
Bureau of Reclamation, Upper Colorado Region,
Western Colorado Area Office, Northern Division
and in Cooperation with
U. S. Fish and Wildlife Service, Recovery Implementation Program, Colorado River Fish Project,
and the Grand Valley Irrigation Company

THE GRAND VALLEY IRRIGATION COMPANY

Bureau of Reclamation, Technical Service Center, Denver, Colorado

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Executive Summary

The Value Study Team met on February 14, 2000, for a 4-day study of the Grand Valley Irrigation Company Fish Screen Project. The estimated field cost of the baseline concept is $1,645,000. The Team developed eight proposals which are summarized in random order below. If the highest value savings proposals are accepted, the maximum savings potential is $1,125,000. In calculating the maximum savings, the cost of the study ($20,000) was deducted only once.

This study was one of a series of meetings on the project and was performed to develop a consensus and partnership approach between the Grand Valley Irrigation Company, the U. S. Fish and Wildlife Service, and the Bureau of Reclamation. Within Reclamation, the value engineering process has proven to be a successful technique to solve problems, improve project value and achieve consensus solutions. The value engineering process is consistent with Reclamation's Customer Service Plan, specifically as a technique to resolve customer needs in a central forum, to ask for and consider customer ideas about agency plans, programs, and services, and to respond to customer suggestions and concerns. Accordingly, the team was formed of representatives from the three public and private stakeholders of the project. The team was not able to fully assess the contribution of the existing facilities to the project's effectiveness, safety or environmental value. More importantly, however, there was a recognition of the study's value to promote goodwill, develop a cooperative solution, and establish an environment of mutual aid.

Dependent Proposals: The following proposal is interdependent and only one can implemented.

Proposal No. 1A. Monitoring Endangered Fish Movement (Weir). The estimated added cost of this proposal is $150,000 to $250,000 before adding any study and/or implementation costs.

Proposal No. 1B. Monitoring Endangered Fish Movement (Seines). The estimated added cost of this proposal is $100,000 to $200,000 before adding any study and/or implementation costs.

Proposal No. 1C. Hydraulic and Biological Modeling. The estimated added cost of this proposal is $500,000 before adding any study and/or implementation costs.

Independent Proposals: The following proposals are independent of all other proposals and could be accepted or rejected individually without affecting other proposals.

Proposal No. 2. Install a Trashrack in Front of the Headgates. The estimated added cost of this proposal is $82,000 before adding any study and/or implementation costs.

Proposal No. 3. Build a Sedimentation Basin in the River. The estimated added cost of this proposal is $16,600 before adding any study and/or implementation costs.

Proposal No. 4. Install a Sluice Pipe at the Silt Ledge. The estimated added cost of this proposal is $96,300 before adding any study and/or implementation costs.

Proposal No. 5. Install a Stoplog Check Structure. The estimated added cost of this proposal is $68,600 before adding any study and/or implementation costs.

Proposal No. 6. Implement Option E instead of Option A. The estimated added cost of this proposal is $1,739,000 before adding any study and/or implementation costs.

Proposal No. 7. Install a Siphon to Use Orchard Mesa Irrigation District Water. The estimated added cost of this proposal is $967,500 before adding any study and/or implementation costs.

Proposal No. 8. Electrical Barrier. The estimated savings of this proposal are $1,145,000 before deducting any study and/or implementation costs.

Other Ideas: The Team identified 15 additional ideas for further consideration and development that are listed in the "Disposition of Ideas" table near the end of this report.

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Acknowledgment of Design Team and Consultant Assistance

The Value Study Team wishes to express their thanks and appreciation to the Design Team Leader, Mr. Dennis Hawkins, and the members of the design team, who fully and cordially provided all requested information and consultation on the conceptual design. The team would not have been as successful without the design team's cooperation and assistance.

The Value Study Team wishes also to express thanks and appreciation to those listed on the Consultation Record of this report. Their cooperation and help contributed significantly to the technical foundation and scope of the team's investigation and final proposals.

The goal of the value method is to achieve the most appropriate and highest value solution for the project.. It is only through the effort of a diverse, high performing team, including all those involved, that this goal can be achieved. This study is the product of such an effort.

Value Method Process

The Value Method is a decision making process, originally developed in 1943 by Larry Miles, to creatively develop alternatives that satisfy essential functions at the highest value. It has many applications but is most often used as a management or problem-solving tool.

The study process follows a Job Plan that provides a reliable, structured approach to the conclusion. Initially, the team examined the component features of the program, project or activity to define the critical functions (performed or desired), governing criteria, and associated costs. Using creativity (brainstorming) techniques, the team suggested alternative ideas and solutions to perform those functions, consistent with the identified criteria, at a lower cost or with an increase in long term value. The ideas were evaluated, analyzed, and prioritized and the best ideas were developed to a level suitable for comparison, decision making and adoption.

This report is the result of a "formal" Value Study, by a team comprised of people with the diversity, expertise, and independence needed to creatively attack the issues. The team members bring a depth of experience and understanding of the discipline they represent, and an open and independent enquiry of the issues under study, to creatively solve the problems at hand. Ideally, the team members have not been notably involved in the issues prior to the study. The team applied the Value Method to the issues and supporting information, and took a "fresh look" at the problems to create alternatives that fulfill the client's needs at the greatest value.

Current Description

This project is a part of the Upper Colorado River Endangered Fish Recovery Program. The project is designed to prevent the loss of Colorado pikeminnow and razorback sucker 300mm in length or larger into the Grand Valley Irrigation Company system. Much of the design criteria is based on (1) the US Fish and Wildlife Biological Opinion (December 20, 1999), (2) data for juvenile salmon specified by the National Marine Fisheries Service (NMFS), and (3) unpublished research by Mr. Rich Valdez, which developed relationships between total length and body diameter for the two target species.

The Grand Valley Irrigation Company (GVIC) diversion is located on the Colorado River 15 miles upstream from the confluence of the Gunnison River, near the City of Palisade, Colorado. Figures 1, 2, and 3 show the project location and existing site conditions. The major components of the existing GVIC system include the diversion dam, flood gates, headworks structure and canal. The GVIC has adjudicated water rights to 640 CFS of water and a 1977 contract agreement to deliver up to another 20 CFS to the Clifton Water District through the GVIC system based on their water right. Typically, irrigation deliveries are made between April 1 and November 1, and one to two winter deliveries are made outside the irrigation season.

The baseline concept, for purposes of comparison with alternative proposals generated by this study, is Option A which is described in the Predesign Memorandum. The baseline concept consists of a trashrack, a sedimentation basin, a fishscreen structure, a fishscreen and a bypass pipe. All the elements of the baseline concept would be contained within the GVIC canal downstream of the headgate structure and upstream of the gauge, except the bypass pipe. The proposed plans of the baseline concept are shown on Figures 4 and 5. The project would bring the GVIC diversion into compliance with the Endangered Species Act (ESA) by separating endangered fish (Colorado pikeminnow and razorback sucker) from the flows diverted from the Colorado River for irrigation. Conceptually, fish entering the canal through the headgate would be separated from the canal delivery flows and returned to the river in a downstream pool through a bypass pipe. The large pool was selected as the best point of return based on its ability to maximize reorientation and minimize predation of fish returning to the river.

In conjunction with the installation, the three parties would enter into cooperative, and operation and maintenance agreement(s) to define the planned project scope, cost, reimbursement, and operation.

As shown in the Life Cycle Cost Analysis, following Figure 5, the present estimated annual cost of removing sediment from the area in front of the GVIC main headgate and in front of the GVIC flood gates is $18,500. The estimated annual cost of removing sediment from the sedimentation basin, as shown in the Baseline Option (Option A) Figure 4, is $6,475. This would result in an annual savings of $12,025. Based on a 20 year project life and a discount rate of 5.5 percent, the present value of the savings would be $143,703 over the project's life.

Figure 1. Project Vicinity Plan.

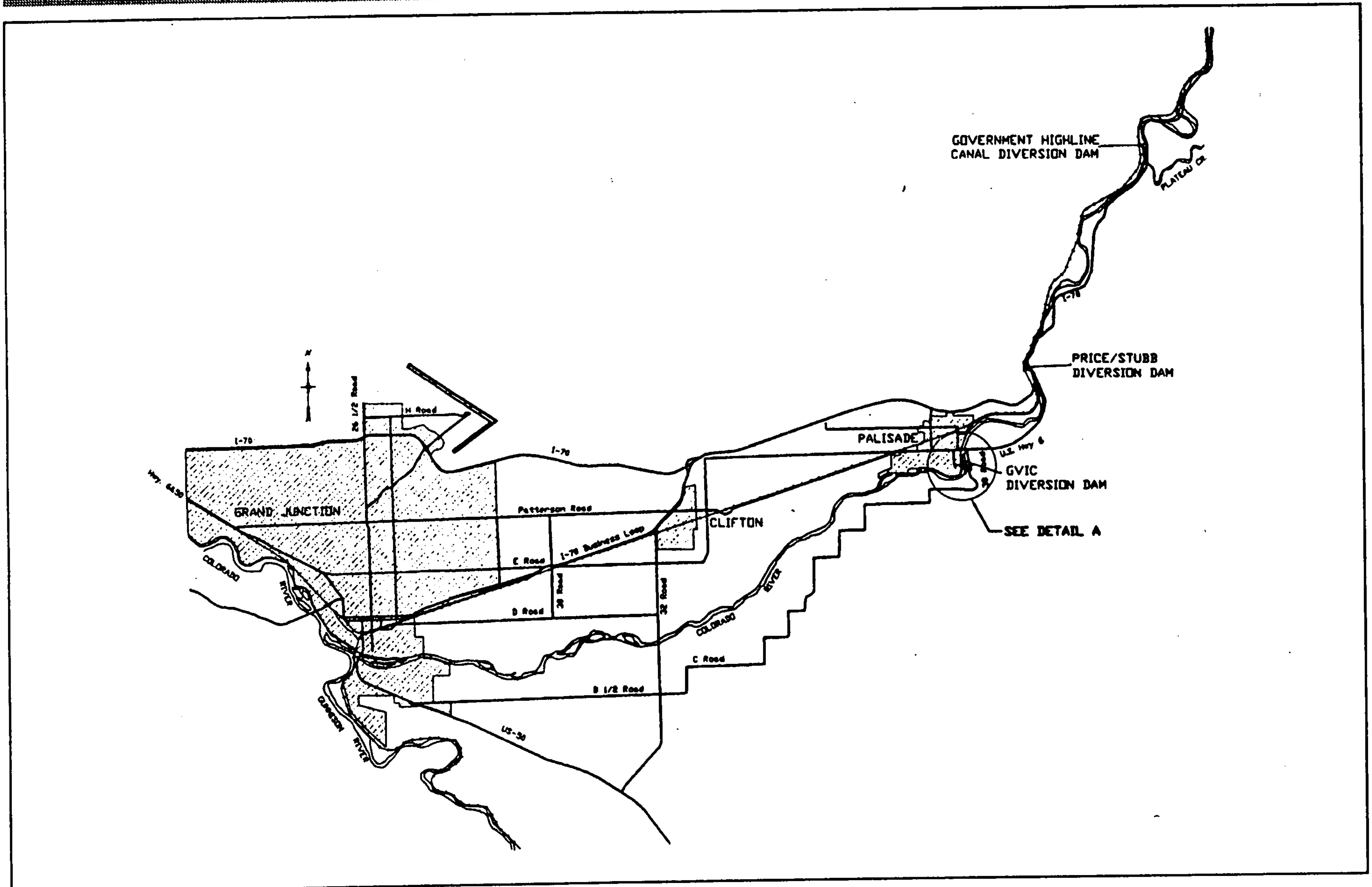


Figure 2. Project Location Map.

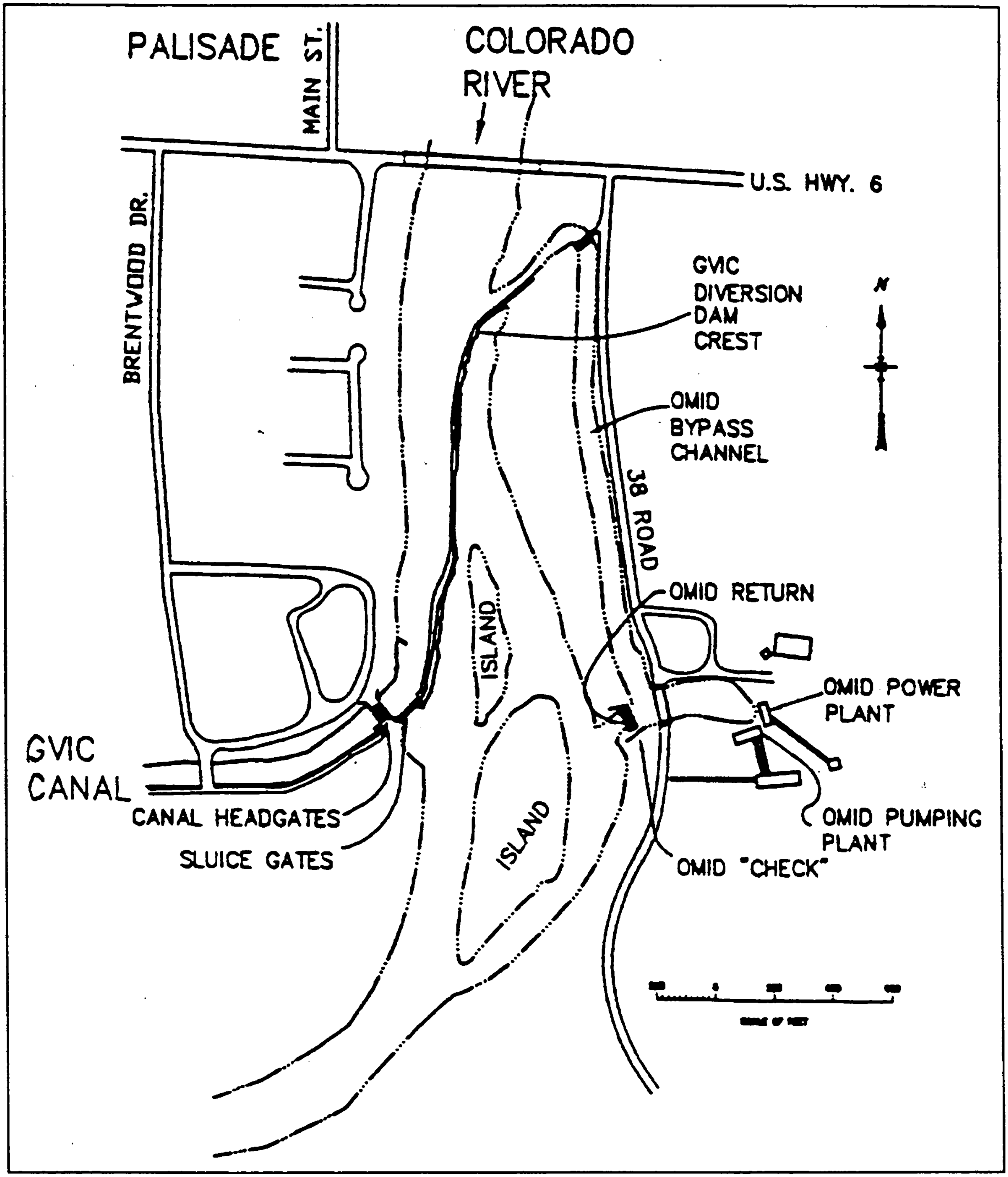


Figure 3 . Existing Site Conditions.

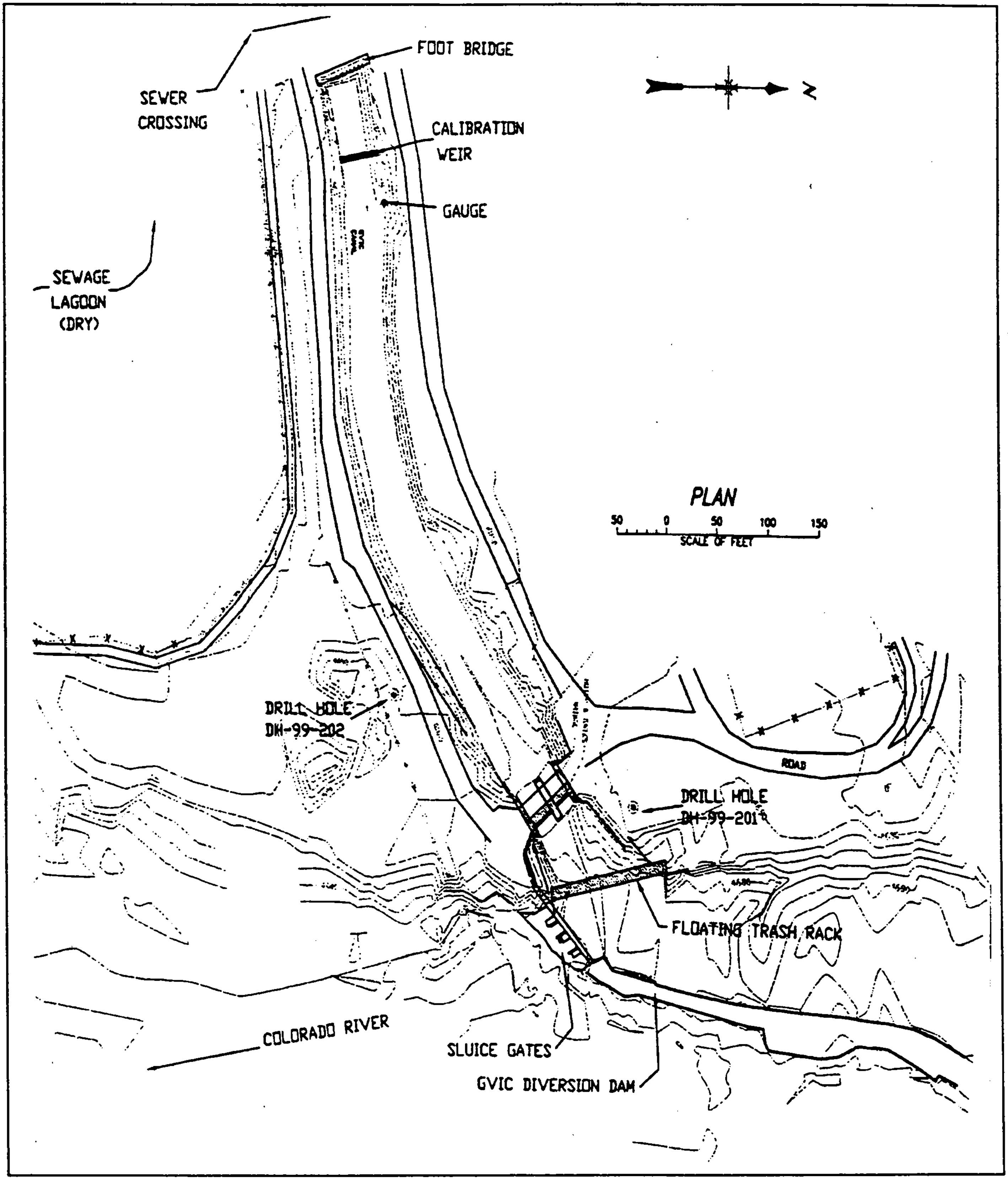


Figure 4. Baseline Option Site Plan.

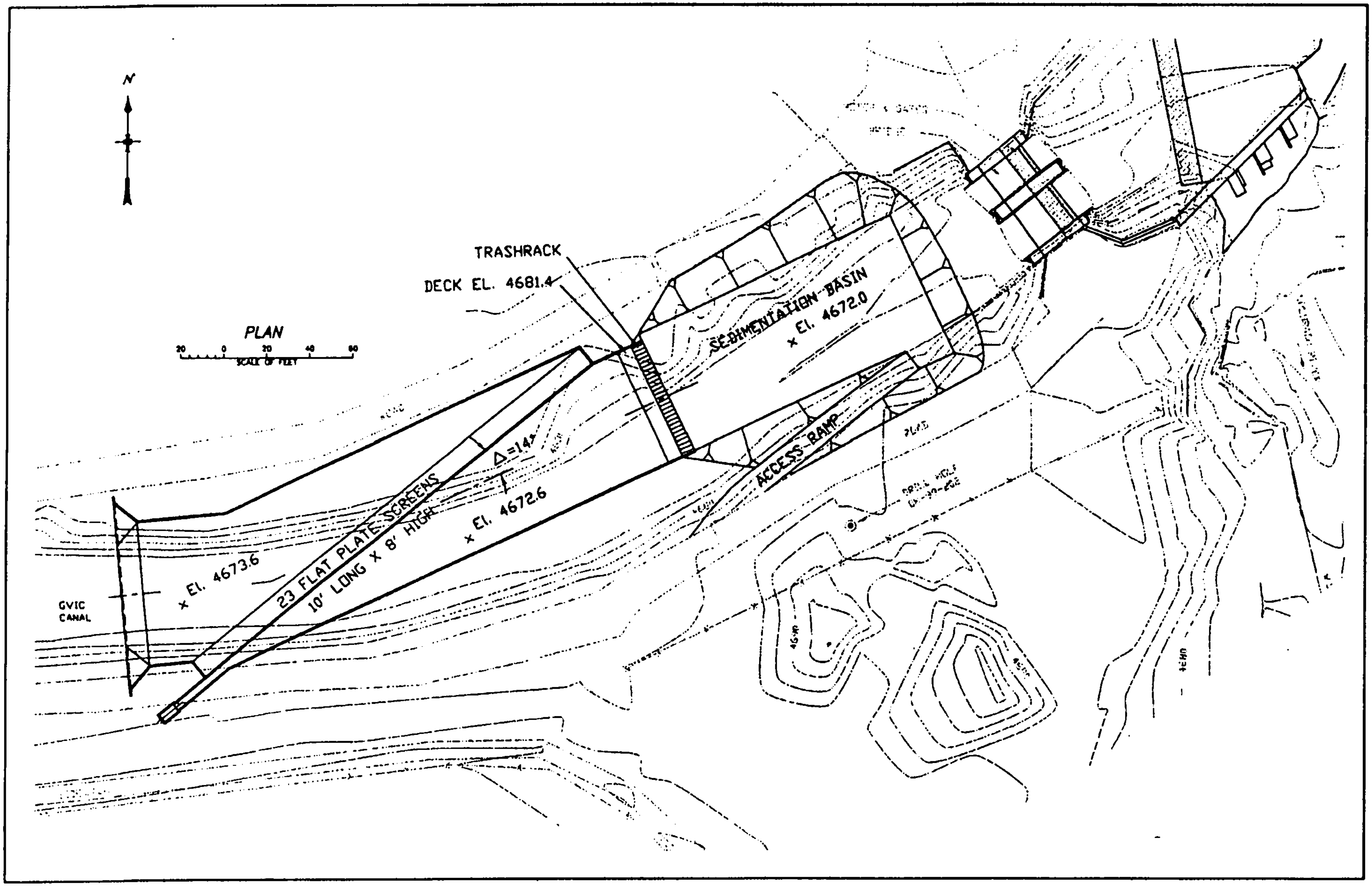
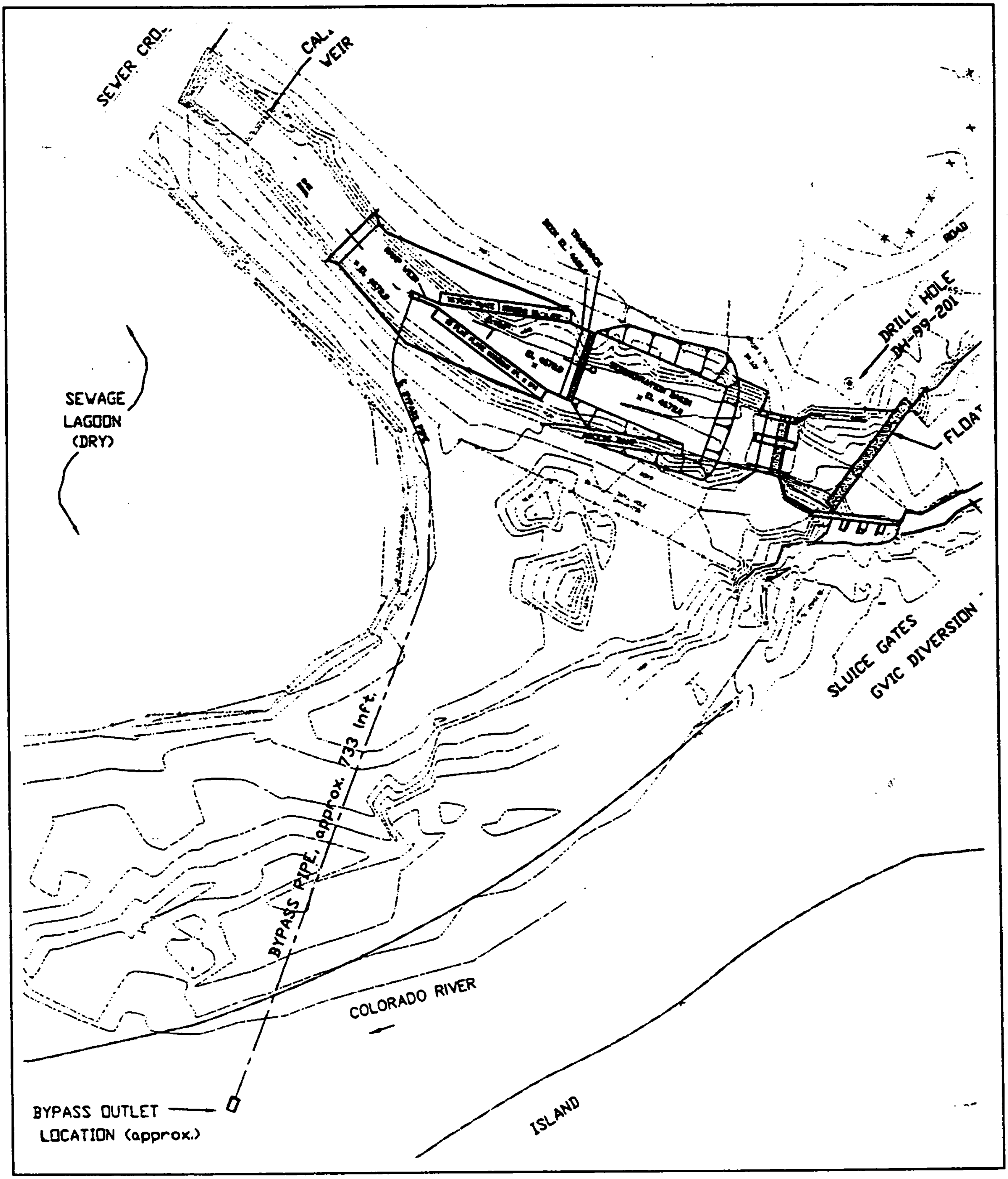


Figure 5. Bypass Pipe Alignment. (Typical)



LIFE CYCLE COST ANALYSIS - Current Operations and Baseline Concept (Option A)

USING PRESENT WORTH (PW) COSTS

Date: 2/29/00

PROJECT: Grand Valley Irrigation Company
COMPONENT: Fish Screen
Discount Rate: 5.5%
Economic Life: 20

			BASELINE CONCEPT		PROPOSAL 1		PROPOSAL 2A		PROPOSAL 2B	
			Estimated Costs	Present Worth	Estimated Costs	Present Worth	Estimated Costs	Present Worth	Estimated Costs	Present Worth
INITIAL/COLLATERAL COSTS										
A. Do Nothing (Current Operations)			$0							
B. Baseline (Option A) - Field Cost					$1,645,000	$1,645,000				
C.										
D.										
E.										
F.										
G.										
Total Initial/Collateral Costs						$1,645,000				
REPLACEMENT/SALVAGE (Single Expenditures)	Year	PW Factor								
A.										
B.										
C.										
D.										
E.										
F.										
G.										
H.										
I.										
J.										
K.										
Total Replacement/Salvage Costs										
ANNUAL COSTS *Maintenance & Operations*	Escal. Rate	PWA Factor w/Escalation								
A. Sediment Removal Cost - Current		11.950	$18,500	$221,082						
B. Sediment Removal Cost - Option A		11.950			$6,475	$77,379				
C.		11.950								
D.										
E.										
F.										
Total Annual Costs				*$221,082*		*$77,379*				
TOTAL PRESENT WORTH COSTS				*$221,082*		*$1,722,379*				
LIFE CYCLE (PW) SAVINGS						*($1,501,297)*				

Note: Based ONLY on sediment removal costs, Option A (Baseline Concept) would save $12,025/Year or $143,703 over the life of the project IN CURRENT YEAR DOLLARS.

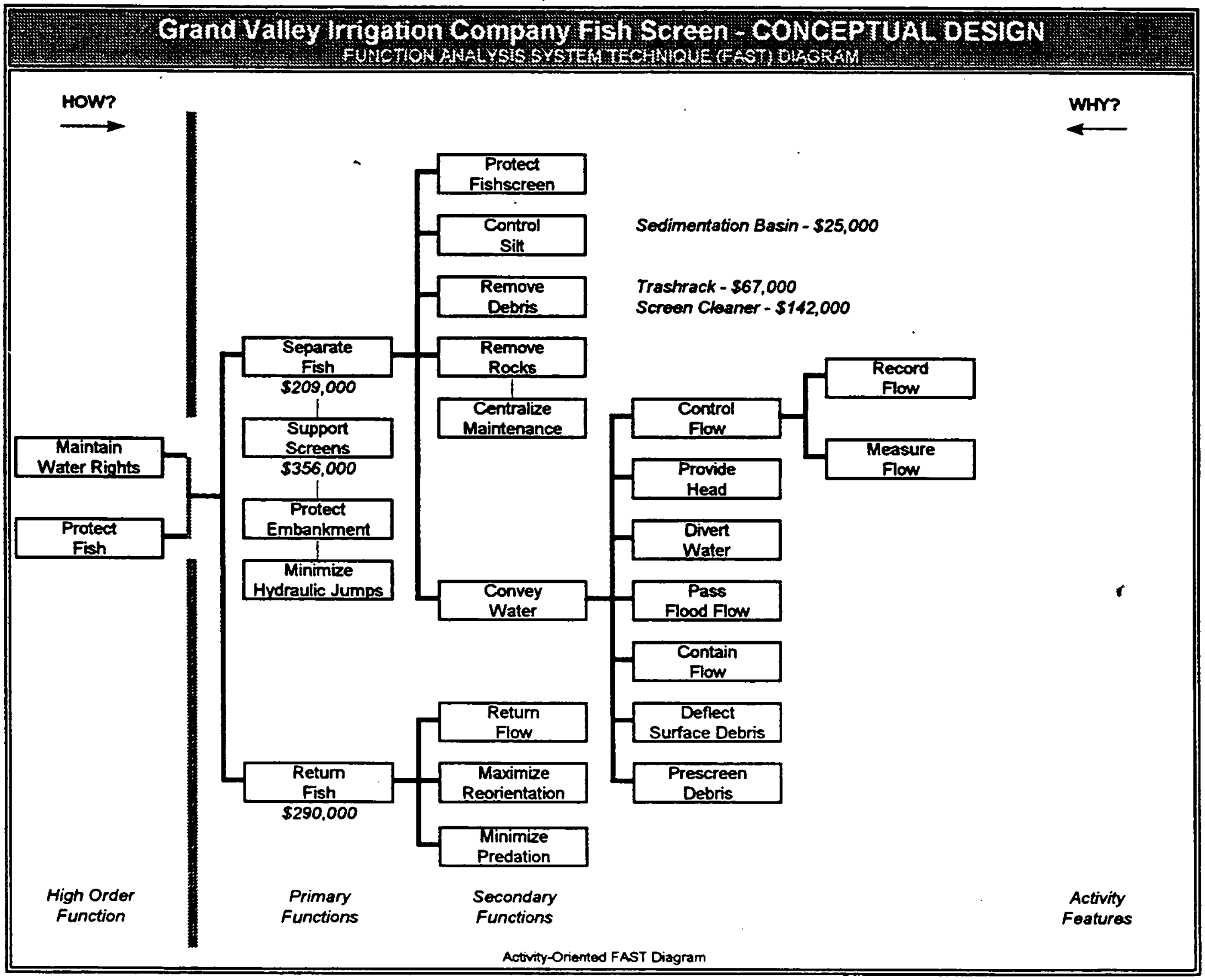
Function Analysis

Component	Active Verb	Measurable Noun
Project	Maintain Protect	Supply Fish
Fish Screen	Separate	Fish
Fish Screen Structure	Protect Minimize Support	Embankment Hydraulic Jumps Screens
Trashrack	Protect Remove Centralize	Fish Screen Debris Maintenance
Sedimentation Basin	Control Remove Centralize	Silt Rocks Maintenance
Bypass Pipe	Return Return	Fish Flow
Outfall	Maximize Minimize	Reorientation Predation
Canal	*Convey* *Contain*	*Water* *Flow*
Flood Gates	*Control* *Provide* *Divert* *Pass*	*Flow* *Head* *Water* *Flood Flow*
Head Gate	*Control* *Maintain*	*Flow* *Water Right*
Boom	*Deflect* *Prescreen*	*Surface Debris* *Debris*
Gauge and Calibration Weir	*Record* *Measure*	*Flow* *Flow*

Note: *Italicized words in the table above refer to the existing water distribution system owned by the Grand Valley Irrigation Company.*

Function Analysis System Technique (FAST)

The Value Study Team used the function-analysis process to generate a Function Analysis System Technique (FAST) diagram, designed to describe the present solution from a functional point of view. The FAST diagram helped the Team identify those design features that support critical functions and those that satisfy noncritical objectives. The FAST diagram also helped the Team focus on potential value mismatches, and generate a common understanding of how project objectives are met by the present solution.



** Function costs are identified in italics based on the component's estimated cost.*

Proposal No. 1A

Description

Proposal No. 1A. Monitoring Endangered Fish Movement into the Grand Valley Irrigation Company Canal, Grand Junction, Colorado (Weir)

- Proposal Description: Colorado pikeminnow and Razorback sucker were once found throughout the upper Colorado River Basin. However, populations have declined as a result of water development, loss of habitat, interaction with nonnative fishes, and past management practices. These fish have been listed as endangered species by the Endangered Species Act.

  Dams and diversion structures, built over the past century, that provide hydroelectricity and water for irrigation and municipal purposes, have blocked fish access to important habitat and spawning areas and funneled fish into canal systems (Burdick 1999). Some fish move unharmed through the canal system and eventually return to the river downstream, while others often perish as they encounter pumps, drains or dewatered areas. The U.S. Fish and Wildlife Service is concerned that the canals present a potential risk to endangered fish. Although there is evidence that endangered fish access these canals, data is limited and not conclusive. For example, Razorback suckers are currently found in Highline Reservoir and must have accessed it through the canal system (Chuck McAda, U.S. Fish and Wildlife Service, personal communication). Numerous native (Flannelmouth and Bluehead suckers, Roundtail chub) and nonnative fishes have been captured in these canals (Anita Martinez, Colorado Division of Wildlife, personal communication).

  The Recovery and Implementation Program for Endangered Fishes in the upper Colorado River Basin (RIP) proposes that fish screens be used to keep the endangered fish from entering the canals. The RIP also anticipates that more fish may get into the canals as recovery efforts continue. For example, large numbers of juvenile Razorback suckers have and will be stocked in the river upstream of diversion sites from hatchery grow-out ponds. In addition, fish passage structures at diversion dams will also allow Colorado pikeminnow and Razorback suckers to access historic habitat and spawning areas above the dams.

  The first screening structure is planned to be constructed in or just upstream of the Grand Valley Irrigation Company Canal (Figure 6). The GVIC wants to work cooperatively with the U.S. Fish and Wildlife Service to protect Colorado pikeminnows and Razorback suckers, but they also must continue to maintain the water supply to their water users. Although U.S. Fish and Wildlife Service biologists argue that it is only a matter of time before endangered fish enter the GVIC canal, water users believe there is not enough evidence to date to justify or support the costly construction of the fish screen structure in the canal. The question is whether to move ahead with the current project based on the limited information or to spend additional time now to collect fish movement data to insure a better design and project success. The Value Engineering Team proposes that additional studies be conducted to collect this information.

Proposal No. 1A

- <u>Critical Items to Consider</u>: The RIP believes that preventing Colorado pikeminnow and Razorback suckers from entering diversion canals is essential to the recovery of these fishes. A phased approach is needed to: 1) confirm whether endangered fish enter the canal, 2) make sure the current project will solve the problem, 3) use the data to refine the project designed for the situation and fish species involved, and 4) make sure the project works because it may be used as a precedent for future screening projects.

- <u>Ways to Implement</u>: A study is needed to determine endangered fish movement into the GVIC canal. This can be accomplished by building a small nonpermanent fish weir and trap in the canal downstream of the headgate. Fish can be collected throughout the water delivery season (April-November). This data would then be used to confirm the presence or absence of fish, fish movement patterns, and fish species type, size, and age. In addition, this data could also be used to explore the possibility of using a weir to capture and remove endangered fish from the canal and returning them to the river instead of using a more permanent fish screening structure. Sampling may need to occur during the day and at night, and during different flows and operations times of the head gates. It will cost approximately $150,000 for the study; $50,000 for the weir and $100,000 for two biologists, equipment, and travel expenses to sample the canal for one season.

- <u>Changes from the Baseline Concept</u>: This proposal postpones the preferred alternative until further data is collected on endangered fish movement into the GVIC canal. It is hoped that the data will either confirm the need for the fish screens, or provide additional information for refining the current project design and assuring success.

Advantages	Disadvantages
• Helps confirm the need for and credibility of the project. • Helps educate the public to understand the need and importance of the project. • Phased approach helps in refining project design. • A nonpermanent weir structure could be removed as needed. • Provide way for hands on data collection of endangered fishes and removal of nonnative fishes. • Fish movement, river discharge, and gate operation data will help in future management and operation decisions. • Provides a way to measure project success and its contribution to endangered fish recovery.	• Delays designing and construction of the project. • Without screens endangered fish may continue to enter the canal until preventive measure are taken. • No conclusive data may be collected from the sampling work. • If no endangered fish are collected, they may have to release fish just upstream of the canal and capture them in the canal to properly evaluate screening design and success

Proposal No. 1A

• Helps to justify future screening projects. • May be able to tie this proposal in with check dam proposal to help maintain return flow for screening structure. • Need to trap the entire canal.	

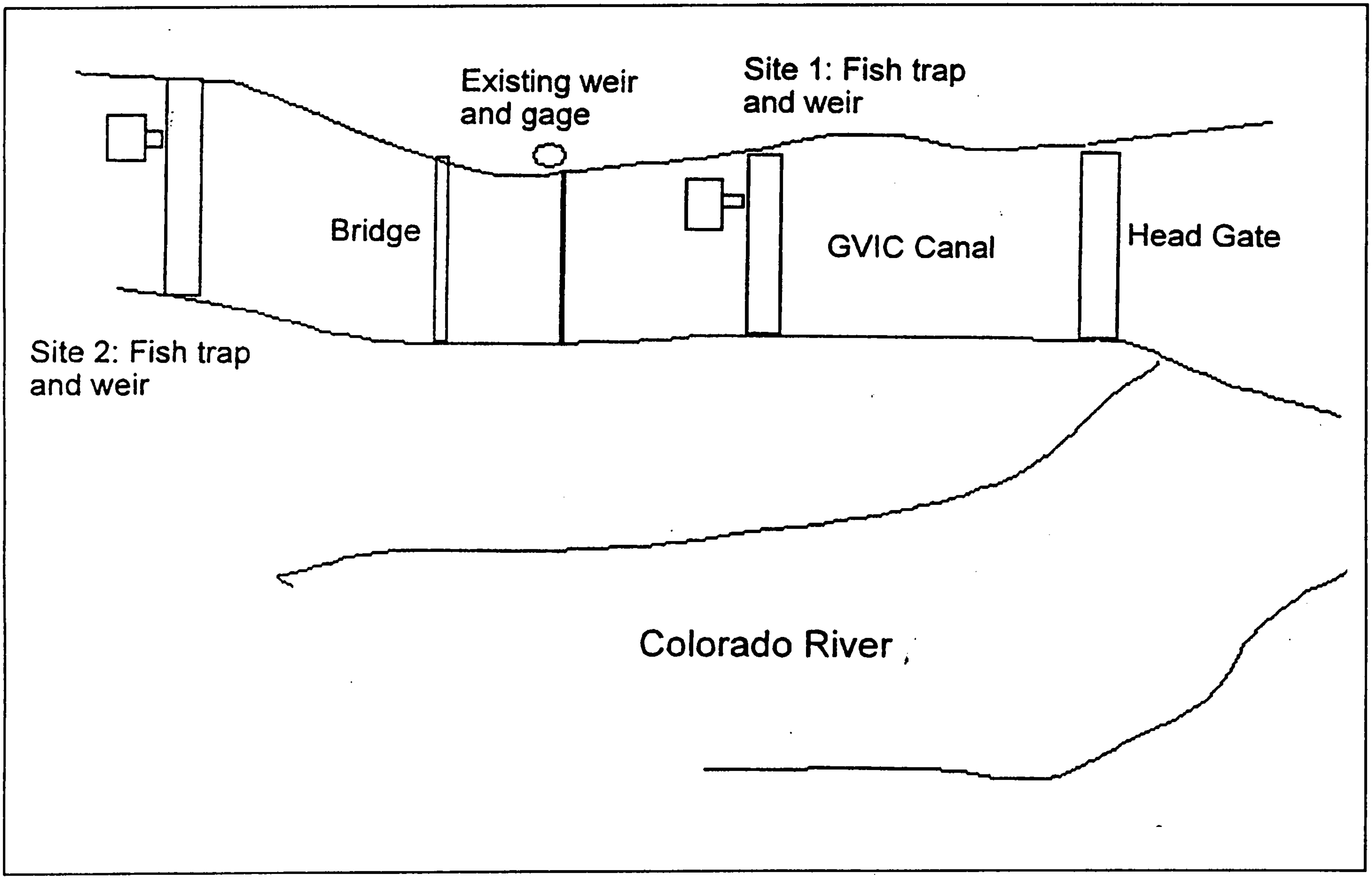
Potential Risks

- What if no endangered fish are captured during sampling efforts, what does this mean?
- What if weather, flow, or high debris conditions disrupt or hamper sampling efforts and interfere with collection of needed data?
- What if one season's worth of data collection is not enough information to justify the project?
- What if the endangered fish are killed during the sampling work?
- What if the sampling work interferes with the water delivery operations?
- If endangered fish are found, that may be considered a "take."

Cost Items	Nonrecurring Costs			
	One Season Cost		Two Season Cost	
Original Baseline Concept	$	0	$	0
Value Concept	$	150,000	$	250,000
Savings	$	(150,000)	$	(250,000)
Value Study Costs	$	20,000	$	20,000
Implementation Costs	$	0	$	0
Net Savings *	**$**	**(170,000)**	**$**	**(270,000)**

* Note: Since this is an additional cost, not anticipated in the baseline concept (Option A), any savings could only be determined based on the results of the monitoring.

Figure 6. Overview Plan Proposal No. 1A.



Proposal No. 1B

Description

Proposal No. 1B. Monitoring Endangered Fish Movement into the Grand Valley Irrigation Company Canal, Grand Junction, Colorado (Seines)

- Proposal Description: Colorado pikeminnow and Razorback sucker were once found throughout the upper Colorado River Basin. However, populations have declined as a result of water development, loss of habitat, interaction with nonnative fishes, and past management practices. These fish have been listed as endangered species by the Endangered Species Act.

  Dams and diversion structures, built over the past century, that provide hydroelectricity and water for irrigation and municipal purposes, have blocked fish access to important habitat and spawning areas and funneled fish into canal systems (Burdick 1999). Some fish move unharmed through the canal system and eventually return to the river downstream, while others often perish as they encounter pumps, drains or dewatered areas. The U.S. Fish and Wildlife Service is concerned that the canals present a potential risk to endangered fish. Although there is evidence that endangered fish access these canals, data is limited and not conclusive. For example, Razorback suckers are currently found in Highline Reservoir and must have accessed it through the canal system (Chuck McAda, U.S. Fish and Wildlife Service, personal communication). Numerous native (Flannelmouth and Bluehead suckers, Roundtail chub) and nonnative fishes have been captured in these canals (Anita Martinez, Colorado Division of Wildlife, personal communication).

  The Recovery and Implementation Program for Endangered Fishes in the upper Colorado River Basin (RIP) proposes that fish screens be used to keep the endangered fish from entering the canals. The RIP also anticipates that more fish may get into the canals as recovery efforts continue. For example, large numbers of juvenile Razorback suckers have and will be stocked in the river upstream of diversion sites from hatchery grow-out ponds. In addition, fish passage structures at diversion dams will also allow Colorado pikeminnows and Razorback suckers to access historic habitat and spawning areas above the dams.

  The first screening structure is planned to be constructed in or just upstream of the Grand Valley Irrigation Company Canal. The GVIC wants to work cooperatively with the U.S. Fish and Wildlife Service to protect Colorado pikeminnows and Razorback suckers, but they also must continue to maintain the water supply to their water users. Although U.S. Fish and Wildlife Service biologists argue that it is only a matter of time before endangered fish enter the GVIC canal, water users believe there is not enough evidence to date to justify or support the costly construction of the fish screen structure in the canal. The question is whether to move ahead with the current project based on the limited information or to spend additional time now to collect fish movement data to insure a better design and project success. The Value Engineering Team proposes that additional studies be conducted to collect this information.

Proposal No. 1B

- Critical Items to Consider: The RIP believes that preventing Colorado pikeminnow and Razorback suckers from entering diversion canals is essential to the recovery of these fishes. A phased approach is needed to: 1) confirm whether endangered fish enter the canal, 2) Make sure the current project will solve the problem, 3) use the data to refine the project designed for the situation and fish species involved, and 4) make sure the project works because it may be used as a precedent for future screening projects.

- Ways to Implement: A sampling study is needed to determine endangered fish movement into the GVIC canal. Fish can be sampled using seines, trammel nets or electrofishing. Sampling can either be conducted until fish are found, or only during the most likely period that fish are in the canal, or throughout the water delivery season (April-November) to confirm presence or absence, fish movement patterns, and fish species type, size and age. Sampling may need to occur during the day and at night and during different flows and operations times of the head gates. It will cost approximately $100,000 for two biologists, equipment, and travel expenses to sample the canal for one season.

- Changes from the Baseline Concept: This proposal postpones the preferred alternative until further data is collected on endangered fish movement into the GVIC canal. It is hoped that the data will either confirm the need for the fish screens, or provide additional information for refining the current project design and assuring success.

Advantages	Disadvantages
• Helps confirm the need for and credibility of the project. • Helps educate the public to understand the need and importance of the project. • Phased approach helps in refining project design. • Fish movement, river discharge, and gate operation data will help in future management and operation decisions. • Provides a way to measure project success and its contribution to endangered fish recovery. • Helps to justify future screening projects.	• Delays designing and construction of the project. • Without screens endangered fish may continue to enter the canal until preventive measure are taken. • No conclusive data may be collected from the sampling work. • If no endangered fish are collected, they may have to release fish just upstream of the canal and capture them in the canal to properly evaluate screening design and success.

Proposal No. 1B

Potential Risks

- What if no endangered fish are captured during sampling efforts, what does this mean?
- What if weather, flow, or high debris conditions disrupt or hamper sampling efforts and interfere with collection of needed data?
- What if one season's worth of data collection is not enough information to justify the project?
- What if the endangered fish are killed during the sampling work?
- What if the sampling work interferes with the water delivery operations?
- If endangered fish are found, that may be considered a "take."

Cost Items	Nonrecurring Costs	
	One Season Cost	Two Season Cost
Original Baseline Concept	$ 0	$ 0
Value Concept	$ 100,000	$ 200,000
Savings	$ (100,000)	$ (200,000)
Value Study Costs	$ 20,000	$ 20,000
Implementation Costs	$ 0	$ 0
Net Savings *	**$ (120,000)**	**$ (220,000)**

* Note: Since this is an additional cost, not anticipated in the baseline concept (Option A), any savings could only be determined based on the results of the monitoring.

Proposal No. 1C

Description

Proposal No. 1C. Hydraulic and Biological Studies (Laboratory and Field).

- Proposal Description: The need for design criteria was identified as a critical component in the development of viable alternatives for fish exclusion at GVIC canal headworks. Without this information it is difficult to identify and assess alternatives representing the greatest potential for success in achieving effective fish exclusion while at the same time ensuring GVIC's adjudicated water right. This proposal identifies critical data needs and outlines an approach for obtaining such data. Two phases are proposed and include biological and hydraulic studies. The first phase consists of developing design criteria for the target endangered species (Colorado Pikeminnow and Razorback Sucker). This phase requires a fisheries-engineering approach combining laboratory hydraulic and biological investigations to establish, for the associated life stages, swimming strength, positive barrier screen impingement potential, and basic behavioral characteristics. The second phase consists of laboratory physical modeling to further develop any alternatives identified as viable. The purpose of the laboratory studies is to provide a demonstration or proof of concept. Furthermore, these studies allow for refinements in the design to ensure acceptable field performance.

- Critical Items to Consider:
  - Cost and funding sources to support studies.
  - Literature review of existing data related to behavior of target species in the context of screening.
  - Scope of studies and resource agency US Fish and Wildlife Service approval.
  - Scheduling requirements.
  - Laboratory and field personnel resource availability.
  - Resource agency meetings and advisory protocol.
  - Laboratory use of endangered species.
  - Transporting native fish out-of-state may be difficult.
  - Consider using Lower Basin Razorback data, and/or Northern/California Pikeminnow data.
  - Consider expanding the scope to evaluate both species at the same time.

Ways to Implement: The first step is to conduct a thorough literature review to acquire all currently available data on target species. This information would then be reviewed to identify data gaps and develop a study approach. Following study design, a proposal would be prepared and submitted to the various funding and resource agencies for review. Assuming approval is obtained, the proposed studies could then be completed and the required design criteria established. After the criteria have been established, a design concept would be developed and refined using laboratory physical modeling and then passed to the design team for final design and implementation.

Proposal No. 1C

Fish screen velocity criteria for the target species would be established using a laboratory test facility (i.e., existing fish treadmill, newly constructed fish treadmill, or existing laboratory flume).

Sweeping and approach velocity components would be varied independently to identify the optimum velocity magnitudes and sweeping to normal component velocity ratios. Furthermore, screen exposure time, delayed mortality, and fish injury potential would be determined during these studies. The duration of these studies would likely be more than 1 year from initiation. A minimum of 4-6 months would be required to construct a new laboratory test facility and set-up the required fish holding and evaluation facilities.

The hydraulic model study would likely take an additional 6-9 months to investigate a series of alternatives. The scope of these studies would consist of demonstrating adequate hydraulic performance of each alternative consistent with the previously establish velocity criteria and field hydraulic operating conditions.

- Changes from the Baseline Concept: This proposal does not address any modifications to the baseline concept. It simply identifies the need for design criteria and suggests a preliminary approach to obtaining such criteria.

Advantages	Disadvantages
• Increases the potential for successful exclusion of endangered species from GVIC Canal and future projects of this type. • Provides valuable information for endangered species recovery program and future implementation of all engineering solutions. • Some cost may be recoverable if there is a reduction in the screen cost.	• Requires additional time that may delay immediate implementation of exclusion at GVIC Canal. • Represents additional cost.

Proposal No. 1C

Potential Risks

- Delays immediate implementation of exclusion at GVIC Canal.
- Cost is dependent on scope of studies. $500K for a two-year study program is a conservative estimate.

Cost Items	Nonrecurring Costs	
Original Baseline Concept	$	0
Value Concept	$	500,000
Savings	$	(500,000)
Value Study Costs	$	20,000
Implementation Costs	$	0
Net Savings *	$	**(520,000)**

* Note: Since this is an additional cost, not anticipated in the baseline concept (Option A), any savings could only be determined based on the results of the monitoring.

Proposal No. 2

Description

Proposal No. 2. Install the Trashrack In Front of the Headgates.

- Proposal Description: Install the trashrack in front of the headgates as shown on Figure 7.
- Critical Items to Consider: 1) In river construction requiring 404 permitting, 2) construction around existing headgates, and 3) cooperate with GVIC to allow alterations to be made to the headgates at the same time. This may permit an adjustment to the location of the sedimentation basin.
- Ways to Implement: Construct cofferdam and install during low water (winter).
- Changes from the Baseline Concept: Remove the proposed trashrack in the canal from the baseline (Option A) and move it in front of the headgates.

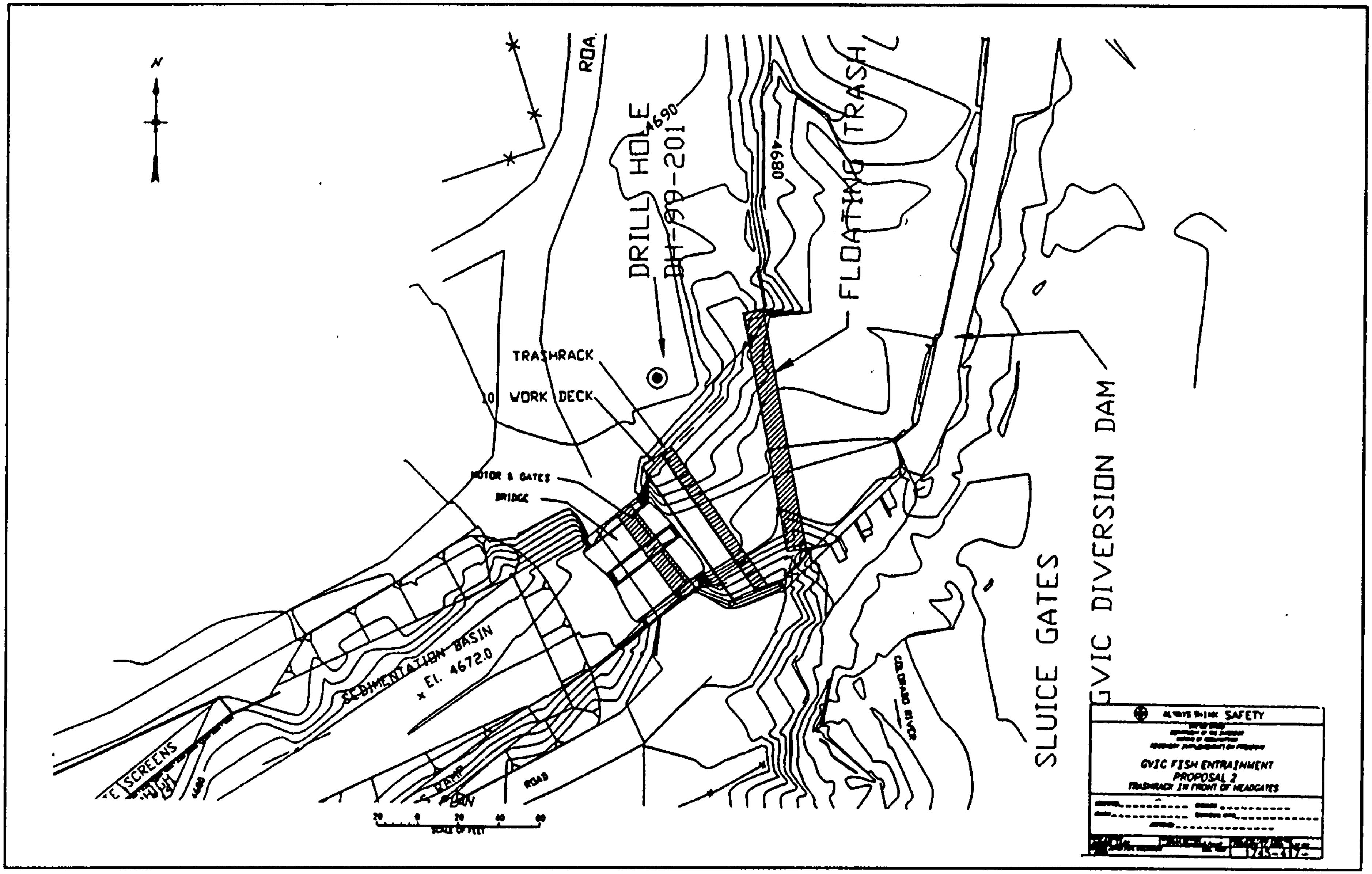
Advantages	Disadvantages
• Catches debris before headgates. • Reduces footprint of baseline structure. • Provides easier removal of debris (providing a machinery deck). • Allows GVIC to work on headgates. • Reduces trash O&M cost at headgates.	• Head loss through the trashrack. • Possible changes in canal operation. • Possible changes in flow patterns. • Possible siltation in front of the headgates. • Possible added congestion around existing headworks. • Trashrack may impact headgate operations.

Potential Risks

Possible clogging of the trashrack, reducing the required 660 cfs delivery until cleared, much in the same way debris clogs the headgates now.

Cost Items	Nonrecurring Costs
Original Baseline Concept	$ 67,000
Value Concept	$ 149,000
Savings	$ (82,000)
Value Study Costs	$ 20,000
Implementation Costs	$ 0
Net Savings	$ **(102,000)**

Figure 7. Overview Plan Proposal No. 2.



Proposal No. 3

Description

Proposal No. 3. Build a Sedimentation Basin in the River.

- Proposal Description: Build a sedimentation basin upstream of the diversion dam with sluicing capabilities, as shown in Figure 8.
- Critical Items to Consider: 1) In river construction with 404 permitting required, 2) cofferdam at low water construction (Winter construction), 3) if the flow capacity and drop of the floodgates was increased, this would improve the sluicing of the proposed basin, and. 4) some sediment would probably still have to be removed from in front of the fish screen.
- Ways to Implement: Cofferdam and divert river upstream, excavate basin.
- Changes from the Baseline Concept: Moves sedimentation basin out of the canal. Shortens footprint of the baseline (Option A) structure.

Advantages	Disadvantages
• Eliminates dredging and handling silt at the canal. • O&M Costs reduced. • Smaller baseline footprint in the canal.	• In river construction. • 404 permitting required. • Winter construction. • More wear and tear on fish ladder during construction. • More costly to excavate in bedrock. • Continual annual dredging of unsluiced material. • Some sediment would continue to be deposited in front of the fish screen.

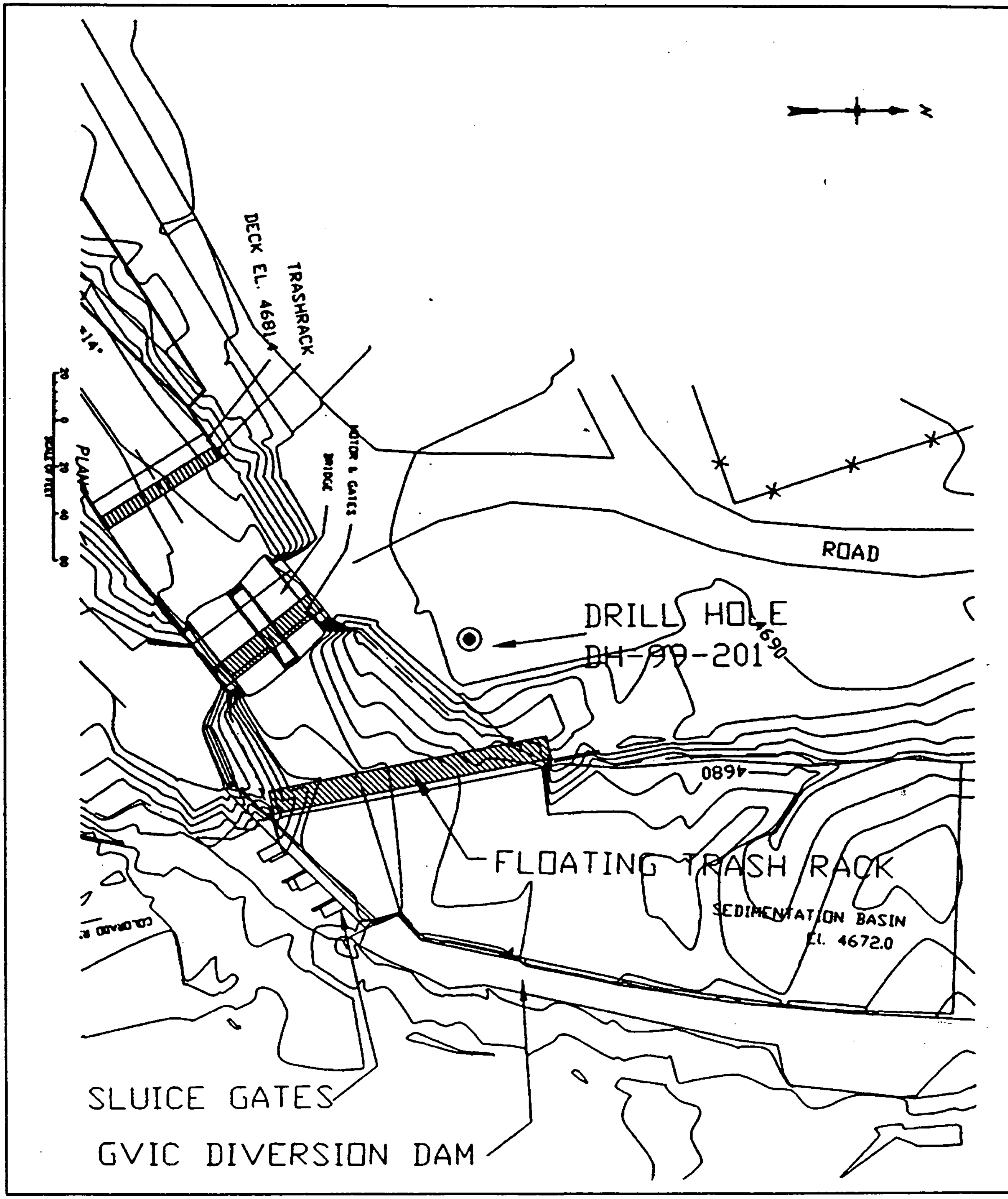
Potential Risks

- Sluicing of basin may not be complete, requiring dredging of basin, which would result in increased maintenance costs for dredging and hauling off site.

Proposal No. 3		
Cost Items	**Nonrecurring Costs**	
Original Baseline Concept	$	25,000
Value Concept	$	41,600
Savings	$	(16,600)
Value Study Costs	$	20,000
Implementation Costs	$	0
Net Savings	**$**	**(36,600)**

Note: The difference between the cost of added equipment maintenance and the reduced cost of sedimentation removal in the canal could not be reasonably estimated. If the changed flows were able to effectively sluice the sediment from the proposed basin without dredging, there would be a reduction in the cost of sediment removal.

Figure 8. Overview Plan Proposal No. 3.



Proposal No. 4

Description

Proposal No. 4. Install a Sluice Pipe at the Silt Ledge.

- Proposal Description: Install a sluice pipe at the silt ledge to remove silt, utilizing proposed bypass pipe. See Figure 9.
- Critical Items to Consider: Fish friendliness of transporting silt through the fish by-pass pipe.
- Ways to Implement: Install secondary pipe in foundation structure during construction using manifold structure.
- Changes from the Baseline Concept: Adds self cleaning capability to the baseline structure.

Advantages	Disadvantages
• Ease of removing silt at the silt step. • Allows brush cleaner to work more efficiently. • Minimizes handling of silt and directs the silt back into the river.	• Environmental concerns with dumping silt back into the river. • Silt build up at the outlet decreasing water depth cover and increasing predation. • Silt build up at outlet closing off outlet.

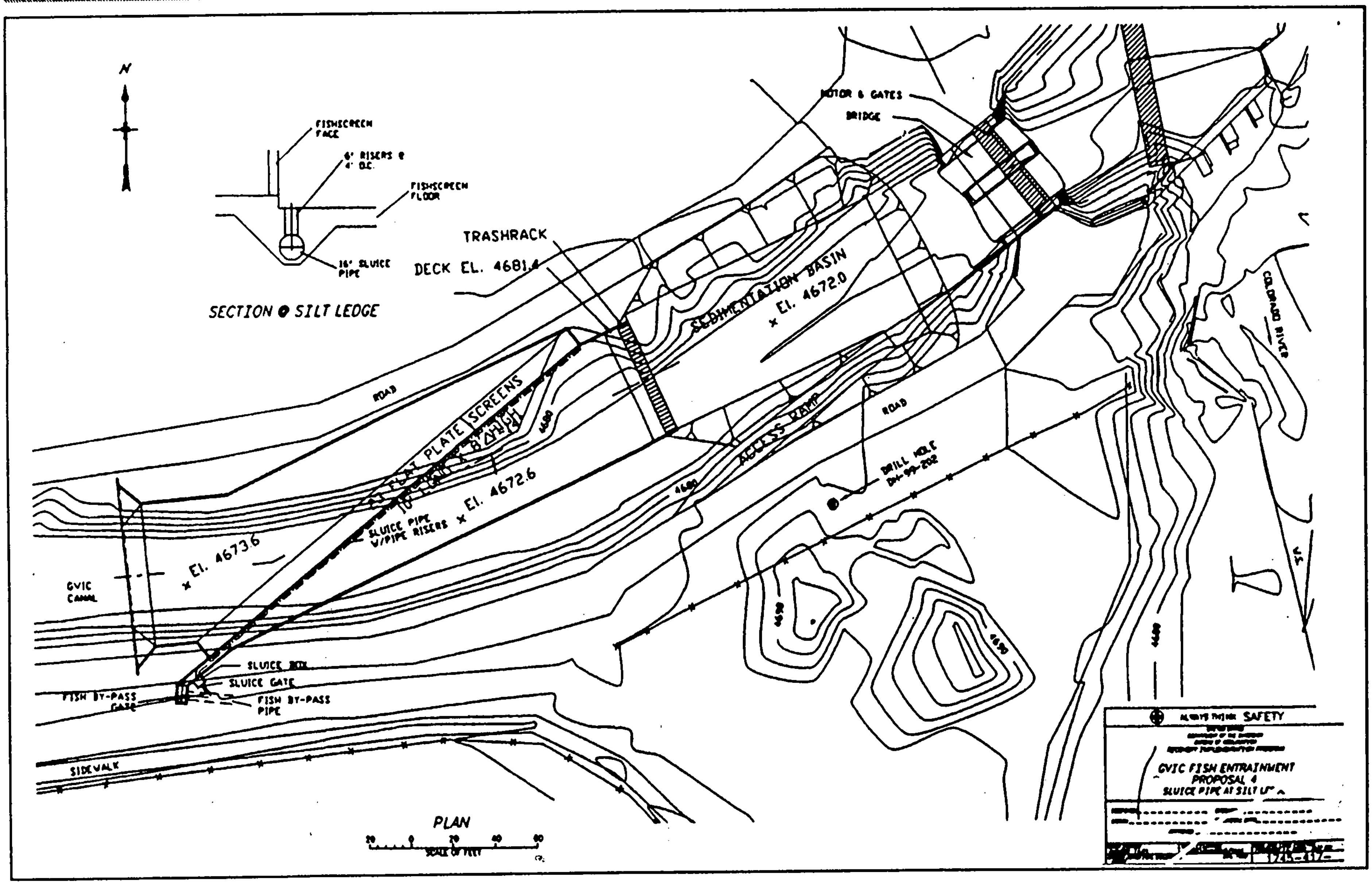
Potential Risks

Clogging of sluice pipe/fish bypass pipe rendering the pipes useless.
The silt sluiced out through the bypass pipe may fill the pool at the bypass outfall.
Endangered fish may be passed through the pipe during sluicing.

Cost Items	Nonrecurring Costs	
Original Baseline Concept	$	0
Value Concept	$	96,300
Savings	$	(96,300)
Value Study Costs	$	20,000
Implementation Costs	$	0
Net Savings	**$**	**(116,300)**

Note: The difference between the costs of sedimentation removal in the canal under the Baseline (Option A) and this proposal could not be accurately estimated. If the proposed sluicing flows were able to effectively remove the sediment from the basin without dredging, the proposal would save a maximum of $6,475 annually or about $77,379 over the life of the project in present dollars.

Figure 9. Overview Plan Proposal No. 4.



Proposal No. 5

Description

Proposal No. 5. Install a Stoplog Check Structure to Operate the Bypass During High Flows.

- Proposal Description: Install a stoplog check structure to check head to allow the baseline fish by-pass to operate at high river flows (approximately 20,000 cfs). See Figure 10.
- Critical Items to Consider: Effects on GVIC canal operations.
- Ways to Implement: Construct check structure just downstream of baseline structure in the canal during winter shut down.
- Changes from the Baseline Concept: Adds another structure to the baseline concept.

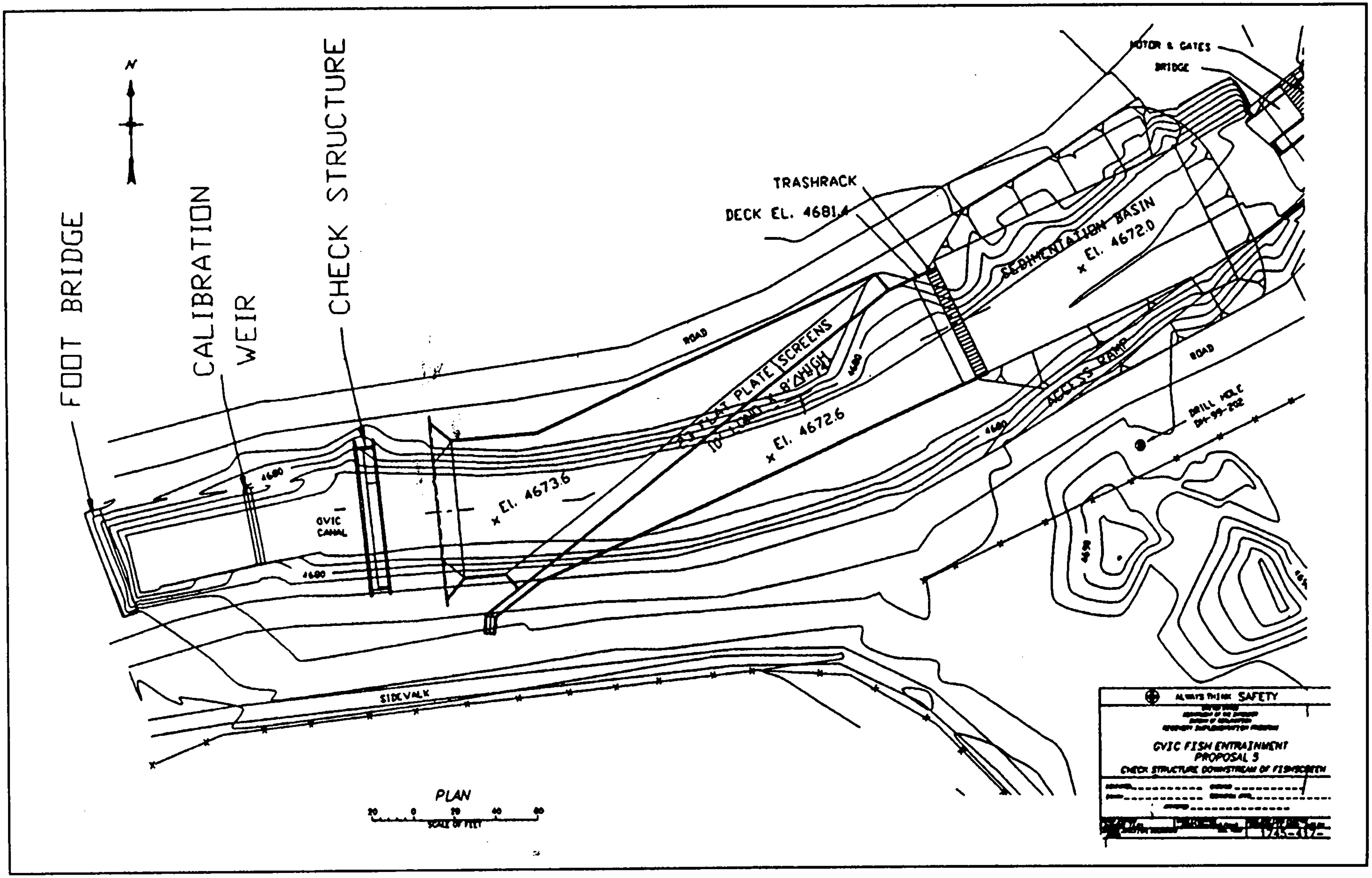
Advantages	Disadvantages
• Increases operational period of fish by-pass during high river flow conditions. • Allows for passage of smaller debris through the by-pass during times when debris removal is needed. • Allows for addition at downstream transition of fish screen.	• Increase maintenance due to addition of a structure. • Increase minor head loss across the check. • Increase concrete volume to baseline structure.

Potential Risks

Possible siltation or debris collection at the check structure. Possible embankment erosion.

Cost Items		Nonrecurring Costs
Original Baseline Concept	$	0
Value Concept	$	68,600
Savings	$	(68,600)
Value Study Costs	$	(20,000)
Implementation Costs	$	0
Net **Additional** Cost	**$**	**(88,600)**

Figure 10. Overview Plan Proposal No. 5.



Proposal No. 6

Description

Proposal No. 6. Implement Option E Instead of Option A.

- Proposal Description: Option E would place all components in the river upstream (outside) of the Grand Valley Irrigation Company facilities, as shown in Figure 11.
- Critical Items to Consider: Location, depth, maintainability and unknown factors.
- Ways to Implement: Study in more detail and redesign to: include refinements to enclose the gap between the deck and the flood gates, improve trash deflection, and clarify access. May require baffling. Requires multiple squeegees to clean.
- Changes from the Baseline Concept:
  . River volume and flows considerably higher than would be experienced in the canal.
  . Significantly larger, more complex and more expensive facility.

Advantages	Disadvantages
• Keep fish closer to their preferred environment. • Right-of-Way and easement are at a central area. • Will keep more larvae fish in the river. • Does not need a bypass pipe. • Uses the water energy in the river to improve sediment and debris flushing. • Keep the river environment in its appointed place. • Keep the low flow bypass channel free of silt.	• May be too large of an installation to maintain and operate in the long haul. • Restricts GVIC access to the diversion dam in the river from the west side. • Sedimentation study in hole. • Eye sore. • Not compatible to river bank, burden. • High cost. • Has to deal with higher river flows. • Not able to use the boom, which typically deflects about 80 percent of the large river debris. • Potential for trash to wrap around the end of the trashrack and impact the fishscreen. • Extensive "404" permit process. • Hydraulics of the river are significantly higher than in the canal and a more detailed analysis and design would be required. • Increases fish exposure time. • Reduces the floodgate capacity.

Proposal No. 6

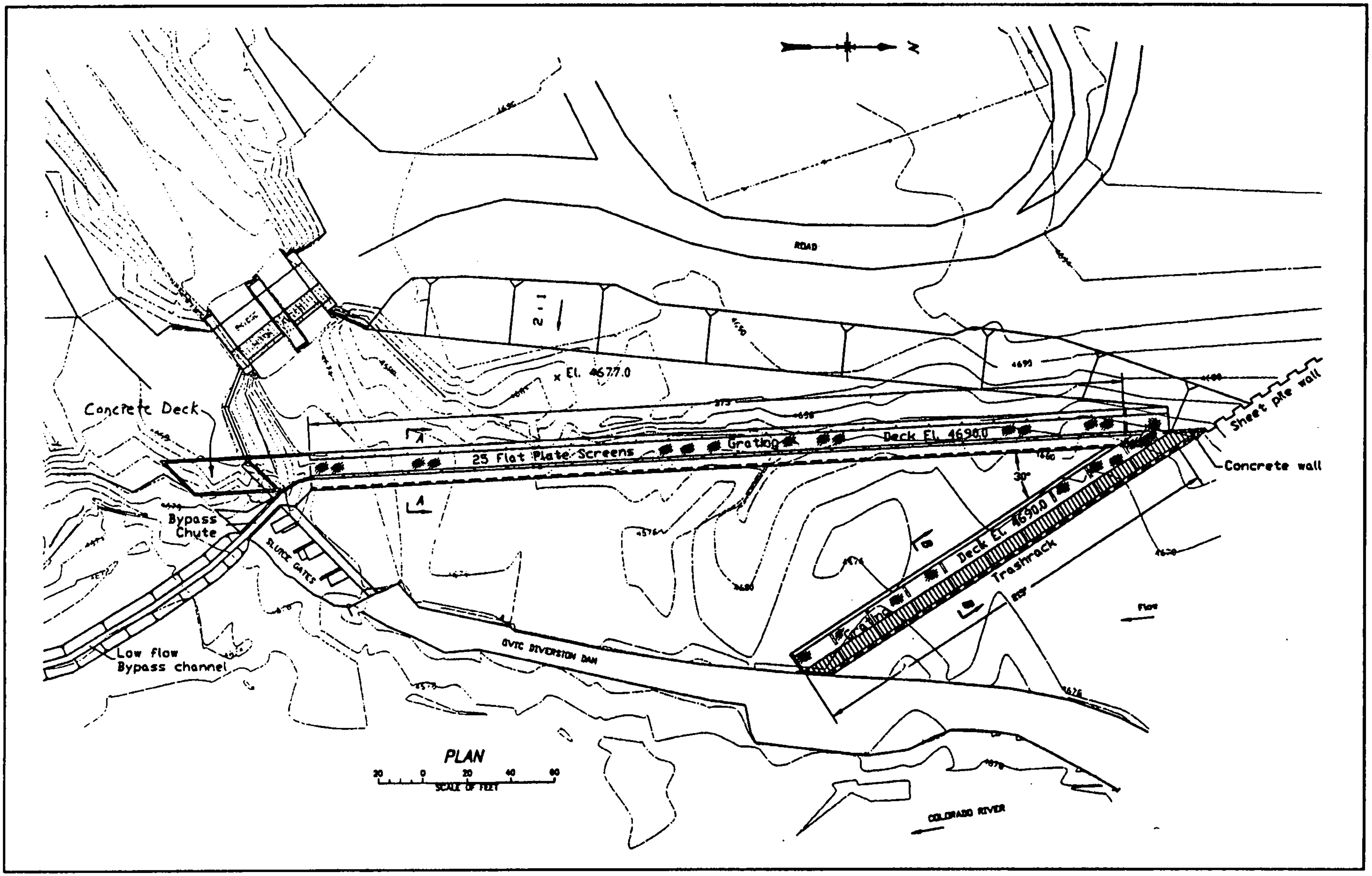
Potential Risks

Complexity of the structure would probably make maintenance and operation more difficult.

Cost Items		Nonrecurring Costs
Original Baseline Concept (Field Cost)	$	1,645,000
Value Concept (Field Cost)	$	3,384,000
Savings	$	(1,739,000)
Value Study Costs	$	20,000
Implementation Costs	$	0
Net **Additional** Cost	**$**	**(1,759,000)**

Note: The differences between the cost of added equipment maintenance and the cost of sedimentation removal under the Baseline concept and this proposal could not be reasonably estimated.

Figure 11. Overview Plan Proposal No. 6.



Proposal No. 7

Description

Proposal No. 7. Install a Siphon to Use Orchard Mesa Irrigation District Water

- Proposal Description: This proposal consists of siphoning water released by the Orchard Mesa Irrigation District (OMID) over to GVIC's canal. See Figures 12 and 13. This proposal appears to have some merit because the water coming from the OMID facilities would not contain trash or native fish. GVIC would have to supplement the OMID water by diverting through existing facilities equipped with small traveling belt screens in front of the head gates.

  The OMID power canal, powerplant and hydraulic turbine pumping plant are across the river east of the GVIC headworks. The OMID power canal and powerplant each have a capacity of approximately 777 cfs. Typically OMID runs 310 cfs through the powerplant during the irrigation season. The remainder of the flow, 443 cfs, runs through the hydraulic turbine pumping plant to lift 171 cfs to the Orchard Mesa conveyance system. It is assumed that 582 cfs (310 cfs plus 272 cfs) is available to siphon across the river to the GVIC canal from the tailwater areas. (See Figure 13). At low river flows, OMID has a check structure which forces the water to back upstream to a point above the upper portion of the GVIC diversion dam. It is assumed that the resulting tailwater surface elevation during this checking has a slight impact to the efficiency (decrease in head) of the powerplant and pumping plant, but this is still in an acceptable operation range.

  Based on available elevations, it appears that there is 2.5 feet of head available to siphon the water from the OMID facilities to the GVIC canal.

  Preliminary siphon design indicates that a 10-foot diameter reinforced concrete pressure pipe would be required to carry the 580 cfs across the river. The remainder of the required GVIC flow (660 cfs - 580 cfs) would continue to be diverted from the river using the existing GVIC facilities.

- Critical Items to Consider:
  . Impacts to existing agreements between OMID and U.S. Fish and Wildlife Service.
  . Reduced efficiencies on power and pumping plants from continuous high tailwater.
  . Is this a change in the point of diversion for GVIC and impact to existing water rights?
  . Administration of water rights by State Water Engineer.
  . Consider how to divert flow when OMID is not operating.
  . Rotating belt screen on the headworks to supply the remaining 80 to 100 CFS.
  . Consider increasing the intake into the Highline Canal to produce the total flow (660 CFS) required by GVIC.

Proposal No. 7

- Ways to Implement:
  . Construct inlet structures at the discharge points of the power and pumping plants.
  . Construct a siphon across the river.
  . Construct a siphon outlet in the canal.
  . Install two small traveling belt screens on existing canal headworks.

- Changes from the Baseline Concept:
  . Substantially reduces quantity of flow to be screened and eliminates proposed trashrack.

Advantages	Disadvantages
• Less flow to screen. • No trashrack. • Reduces future O&M cost compared to baseline concept (could not be quantified).	• Possible impacts to existing agreements between OMID and U.S. Fish and Wildlife Service (Orchard Mesa Check Case). • Higher impacts to river during construction (different permits requirements, extensive 404 permit). • What if OMID shuts down for emergency repairs to power the canal? Operation would have to go back to existing operation and fish may enter the canal. • Potential of change in points of diversions and water right issues. • Administration of this scheme with State Water Engineer. • Potential damage to fish passage by diverting flows during construction. • Depending on OMID to have the same operating season. • Power interference and pumping cost impacts.

Potential Risks

OMID, Grand Valley Water Users Association, and the Public Service Company are all stakeholders in the power generated, and an agreement may be very difficult to consummate and live with operationally.

Proposal No. 7		
Cost Items	**Nonrecurring Costs**	
Original Baseline Concept (Field Cost)	$	1,645,000
Value Concept	$	2,612,500
Savings	$	(967,500)
Value Study Costs	$	20,000
Implementation Costs ** See Note	$	0
Net **Additional** Cost	**$**	**(987,500)**

** Implementation costs have not been calculated. These items might include costs for design, legal fees, 404 permitting, and NEPA.

The difference between the costs of added equipment maintenance and the cost of sedimentation removal under the baseline concept and this proposal could not be reasonably estimated. Since the GVIC main headgates would need to be kept clear of sediment, as is currently performed, in order to draw water from the river when OMID water was unavailable, the cost of sedimentation removal would most likely remain the same as is currently experienced ($12,500/year).

Figure 12. Overview Plan Proposal No. 7.

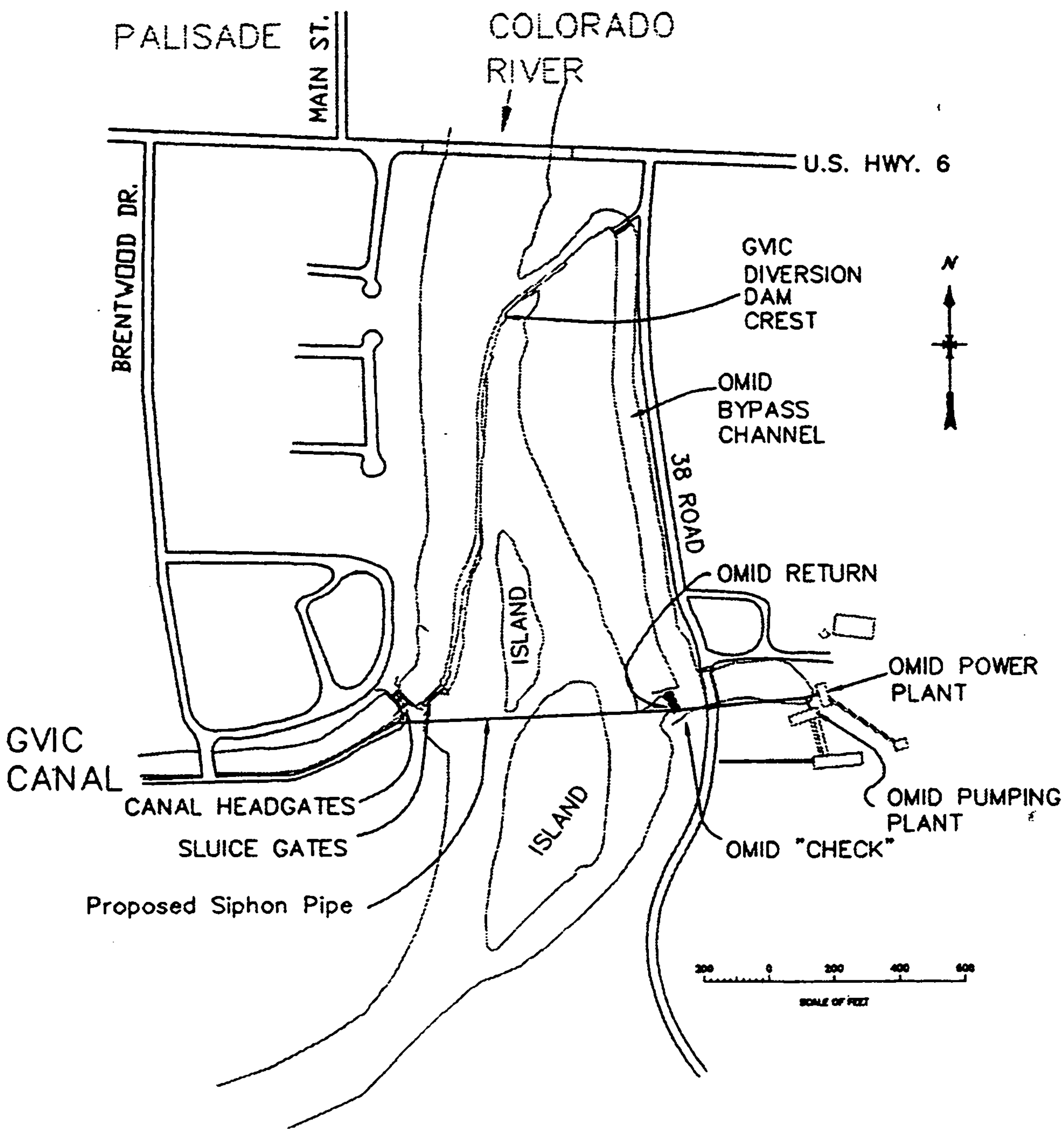
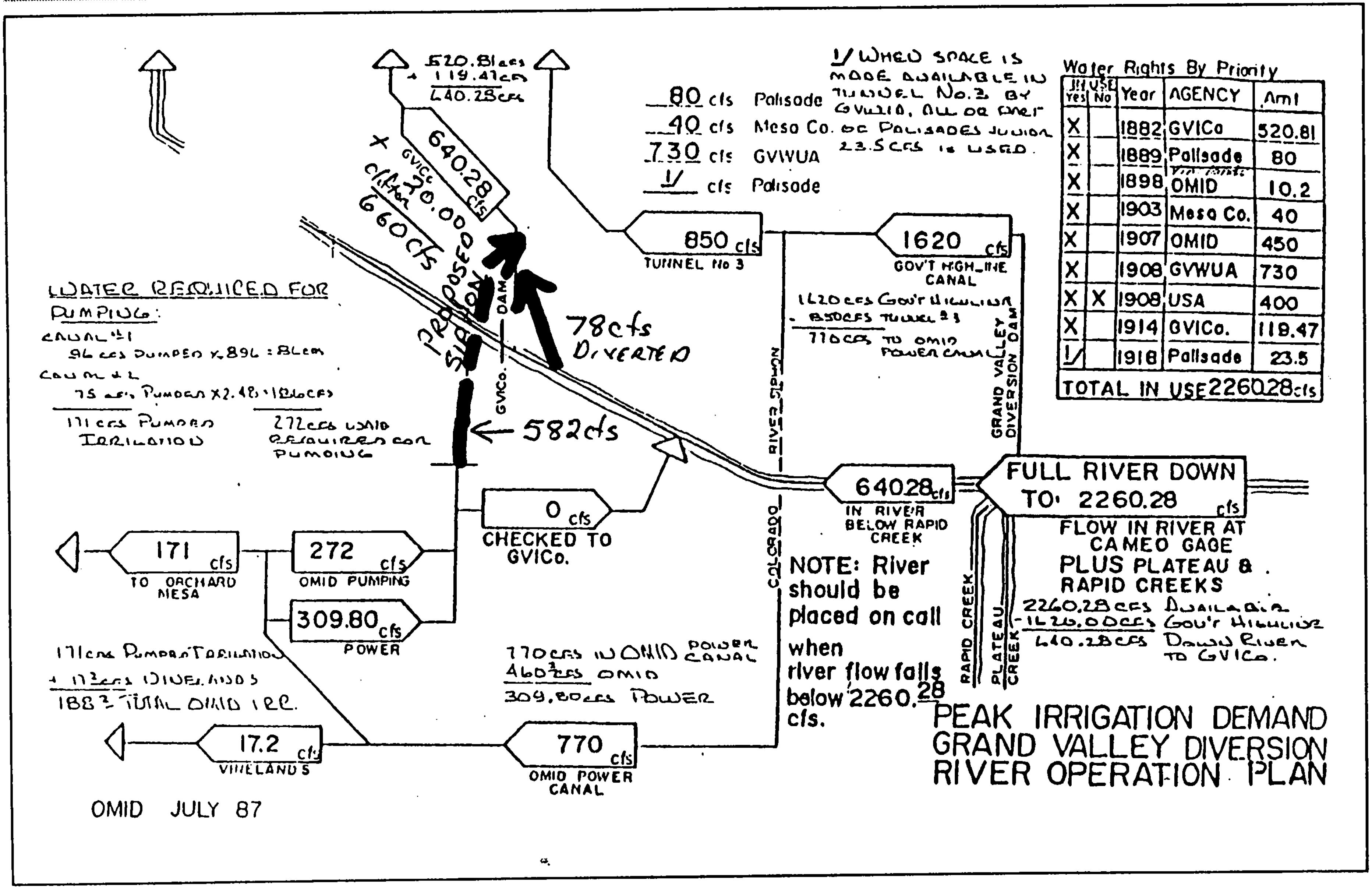


Figure 13. Flow Diagram of Proposal No. 7.



Water Rights By Priority

1/ USE Yes	No	Year	AGENCY	Amt
X		1882	GVICo	520.81
X		1889	Palisade	80
X		1898	OMID	10.2
X		1903	Mesa Co.	40
X		1907	OMID	450
X		1908	GVWUA	730
X	X	1908	USA	400
X		1914	GVICo.	119.47
1/		1918	Palisade	23.5
TOTAL IN USE				2260.28 cfs

Proposal No. 8

Description

Proposal No. 8. Electrical Barrier

- Proposal Description: An electrical barrier would be used instead of a positive barrier fish screen structure to exclude fish from GVIC diversion flows at the existing GVIC Diversion Dam Canal Headworks. The barrier would be located in-river and upstream of the existing head gates (Figure 14). The barrier would be designed and constructed to minimize or eliminate the entrainment of adult and juvenile target species (Colorado Pikeminnow and Razorback Sucker). The barrier can be oriented at an angle with respect to the existing headworks structure to create a barrier that fish could sense and avoid. Adequate sweeping flow for guidance past the barrier could be provided using the existing diversion dam floodgates during times when sufficient river flow is available. However, low flow periods would likely represent a limiting case when the electrical barrier performance is less than optimal. During these periods the barrier could be shut down or remain operating. Debris and trash would be handled in the same manner as with the existing facility (i.e., no additional debris removal facilities are required).

- Critical Items to Consider:
- Public safety.
- Fish injury or mortality (Particularly larvae).
- Exclusion potential for larvae.
- Velocity or hydraulic operating criteria.
- O&M or annual service costs (approximately $5,000/yr or $60,000 over a 20-year project life)
- O&M cost associated sediment handling (assuming no hydraulic solutions can be implemented).
- Effects on existing cathodic protection.
- Proximity to existing debris boom and potential exposure to personnel.
- Laboratory development (See Proposal No. 1C).
- Target species behavioral influence.
- May be more effective for fish going upstream than for those going downstream.

- Ways to Implement: Preliminary laboratory (fisheries-engineering) evaluation/demonstration may be required to demonstrate the potential to exclude target species. Following laboratory development, a field demonstration study could then be conducted. Assuming successful operation, the field demonstration could be optimized and put into permanent service.

- Changes from the Baseline Concept: This concept is different than the baseline concept and makes no use of any components associated with the baseline concept other than existing GVIC facilities.

Proposal No. 8

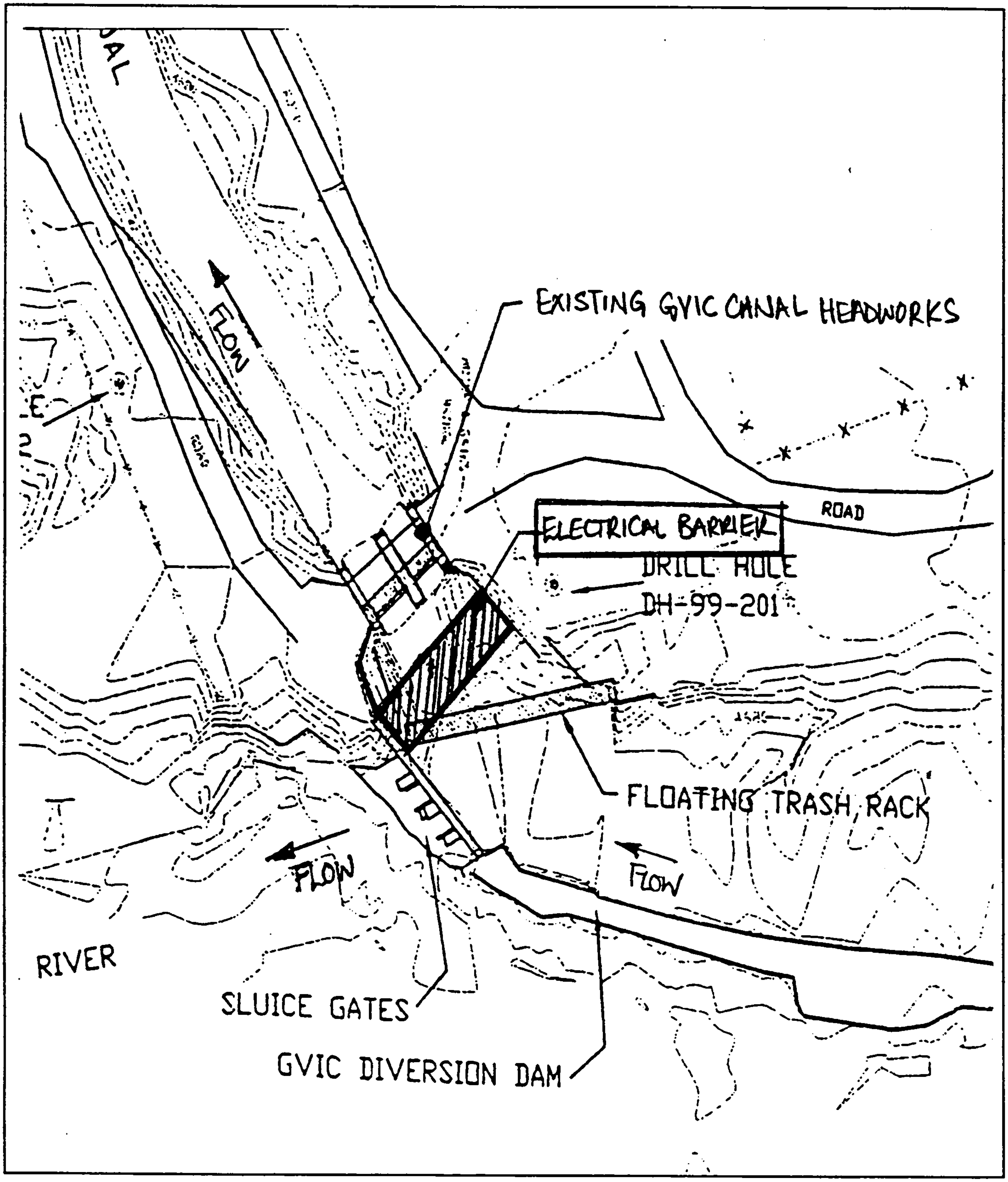
Advantages	Disadvantages
• No screen structure required. • No additional debris handling. • Reduced cost alternative.	• May require seasonal maintenance. • Likely not effective for exclusion of larvae. • May require periodic dredging or sedimentation basin. • May not be 100 percent effective for juveniles or adults, or effectiveness may be species dependent. • Not proven technology for the target species

Potential Risks

- Could represent a public safety hazard.
- Target species behavior may not be conducive to application of electrical barriers (i.e., ineffective for exclusion, causes injury to fish, etc.)
- Long term O&M is a question.

Cost Items	Nonrecurring Costs	
Original Baseline Concept	$	1,645,000
Value Concept	$	500,000
Savings	$	1,145,000
Value Study Costs	$	20,000
Implementation Costs	$	0
Net Savings	**$**	**1,125,000**

Figure 14. Overview Plan Proposal No. 8.



Disposition of Ideas

Value Study Elements Considered as Potential Proposals and Their Disposition	
Idea	**Disposition**
Do Option E.	Proposal No. 6.
Do nothing.	Does not satisfy the requirement to protect fish.
Right-of-Way issues need to be resolved for the by pass pipe.	Identified for continuing action.
Right-of-Way issues, installation, and use of the GVIC canal need to be resolved by an agreement.	Identified for continuing action.
Short and long term contract issues need to be resolved.	Identified for continuing action.
Do we really have a problem with fish?	Proposal Nos. 1A, 1B, and 1C.
Do we have the data to support the project?	Proposal Nos. 1A, 1B, and 1C.
Develop fish in a hatchery or grow out pond to replace the fish that are lost in the GVIC canal. May consider this as a temporary measure pending additional information?	Submitted as another idea.
Monitor fish movement into the GVIC system to determine the scope of the problem. How many fish enter (type, size, species, etc., and how many are lost.	Proposal Nos. 1A, 1B, and 1C.
Measure how the project contributes to (insures) the success of fish recovery.	Proposal Nos. 1A, 1B, and 1C.
Capture fish in the GVIC canal in a weir trap and truck back to the river. Has a bonus of identifying the number, type, age, size, species (native/non-native) and condition of the fish entering the canal.	Proposal No. 1A.
Phase the work to take advantage of additional information. (1) weir structure/ramp flume down stream of the footbridge to capture and identify fish in the canal, (2) use data to verify and scope the problem, (3) master plan a solution, and (4) develop a specific project design.	Proposal Nos. 1A, 1B, and 1C.

Disposition of Ideas

Value Study Elements Considered as Potential Proposals and Their Disposition	
Idea	**Disposition**
Let the fish follow the canal to the end (where they would return to the river) and increase flow volume to have a positive flow (greater than GVIC demand) returning to the river, and screen the turn outs and spillways to contain fish in the canal.	Not developed by the team because this concept would probably prove unacceptable to US Fish and Wildlife Service due to increased risk to the fish.
Install an electrical barrier to prevent fish from entering the headgate. Location, safety, and fish mortality issues are critical.	Proposal No. 8.
Light barrier to prevent fish from entering the headgate.	Rejected by the team because the high turbidity in the Colorado River would most likely limit the effectiveness of this solution.
Acoustic barrier to prevent fish from entering the headgate.	Submitted as another idea.
Consider an O-G screen configuration as the water intake technique.	Abandoned by the team based on high cost, extensive 404 permitting, required head, and complexity. Draft background information in the appendix.
Consider infiltration chambers as the water intake technique.	Not pursued due to turbidity, cost, and operation issues.
Add a means of monitoring the number of fish returned to the river through the by-pass.	Pass to the design team as a refinement to the Option A design.
Add a means of measuring the water (flow) returned to the river through the by-pass.	Pass to the design team as a refinement to the Option A design.
Use jetting to resuspend the sediment and keep it moving. Use a squeegee for moss/algae removal at the screen.	Pass to the design team as a refinement to the Option A design.
Create habitat at the bypass pipe outfall pool to reorient and reduce predation of fish returning to the river through the bypass pipe.	Pass to the design team as a refinement to the Option A design.
Concrete surface to the access ramp down to the sedimentation basin for maintenance.	Pass to the design team as a refinement to the Option A design.
Concrete surface to the floor of the sedimentation basin.	Pass to the design team as a refinement to the Option A design.

Disposition of Ideas

Value Study Elements Considered as Potential Proposals and Their Disposition	
Idea	**Disposition**
Add an opening at the headgate (there is an existing space for another gate in the headgate).	Pass to the design team as a refinement to the Option A design.
Traveling trashrack similar to that in "White River at Suomish"	Pass to the design team as a refinement to the Option A design.
Sluice pipe at the step to remove silt. Consider one or two pipes in the by-pass alignment.	Proposal No. 4.
Redesign the headworks to improve the trash movement, head (pressure), and screening.	Submitted as another idea. Not developed due to time constraints and complexity.
Series of pump diversions downstream to pull smaller amounts of water at a number of locations.	Rejected by the team due to the operation and maintenance costs and water rights issues.
Install a new trashrack to replace the boom and install the fish screen in the canal.	Eliminated by the team in favor of a 2-phase (boom and trashrack) approach.
Install a new trashrack behind the boom and in front of the headgate to remove trash that passes the boom. This would reduce or eliminate the trash impacting the operation of the headgate. Install the fish screen in the canal as in Option A.	Proposal No. 2.
Install a check structure to check up head so that the by pass pipe would continue to operate in high flow conditions.	Proposal No. 5.
Sediment basin upstream of the diversion dam with sluicing capability. (Such as a cleat under the bottom stoplog in the first bay of the flood gate to sluice sediment.)	Proposal No. 3.
Siphon under the river to capture the powerplant outflow that contains no fish or debris and supply that flow to the GVIC canal. This would reduce the amount of water that would have to be diverted at the headgate.	Proposal No. 7.

Disposition of Ideas

Value Study Elements Considered as Potential Proposals and Their Disposition	
Idea	**Disposition**
Return the highline canal administrative flows into the GVIC canal instead of into the river. This could be put anywhere upstream of the GVIC intake.	Submitted as another idea. This quantity of flow was evaluated as not very dependable and difficult to account for by the team and was not developed further.
Build off canal storage so you do not have to divert water when fish are in the river.	Rejected by the team because endangered fish are in the river all the time and the existing water right would need to be amended to allow storage.
Separator schemes to remove fish.	Included as part of the weir design.
Combine screen and trashrack into a single structure.	Rejected by the team because operation and maintenance was believed to be very costly and difficult.
Develop and analyze biological and hydraulic models of the proposed solution and fish behavior. Consider Denver (TSC) and University of California, Davis as potential agencies for modeling.	Proposal No. 1C.
On an in river trashrack, install a conveyor belt on the top of the structure to quickly return some of the debris to the river.	Rejected by the team as of little advantage and costly to purchase, install, and maintain.
Confirm the screening criteria (approach and sweep velocities) because of their significant impact on the size and configuration of the screen. Concern that without adequate, species specific data the facility may not be effective.	Proposal No. 1C.
Consider a trap at the end of the fishscreen in Option A, prior to the bypass pipe, that could be operated as needed to identify target species (number, size, weight, type, condition and age) and remove non-native species. This would provide data for an evaluation to measure the success of the recovery program.	Pass to the design team as a refinement to the Option A design.

List of Consultants

Consultant or Contact	Topic or Information
Frank Pfeifer Project Leader Colorado River Fish Project U.S. Fish and Wildlife Service 764 Horizon Drive, South Annex A Grand Junction, Colorado 970-245-9319	Life history and recovery work on Colorado pikeminnow and Razorback sucker. Fish passage issues, project design, and screening needs in canals.
Chuck McAda Assistant Project Leader Colorado River Fish Project U.S. Fish and Wildlife Service 764 Horizon Drive, South Annex A Grand Junction, Colorado 970-245-9319	Life history and recovery work on Colorado pikeminnow and Razorback sucker. Fish passage issues, project design, and screening needs in canals.
Bob Burdick Fisheries Biologist Colorado River Fish Project U.S. Fish and Wildlife Service 764 Horizon Drive, South Annex A Grand Junction, Colorado 970-245-9319	Life history and recovery work on Colorado pikeminnow and Razorback sucker. Fish passage issues, project design, and screening needs in canals.
Gary Baker Fish Hatchery Manager Colorado River Fish Project U.S. Fish and Wildlife Service 764 Horizon Drive, South Annex A Grand Junction, Colorado 970-245-9319	Life history and recovery work on Colorado pikeminnow and Razorback sucker. Fish passage issues, project design, and screening needs in canals.
Anita Martinez Fisheries Biologist Colorado Division of Wildlife 711 Independent Grand Junction, Colorado 970-245-9319	Information about captures of native and nonnative fish in canals.
Jim Yuricek Owner Ironwood Special Ties PO Box 185 Noxon, Montana 59853 406-847-2719	Information on fish traps and weirs. Life history and recovery work on Colorado pikeminnow and Razorback sucker. Fish passage issues, project design, and screening needs in canals.

List of Consultants	
Kathy Kruger Biologist Avista 406-847-2729	Information on fish traps and weirs.
Dave Smith President Smith-Root, Incorporated 14014 NE Salmon Creek Avenue Vancouver WA 98686 360-573-0202	Discussed GVIC application and features of the Smith-Root electrical barrier systems. Obtained a budget price of $500,000 maximum for design and installation of an 80-foot electrical barrier located upstream of the GVIC canal headworks. Annual maintenance is estimated as $5,000.

Data and Documents Consulted

Title, Author, and Date	Information
Predesign Memorandum Grand Valley Irrigation Company Fish Screens Recovery Implementation Program Colorado River, Palisade, Colorado Pacific Northwest Region Design Group 1150 N Curtis Road, Suite 100 Boise ID 83706-1234 January 2000	Baseline project data and summary of known information about the existing diversion facilities. Describes conceptual design options (A through E) that are to be considered for the improvement of fish protection at the site. The report forms the basis for selecting a preferred option to be used in the final design phase of the project.
Detailed Summary of Final Programmatic Biological Opinion for Bureau of Reclamation's Operations and Depletions, Other Depletions, and Funding and Implementation of Recovery Program Actions in the Upper Colorado River above the Gunnison River Issued by U. S. Fish and Wildlife, Denver December 20, 1999	Requirements.
Evaluation of Fish Passage at the Grand Valley Irrigation Company Diversion Dam on the Colorado River near Palisade, Colorado Issued by U. S. Fish and Wildlife Service June 1999 (Final Report)	Fish passage information on endangered fish at the Grand Valley Irrigation Company diversion dam.

Design Team Presentation Attendance List
February 14, 2000 - 10 a. m.

Name/Title/Discipline	Address/Phone Number
Chris Morell Value Study Team Leader	Bureau of Reclamation, Technical Service Center PO Box 25007 (D-8170), Denver CO 80225-0007 Phone: 303-445-3087 FAX: 303-445-6475 E-mail: cmorell@do.usbr.gov
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Dennis Hawkins Civil Engineer	Bureau of Reclamation, Pacific Northwest Region 1150 N Curtis, Suite 100, Boise ID 83705 Phone: 205-378-5211 FAX: 205-378-5171 E-mail: dhawkins@pn.usbr.gov
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Joe Kubitschek Hydraulic Engineer	Bureau of Reclamation, Technical Service Center Water Resources Research Laboratory PO Box 25007 (D-8560), Denver CO 80225-0007 Phone: 303-445-2148 FAX: 303-445-6324 E-mail: jkubitscheck@do.usbr.gov
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Value Study Team Presentation Attendance List
February 18, 2000 - 10 a.m.

Name/Title/Discipline	Address/Phone Number
Chris Morell Value Study Team Leader General Engineer	Bureau of Reclamation, Technical Service Center PO Box 25007 (D-8170), Denver CO 80225-0007 Phone : 303-445-3087 FAX: 303-445-6475 E-mail: cmorell@do.usbr.gov
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Dennis Hawkins Civil Engineer	Bureau of Reclamation, Pacific Northwest Region, PN-3425 1150 N Curtis, Suite 100, Boise ID 83705 Phone : 208-378-5211 FAX: 205-378-5171 E-mail: dhawkins@pn.usbr.gov
Dave Irving Biologist	US Fish and Wildlife Service Management Assistance Office 855 East 100 North (112-13) Roosevelt UT 84066 Phone : 435-722-3321, Ext.11 FAX: 435-722-5016 E-mail: dave_irving@fws.gov
Joe Kubitschek Hydraulic Engineer	Bureau of Reclamation, Technical Service Center Water Resources Research Laboratory PO Box 25007 (D-8560), Denver CO 80225-0007 Phone : 303-445-2148 FAX: 303-445-6324 E-mail: jkubitscheck@do.usbr.gov
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Value Study Team Presentation Attendance List February 18, 2000 - 10 a. m.

Brent Uilenberg Technical Services Division Chief	Bureau of Reclamation, Upper Colorado Region Western Colorado Area Office, Northern District 2764 Compass Drive, Suite 106, Grand Junction CO 81506 Phone: 970-248-0641 FAX: 970-248-0601 E-mail: builenberg@uc.usbr.gov
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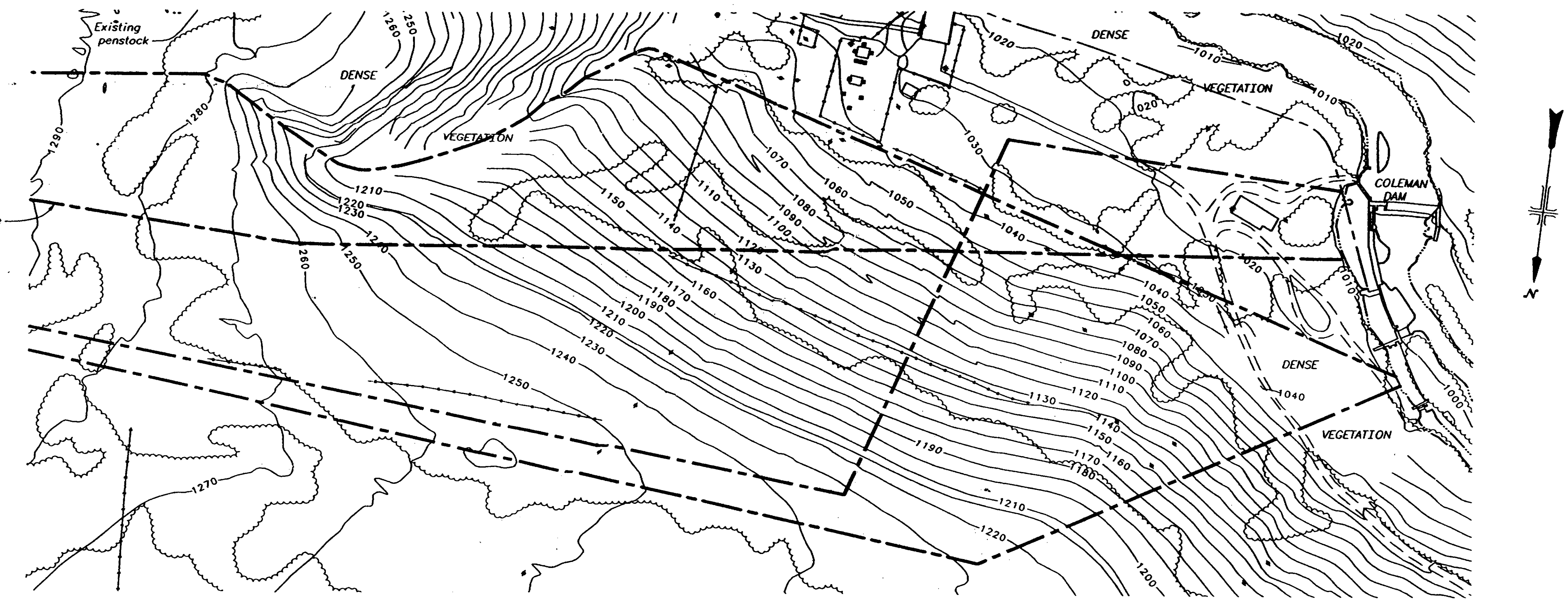
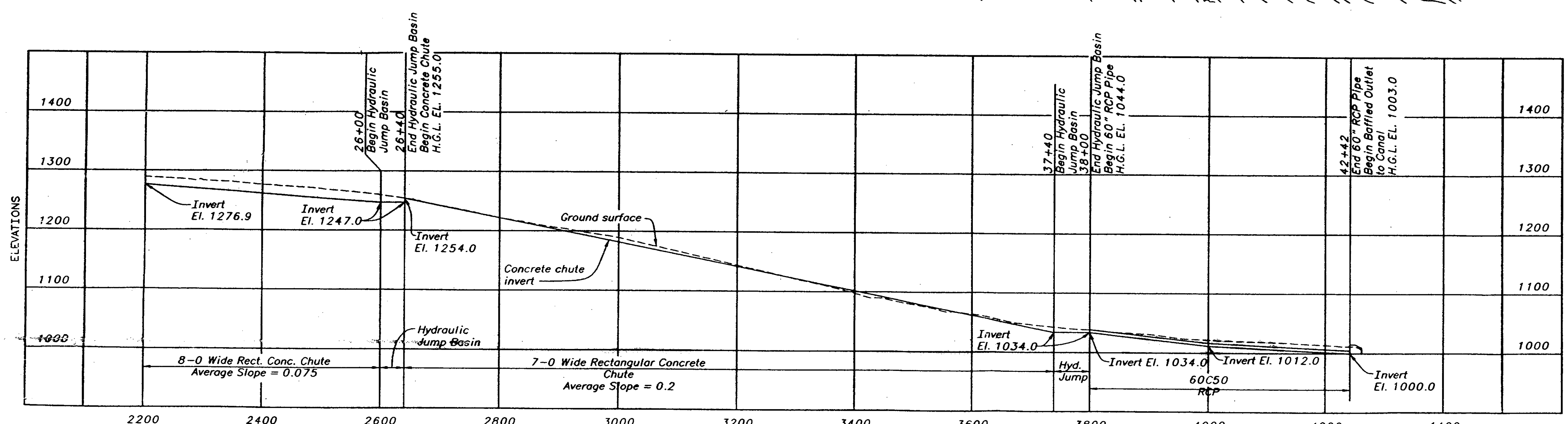
APPENDIX

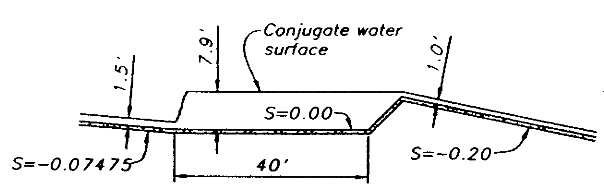
Table of Water Screen Installations and Points of Contact

Screens	Water Users	Contact	Telephone No.
Flat Plate Screens			
Union Gap	Union Gap Irrigation District	Fred Bower	(509) 877-7674
Naches Selah	Naches Selah Irrigation District	Roy Howard	(509) 697-4084
Yakima-Tieton	Yakima-Tieton Irrigation District	Richard Diecker	(509) 678-4101
Fruitvale	Yakima City Irrigation District	Terry Wakefield	(509) 575-6194
Ellensburg Mill	Ellensburg Mill Ditch Company	Gentry Scott	(509) 925-9365
Younger	Younger Irrigation District	Bernard Henshaw	(509) 674-5138
Old Union	City of Yakima - Old Union Ditch Company	Glen Brower	(509) 452-8329
Oak Street	Talent Irrigation District	Hollie Cannon	(541) 535-1529
Phoenix	Medford Irrigation District	Carol Bradford	(541) 779-1462
Rotary Drum Screens			
John Cox	Ahtanum Irrigation District	Forest Marshall	(509) 249-0226
WIP Upper	Wapato Irrigation Project	Pierce Harrison	(509) 877-3155
Other Contacts			
Bureau of Reclamation	Phase II Fish Operations	John Dyson	(509) 575-5848 ext. 255
Washington Department of Fish and Wildlife	Yakima Screen Shop	Pat Schille	(509) 575-2735
Washington Department of Fish and Wildlife		John Easterbrooks	(509) 575-2740

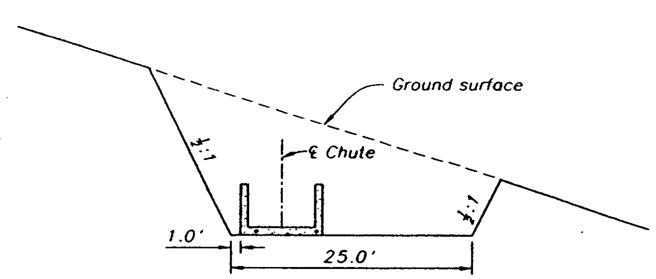




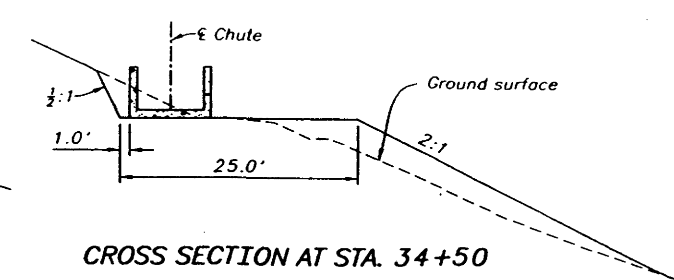
PROFILE



HYDRAULIC JUMP BASIN PROFILE
STA. 26+00 to STA. 26+40
(Jump Basin at Sta. 37+40 will have end wall with a pipe connection)



CROSS SECTION AT STA. 30+00



CROSS SECTION AT STA. 34+50

APPROXIMATE
HYDRAULIC PROPERTIES

SECTIONS	Q	W	n	s	d_n	V	$d_{conj.}$
22+00 – 26+00	300	8.0	.014	.075	1.3	29	7.9
22+00 – 26+00	300	8.0	.010	.075	1.1	36	7.9
26+40 – 37+40	300	7.0	.014	.20	1.0	41	13.5
26+40 – 37+40	300	7.0	.010	.20	0.8	51	13.5

Where: Q = Flow in cfs, W = Width in ft, n = Manning's n, s = Invert slope, d_n = normal depth in feet, V= Velocity in fps, $d_{conj.}$ = jump's conjugate depth in feet

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

BATTLE CREEK SALMON AND STEELHEAD RESTORATION PROJECT – CALIF.

INSKIP POWERHOUSE SITE
WATER CONVEYANCE SYSTEM
ALTERNATIVE # 6

DESIGNED ____ CHECKED ____
DRAWN ____ TECH. APPR. ____
APPROVED ____
PEER REVIEWER

CADD SYSTEM AutoCAD Rel. 15.0b | CADD FILENAME INSKIP2.DWG | DATE AND TIME PLOTTED APRIL 7, 2000 07:18
DENVER, COLORADO | MARCH 31, 2000
SHEET 2 OF 2

Figure V-38

PROPOSAL NUMBER 1

Fish Issues
Applicable to Proposal No. 1
Monitoring Fish Movement into the Grand Valley Irrigation Company Canal

Colorado pikeminnow and Razorback sucker, once abundant in the Colorado River Basin, have been listed as endangered species by the Endangered Species Act. Their numbers have been significantly reduced as a result of water development, loss of habitat and predation by and competition with introduced nonnative fishes.

Dams and diversion structures, built over the past century, that provide water for electricity, irrigation, and municipal purposes, have blocked fish from accessing important habitat and spawning areas above these structures and funneled fish into canal systems (Burdick 1999). Some fish survive as they move through the canal system and eventually return to the river downstream. Other fish perish as they encounter pumps, drains or dewatered areas. There is concern that the canals present a potential risk to the endangered fish. Although there is evidence that endangered fish access these canals, data is limited and not conclusive. For example, Razorback suckers are currently found in Highline Reservoir and must have accessed it through the canal system (Chuck McAda, U.S. Fish and Wildlife Service, personal communication). Numerous native (Flannelmouth and Bluehead suckers, Roundtail chub) and nonnative fishes have been captured in these canals (Anita Martinez, Colorado Division of Wildlife, personal communication).

The Recovery and Implementation Program for Endangered Fishes in the upper Colorado River Basin (U.S. Fish and Wildlife Service) is concerned about problem and proposes that fish screens be used to keep Colorado pikeminnows and Razorback suckers from entering the canals. The Program is also anticipating that more fish may get into the canals as recovery efforts continue. For example, large numbers of juvenile Razorback suckers have and will be stocked in the river from hatchery grow-out ponds. Fish passage structures at diversion dams will also allow Colorado pikeminnow and Razorback suckers to access historic habitat and spawning areas above the dams.

The first screening structure is planned to be constructed in or just upstream of the Grand Valley Irrigation Company Canal. The GVIC wants to work cooperatively with the U.S. Fish and Wildlife Service to protect Colorado pikeminnow and Razorback sucker, but they also must continue to maintain the water supply to their water users. Although the argument can be made that endangered fish could enter their canal, they believe there is not enough evidence to date to justify or support the costly construction of the fish screen in their canal. They propose that additional studies be conducted to collect this information.

There are several ways to determine whether endangered fish are moving into the GVIC canal.

1. Is there a problem with fish moving out of the river into the canal? (It is assumed that since some native fish have been found in the canal that the potential exists for Colorado pikeminnow and Razorback suckers to get into the canal.)
2. Do we have data to support the need for the project? (Razorback suckers in Highline Reservoir, Roundtail chub in the canal, no endangered fishes to date found in GVIC Canal).
3. Monitor fish movement into the canal to determine fish loses.
4. Construct a weir in the canal to trap fish, collect information (e.g., length, weight, species, etc.), and determine if there are loses of fish into the canal. Also find out what type of fish numbers and kinds are in the river just upstream, at, and below the canal intake.

5. Fish data will then help to verify scope of the problem, i.e., determine whether to build fish screen, use weir and truck method, or use hatchery/fish ponds to mitigate for loses.

Questions:

Weir design?
Weir placement?
Will a weir in the canal actually work?
Sample time, how often should weir be checked?
Are flows in canal too high for a weir to work?
Would just netting, electrofishing or some other sample in the canal work just as well?
Will one just one sample period (year, summer, month, etc.) really provide conclusive data?
Will the expense of building a weir large enough to work be too expensive?
Who is responsible to keep weir clean and working properly?
What is the contigency plan if the weir does not catch fish, is it the weir or simply no fish in the canal?

Potential Risks

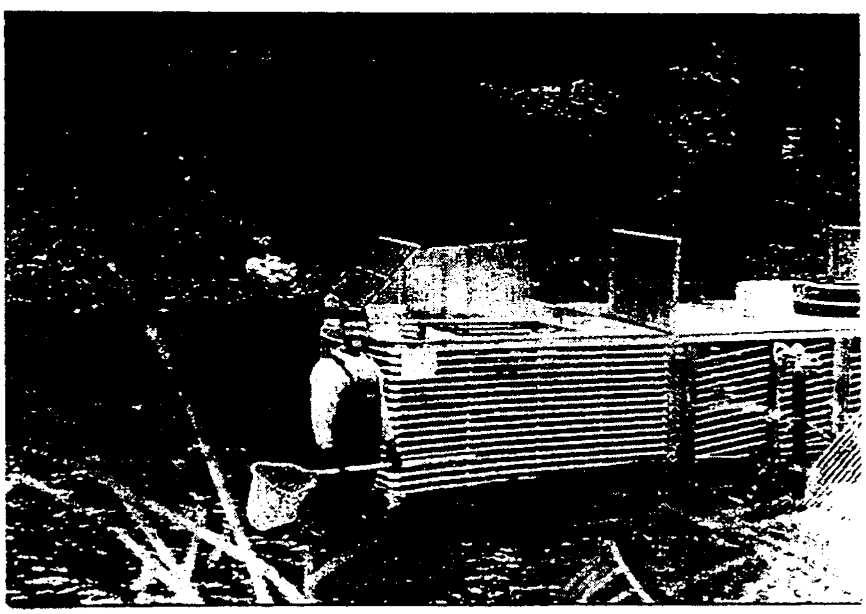
No fish in the weir, what does this mean?
Mortality to fish in the weir from impingement on weir bars.
Mortality to smaller fish from big fish predation.
May not be able to fish weir all the time due to low or high flows or trash problems, what data do you miss during this time?
May kill endangered fish in weir.

MONTANA FISH TRAPS

BUILT TO ORDER BY

IRONWOOD SPECIALTIES

CONSTRUCTION AND PERFORMANCE OF A RESISTANCE BOARD WEIR FOR COUNTING MIGRATING FISH IN RIVERS



Resistance board weirs are a relatively new alternative to other weirs and are capable of consistently producing reliable information in streams that experience debris laden high water periods. Although not impervious to washout, this type of weir is more resilient than a rigid weir. A resistance board weir will temporarily submerge when pressure created by water velocity and debris loading reaches a point that might wash a rigid weir downstream. Resistance board weirs continue to gain popularity as a management and research tool, but relevant design and installation information has been virtually unavailable until now.

This web site will familiarize the visitor with designs that can be created for a specific location.

Sincerely,

Jim Yuricek, Owner
IRONWOOD SPECIALTIES
Box 185
Noxon, Montana 59853
(406) 847-2719
Email: nox5546@montana.com

CONCEPT and PERFORMANCE

The weir consists of a connected array of 4' x 10' panels with PVC pickets. The upstream end of each panel is hinged to a steel rail that is anchored to the stream bottom. The down stream end of each panel is lifted above the water surface by a 2' x4' resistance board that planes upward in flowing water. The angle can be adjusted and is variable with fluctuating water levels and debris loading. Portions of the weir will sink beneath the water surface if loading on the panels overpowers lift created by the resistance boards.

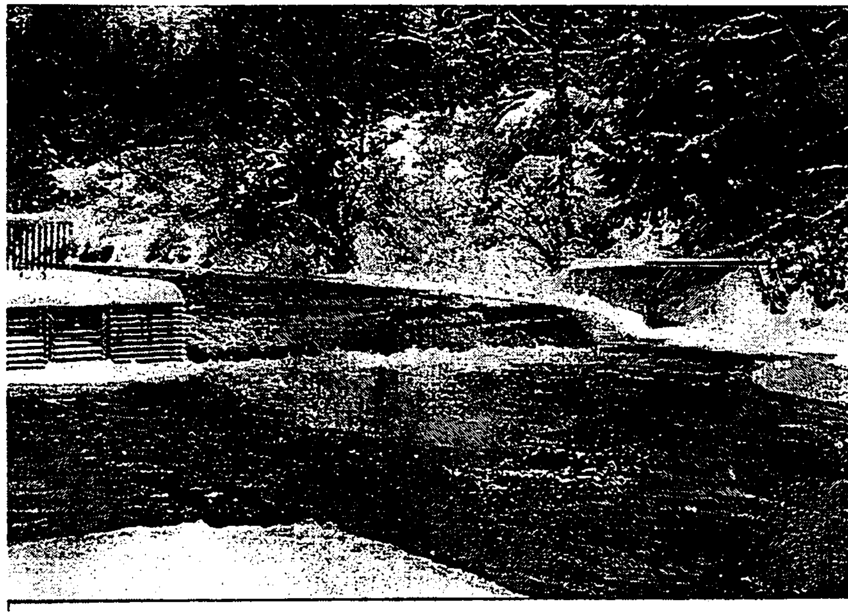
This particular design incorporates a dual trap system that catches fish in both directions of travel. It has welded aluminum chutes and wood framed trap boxes. This unit was installed in Bull River about 3 miles from its mouth near Noxon, Montana in the fall of 1997. The weirs were virtually self cleaning during debris laden high water events and withstood debris loads of trees, sod, and ice floes.

Avista (formerly Washington Water power) sponsored this project and worked closely with the Montana Department of Fish, Wildlife, and Parks.

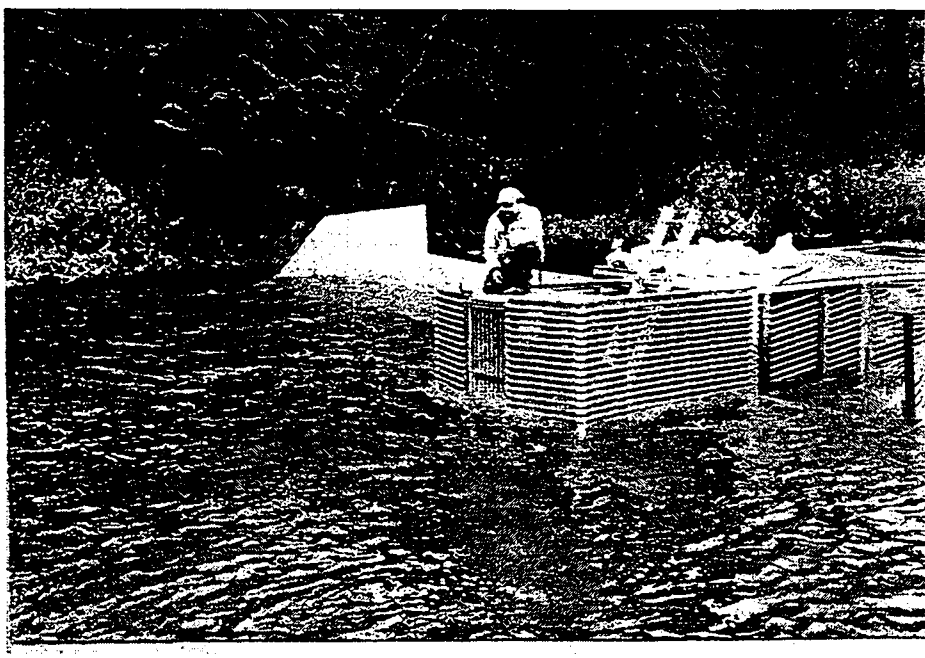
Ironwood Specialties fabricated and installed the unit.

The photo at right shows weir panels submerged from snow and ice pressure.

(Note: the resistance boards which create the lift were reduced in size to accommodate canoes and rafters.)



The photo below shows ***IRONWOOD SPECIALTIES owner, Jim Yuricek,*** inspecting the Bull River trap.



REFERENCES

Avista:

Contact: Tim Swant, Natural Resource Program Manager and Fish Biologist

Phone: 406 847-2729

Email: nox2265@montana.com

Montana Department of Fish, Wildlife, and Parks

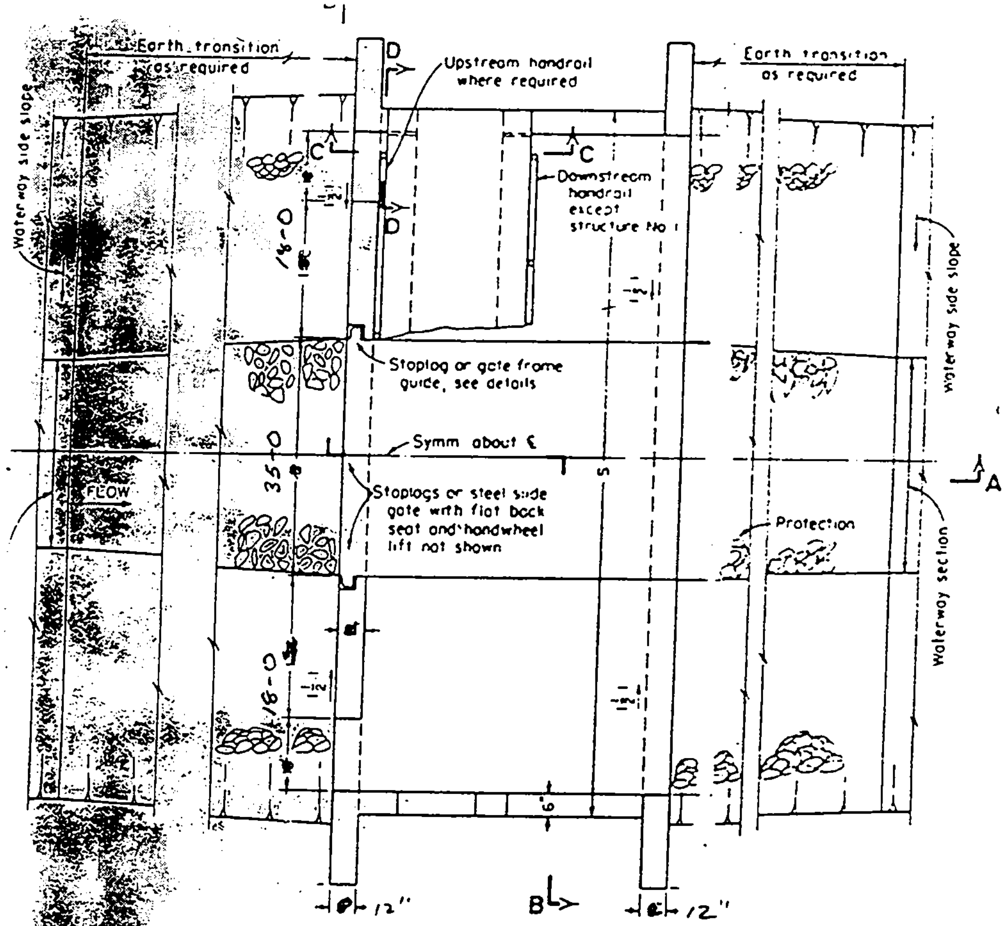
Contact: Pat Saffel, Fish Biologist

Phone: 406 827-9320

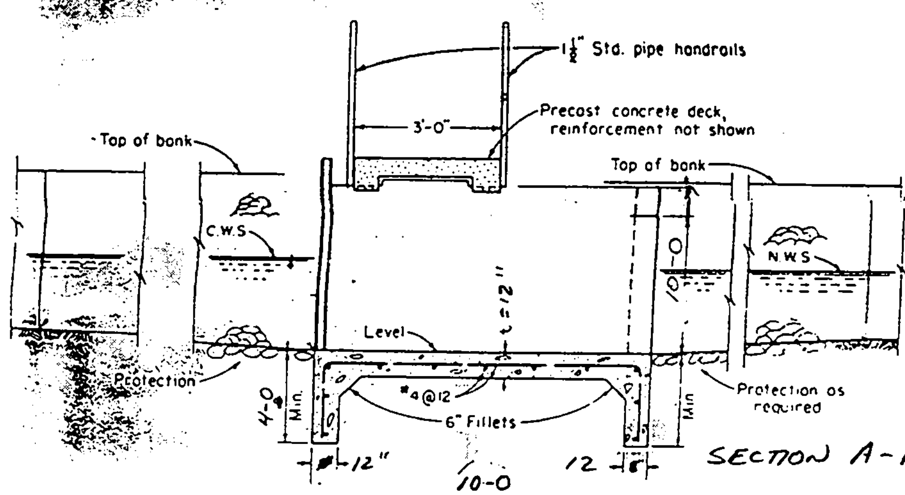
Email: tfl9338@montana.com

DISCLAIMER: This product has not been officially endorsed by the State of Montana Department of Fish, Wildlife, and Parks.

PROPOSAL NUMBER 5

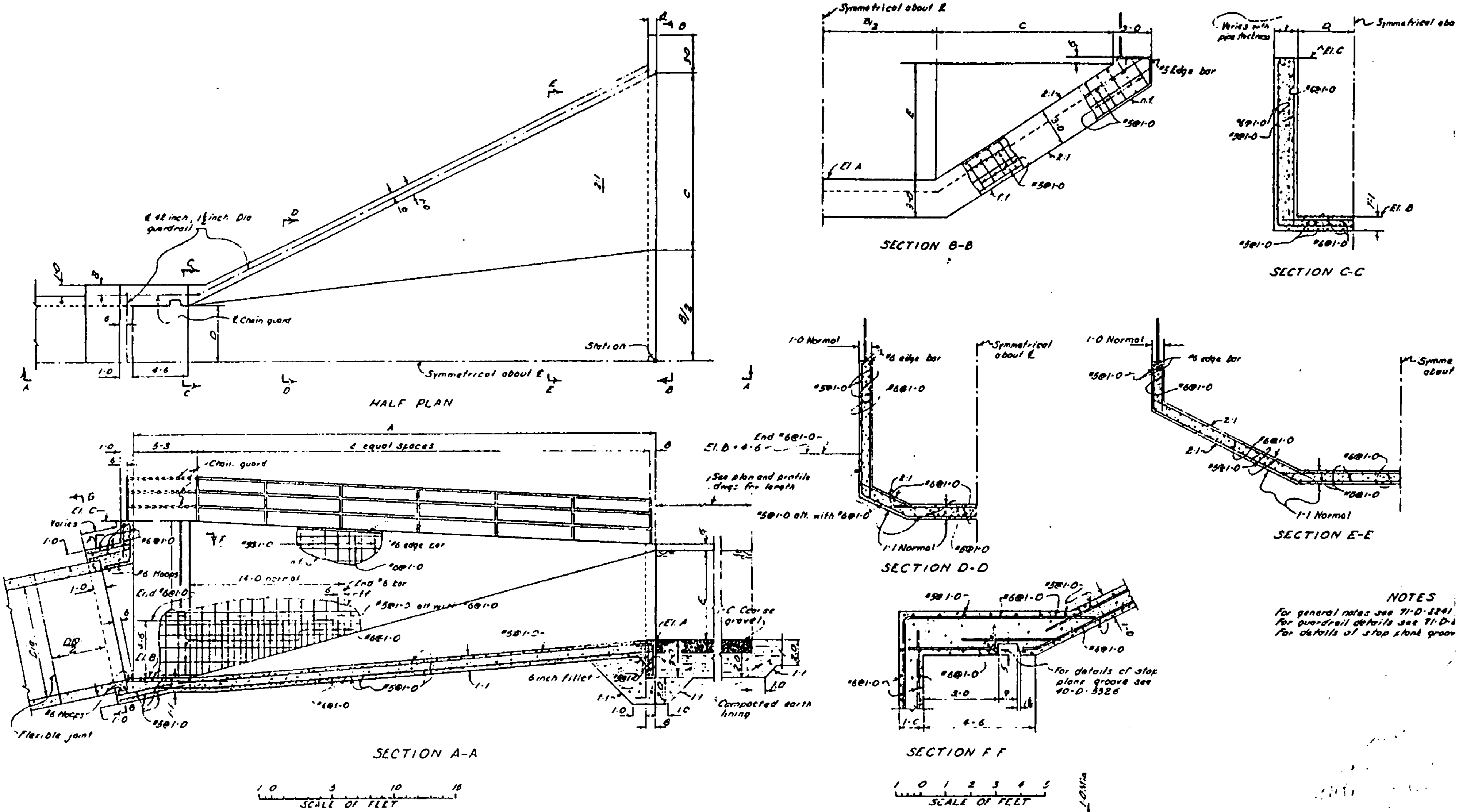


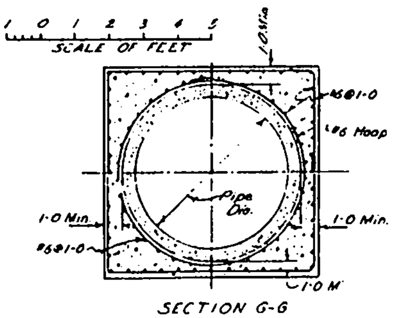
P L A N



SECTION A-A

PROPOSAL NUMBER 7





120"

TABLE OF DIMENSIONS

	Station	El A	El B	El C	Pipe Dia	A	B	C	D	E	
OUTLET →	82+68.50	6940.94	6939.20	6950.69	108 inch	42-6	18-0	14-9	4-6	7-1½	80yd³
	145+77.62	6897.95	6896.23	6847.72	108 inch	42-6	18-0	14-9	4-6	7-1½	
	181+01.70	6896.22	6893.55	6346.04	108 inch	42-6	18-0	14-9	4-6	7-1½	
	276+56.75	6326.77	6324.49	6336.28	75 inch	41-9	16-0	13-8½	3-8	6-10¼	
INLETS →	469+88.42	6248.85	6247.58	6258.15	[illegible]	39-0	16-0	13-4½	3-6	6-8¼	65yd³

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT GVIC VE STUDY	SHEET ___ OF ___
CHKD BY	DATE	FEATURE	
DETAILS SIPHON UNDER RIVER			

ASSUMPTIONS:

OMID POWERPLANT Q_{MAX} = 800 cfs
Q_{TYP} = 310 cfs

OMID HYDRAULIC TURBINE Q_{OUT} = 272 cfs

Q_{TYP} RETURN FLOW = 310 + 272 = 582 cfs

DESIGN SIPHON FOR Q = 580 cfs +/-

INLET(S) TO SIPHON WILL CONSTRUCTED AT DISCHARGE OUTLET OF EACH STRUCTURE.

WE WILL NOT TIE INTO BYPASS STRUCTURES IF THE EXIST DUE TO FLOW RATES AND HEAD. FLOW INTO SIPHON WILL BE GRAVITY AND CONTROLLED BY GATES.

OMID USES A CHECK STRUCTURE TO FORCE WATER ABOVE GVIC DIVERSION DAM AT TIMES WHEN NECESSARY. BASED ON THIS WE ASSUME THE OMID CAN LIVE W/ A RAISED TAILWATER SURFACE AND SLIGHT DECREASE IN HEAD.

UPPER ELEVATION OF GVIC DIVERSION DAM ABOVE NOTCH IS ASSUMED TO BE THE WS ELEVATION OF OMID TAILWATER.

FROM DWG NO. GVIC DIVERSION DAM EL 4682.5

WS IN CANAL @ WEIR - 10/15/99 4679.4
SEE ATTACHED SURVEY NOTES

Δh = 3.1 FT

ASSUME 2.5' LOSS AVAILABLE

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ___ OF ___
CHKD BY	DATE	FEATURE	
DETAILS			

$Q = 580$ cfs

$L = \sim 1000$ FT – SCALED FROM FIG IN PRELIM. DESIGN MEMO

$\Delta h = 2.5'$

ASSUME INLET LOSSES $= 0.4 \Delta h_v$ [1]
OUTLET LOSSES $= 0.7 \Delta h_v$ [1]

[1] DESIGN OF SMALL CANALS

TABLE 8-1

$\phi = 120''$, $Q = 580$ cfs

$V = 7.38$ ft/sec
$h_{vp} = 0.85$ ft
$H = 1.22$ ft /1000'

CALCULATE MAJOR LOSSES

INLET (2) – POWER + PUMPING

ASSUME $h_{v_1} = 0'$ $\Rightarrow h_i = \Delta h_v \times 2 = 2 \times 0.4 \times h_{vp}$
$= 2 \times 0.4 \times 0.85'$
$h_i = 0.68'$ ←

* NOTE: PIPE SIZES FROM OUTLETS OF EACH STRUCTURE COULD BE REDUCED TO CARRY RESPECTIVE Qs (310 cfs + 272 cfs) IN NEXT LEVEL OF DESIGN

FRICTION LOSS

$$h_f = H \cdot \frac{L}{1000'} = 1.22' \left(\frac{1{,}000}{1000'}\right) = 1.22'$$

EXIT LOSS: V_{CANAL} – PHIL & DENNIS ≈ 2 FT/SEC

$$h_{vc} = \frac{(2\,fps)^2}{(2)(32.2)} = 0.06'$$

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE	
DETAILS			

EXIT LOSS (CONT) :

$h_e = (h_{vp} - h_{vc})\,0.7'$

$= (0.85 - 0.06)(0.7)$

$= 0.55'$

$\Sigma h_L = h_i + h_f + h_e$

$= 0.68' + 1.22' + 0.55'$

$= 2.45'$ ← Neglected bend losses but less than 3.10' ASSUMED AVAILABLE

- ASSUME RCP w/ R-4 JOINTS
  - HEAD CLASS (MINIMAL) ASSUME 50
  - COVER ASSUME (15') C

  120 C 50 FOR THIS LEVEL

  1000 LF

GJ PIPE COST QUOTE – MIKE McCABE

BASED ON EST. WEIGHT OF 4300 #/FT ASTM C76

MAT – $550/FT – NOT INSTALLED XX

DENVER SERVICE CENTER – CRAIG GRUSH

TOWAOC CANAL 108 D 50 – FURNISH + INSTALL
– SEE ATTACHED SCH. I;

ENG EST $675/FT $\left(\frac{224}{167}\right)$ – INDEX $\frac{10/99}{6/90}$ 66

= $905/FT GOOD ENOUGH FOR EST.

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE	
DETAILS			

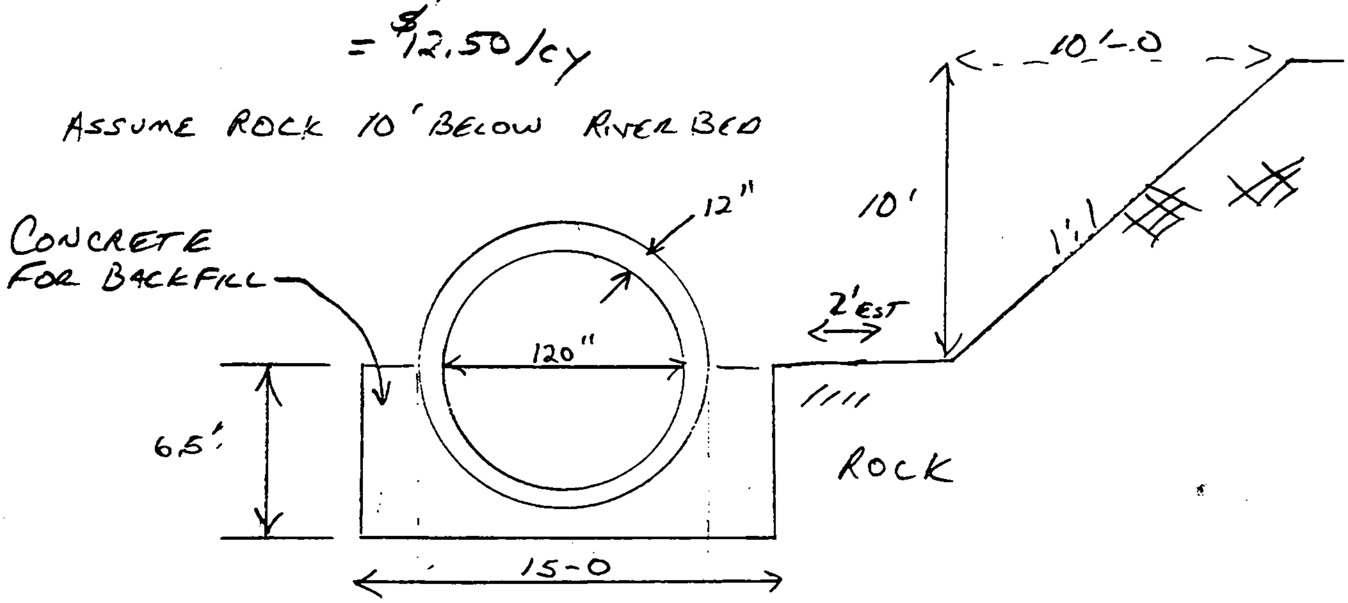
ROCK EXCAVATION — CRAIG GRUSH
PN REGION SI-10-06490
8,000 CY

ENG EST	$10.00/CY
LOW	$5.75/CY
HIGH	$14.00/CY
AVG	$14.50/CY

USE ENG. EST $\frac{\$10}{CY}\left(\frac{224}{180}\right)$ $\frac{10/99}{2/94}$ — INDEX

$= \$12.50/CY$

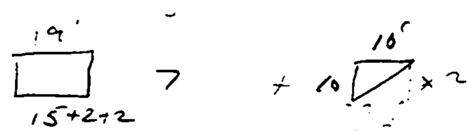
ASSUME ROCK 10' BELOW RIVER BED



ROUGH EXC. IN ROCK

$$V_{ROCK} = \frac{1000' \times 6.5' \times 15'}{27\ FT^3/CY} = 3600\ CY$$

COMMON EXCAVATION



$$V_{exc} = \left[\frac{(19' \times 10') + (10 \times 10')}{27\ FT^3/CY}\right] 1000' = 10{,}750\ CY$$

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE	
DETAILS			

$V_{CONCRETE} = V_{ROCK} - \frac{1}{2} V_{PIPE}$

WHERE $V_P = \frac{\pi D_o^2}{4} \times L = \frac{(\pi)(12')^2}{4} \times \frac{1000'}{27 FT^3/CY} = 4{,}200 CY$

$V_{CONCRETE} = 3600 cy - \left(\frac{4200}{2}\right) = 1500 CY$

$V_{backfill} = V_{EXC} - \frac{1}{2} V_{PIPE}$

$= 10750 cy - \left(\frac{4200}{2}\right) = 8650 cy$ NOT COMPACTED!

INLET STRUCTURES - SEE 71-D-2280

FOR THIS LEVEL OF DESIGN ASSUME STRUCTURES SIMILAR TO ~~THAT~~ FOR STA 469+88.42

PIPE DIA. MAY BE SMALLER BECAUSE DISCHARGE FROM PUMPING PLANT AND POWER PLANT ARE 310 cfs AND 270 cfs. * THE LENGTH MIGHT BE SHORTE

QUANTITIES OF CONCRETE CALCULATED BY RUDY CAMPL

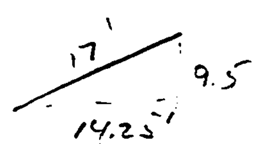
$V_{CONC} = 65 cy$ each $= 130 cy$ TOT

V_{EXC} BY FOOT PRINT * 2' DEEP (CHANNEL EXISTS ALREAD

INVERT; $\left[\frac{18' + \sim 8'}{2}\right] \frac{39' * 2'}{27 FT^3/CY} = 38 CY$

SIDESCOPES (* 2)

$2 * \frac{1}{2} * 17' * 39' * 2' \div 27 = 50 CY$



$V_{TOT} = 88 CY$ SAY 100 CY OR 200 CY TOTAL

7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ___ OF ___
CHKD BY	DATE	FEATURE	
DETAILS			

VCOMPACTED BACKFILL = ASSUME = VOL EXCAVATION = 100 cy ea
= 200 cy TOT

- WE DO NOT KNOW THE CONTOURS ABOUT PROPOSED SITE. THIS IS A LOW QUANTITY WHEN COMPARED TO ENTIRE JOB

OUTLET STRUCTURE (ONE) SEE 71-D-2280 STA 82+68.50

VCONC = 80 cy RUDY CAMPBELL

VEXC - BASED ON RATIO OF CONCRETE OF INLET AND COMPUTED QUANTITIES

— RATIO OF CONCRETE

$= 100\,cy\left(\frac{80}{65}\right)$

$= 125\,cy$

VCOMPACTED = 125 cy SAME AS ABOVE

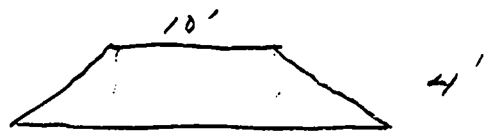
7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE	
DETAILS			

COFFER DAM

ASSUME 4' HIGH, 1/2 LENGTH ≈ 500' LONG
10' WIDE, 1:1 SLOPES



$V = \frac{(14)(4)(500')}{27} = 1037c$

SAY 1200CY

WHITEWATER BUILDING MAT. (ARLINE)
$4.80/CY, ±10CY MAX/TRIP, $50/TRIP

TRIPS = 1200CY / 10CY/TRIP = 120 TRIPS

DELIVERY = $50/TRIP * 1.35 OH+P = $68/TRIP

$68/TRIP * 120 TRIP = $8,160 Delivery ←

MATERIAL = $4.80/CY * 1.35 (OH+P) * 1200CY = $7800 ←

TOTAL COFFER DAM ≈ $20,000

DEWATERING – PER MARK WERNKE
PAST JOBS SAY $125,000

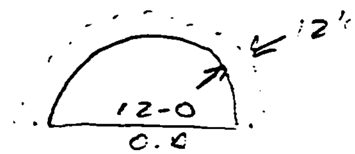
7-1654 (11-94)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE	
DETAILS			

SELECT BACKFILL FOR PIPE (1 FT)

TOP OF PIPE ONLY



$$\frac{\pi D}{2} = \frac{\pi (13)'}{2} = 21'$$

$$V_{select} = 21' * 1' * \frac{1000'}{27 \frac{FT}{CY}} \approx 780\,CY \text{ SAY } 800\,CY$$

GVIC CANAL DIVERSION
10/15/99 ELEV. WATER Surface CK'S

Rebar # 2000			4687.99
	+ 1.10		
	T.H.I. 4689.09		
WEST Hoist Deck Div. Sidewalk	−1.28		4687.81
EAST Hoist Deck Div. Sidewalk	−1.24		4687.85
EAST Most Stop Log (Top)	−8.19		4680.90
Radial Gate (EAST)	−8.12		4680.97
Radial Gate (WEST)	−8.13		4680.96
Floor Elev. @ WEST Radial Gate	−12.48		4676.61
Stilling Basin (WATER Surface)	−7.83		4681.26
U/S Side Trash Rack (WATER Surface)	−7.72		4681.37
Top Conc. Diversion (END of Hoist Deck)	−7.94		4681.15
		−1.10	(4687.99)
			4687.99
+ 1.34			
T.H.I. 4689.33			
Rt. Side (CANAL D/S Check) WATER Surface	−9.66		4679.67
WATER Surface ℄ CANAL @ Weir	−9.95		4679.38 ←
WATER Surface @ Gauge 3' U/S	−9.94		4679.39

Gauge Reading @ W/S on 10/15/99 10:15 AM 3.98

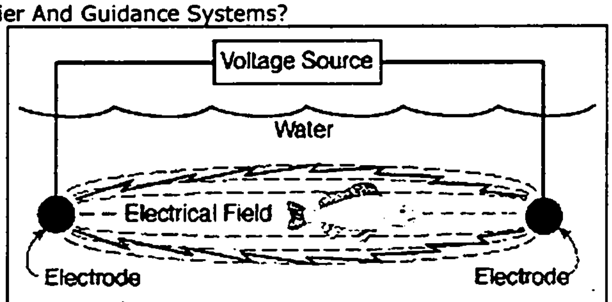
* 4.00 on Gauge = ± 4679.40 @ WATER Surface

Rebar # 2000		−1.35	4687.98

PROPOSAL NUMBER 8

Introduction to Fish Barriers

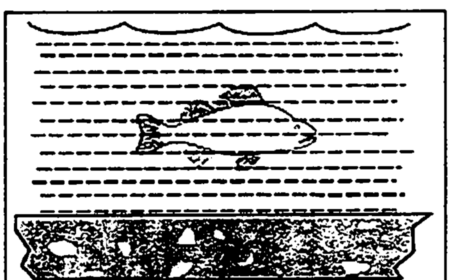
What Are Electric Fish Barrier And Guidance Systems?
The electrical fish barrier can be thought of as an impassible barricade, and the fish guidance system as a repelling zone. Both consist of electrical current passing through water. The electrical circuit is made up of two or more metal electrodes submersed in water with a voltage applied between them. Electric current passing between the electrodes, via the water medium, produces an electric field. When fish are within the field, they become part of the electrical circuit with some of the current flowing through their body. The electric current passing through fish can evoke reactions ranging from a slight twitch to full paralysis, depending on the current level and shock duration they receive.



Basic electric field in water.

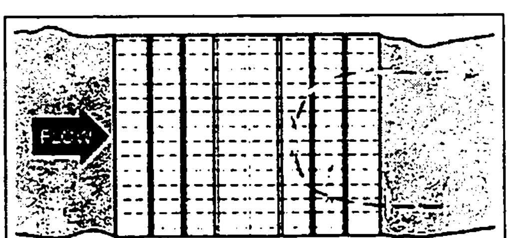
Types Of Current
In the past, both Alternating Currents (AC) and Direct Current (DC) have been used to energize fish barrier and guidance systems; however, AC is known to be much more stressful to fish. Therefore, Smith-Root electrical fish barrier and guidance systems employ DC pulses of very short duration.

Electric Field Pattern
To produce the most efficient electric field pattern for blocking or guiding fish, it is desirable to produce a field with electric lines running head-to-tail along the fish. This orientation transfers the maximum power from water into the fish. In flowing water of 1.5 to 2 fish body lengths per second or greater, fish instinctively swim with their heads into the flow. Therefore, the most effective field pattern is one with the electric field lines running parallel to water flow. In sites with flowing water, Smith-Root electric fish barrier and guidance systems produce electric field lines which run parallel to water flow.



Electric field lines which run head-to-tail along the fish transfer the maximum power from water to fish.

One of the most important advantages of the parallel field orientation is that when a fish is crosswise to the electric field it receives almost no electric shock. Fish learn very quickly that by turning side ways to the flow they can minimize the effects of the electric field. In this orientation, upstream migrating fish are swept clear of the field by water flow. The figure below shows the typical reaction of migrating fish challenging an oriented electric field. In slow or static water a high percentage of fish also learn to turn in relation to the field and swim away from the electric field.



Typical fish path within a graduated field.

This information is also available for download. Adobe Acrobat 3.0 or higher is required to view the catalog.

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Safety

The danger of receiving electric shock is increased when working around water. To receive an electrical shock, a person must be part of a closed circuit in which current can flow through them. Just how badly a person is affected by electric shock depends on the following:

1. The path the current takes through the body. The chest and head are the most vulnerable areas. All personnel should wear rubber lineman?s gloves and a safety helmet.

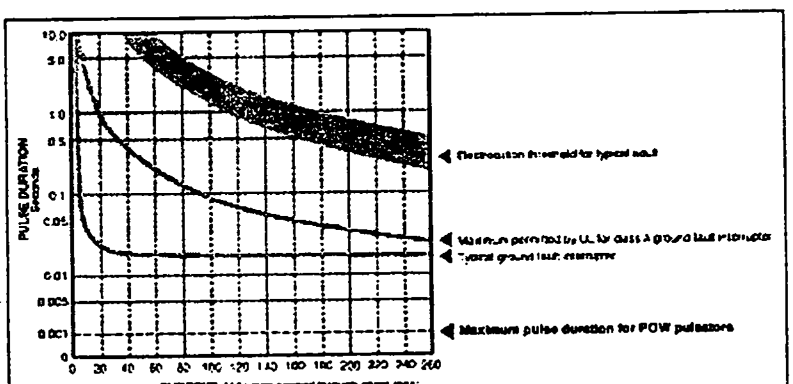
2. The time spent in the circuit. The sooner the circuit is interrupted the better.

3. The person's age, size, and health. The greatest danger is to a person with a prior heart ailment.

4. The amount of current that flows through the body. When the body is submerged in water this becomes a complex situation involving many variables and very little data is available.

5. The type of current, AC or DC. Humans are three times more likely to be electrocuted by AC current than by DC. For this reason Smith-Root barrier and guidance systems only use DC current.

6. Whether the current flow is continuous or pulsed. UL Laboratories found that short pulses are much less likely to be lethal, see figure below. Smith-Root barrier and guidance systems use a pulse of much shorter duration than that of a typical Ground Fault Interrupter Circuit.



Effects of an electrical pulse on humans passed through the chest. Adapted from the Handbook of Electronic Safety Prodecures 1982.

Product Information

- Introduction
- Graduated Fields
- Upstream Barriers
- Downstream Barriers
- Safety
- Barrier Monitoring
- Pulsators
- Cast Culvert Barrier
- Plastic Culvert Barrier
- Portable Array Barrier
- Equipment Building
- Tailrace Barrier
- Canal Barrier
- Intake Barrier
- Louvered Intake Barrier
- Strobe Light Guidance
- Sonic Barrier

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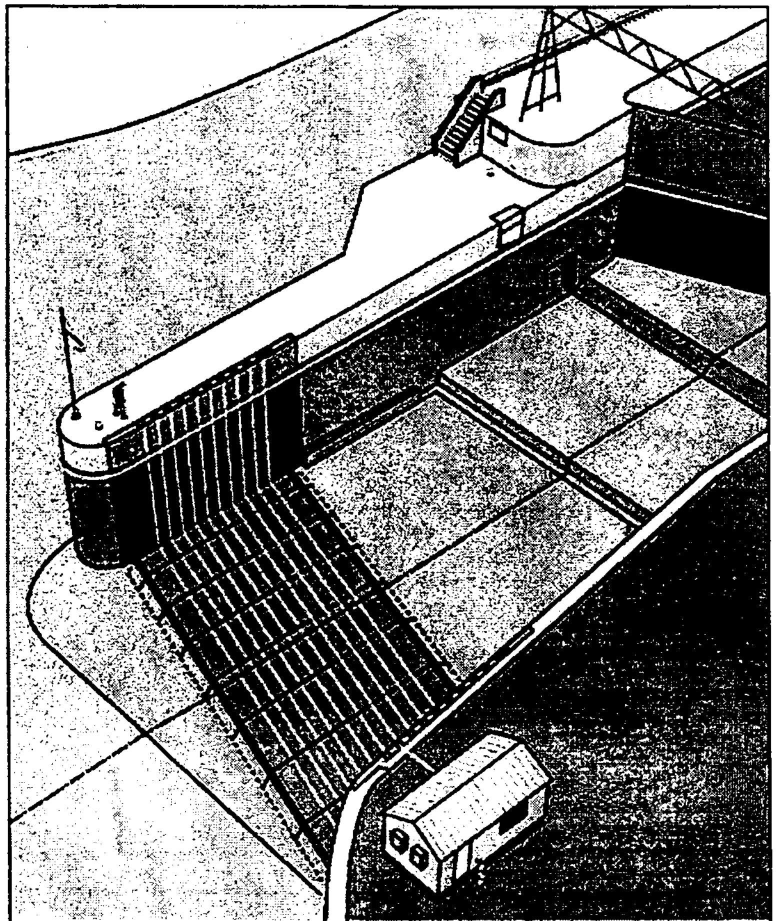
Products For Fisheries Conservation

Canal Barrier

This canal connects a river to a lake. Sea lampreys and alewives entering the lake would have substantial ecological impact, threatening the native species. But no more fish will swim through the canal with this barrier installed. This electrode array is large: over 50 feet across, with a water depth of up to 15 feet. It is powered by nine pulsators housed in the equipment building in front of it. The IEB building also contains monitoring equipment and an automatic back-up generator.


Canal barrier.

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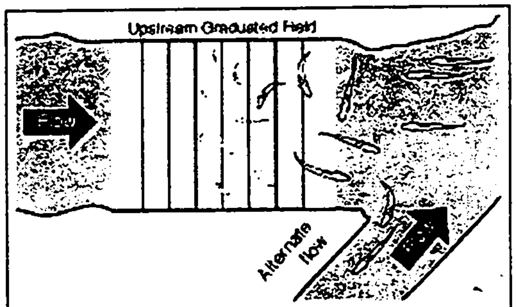
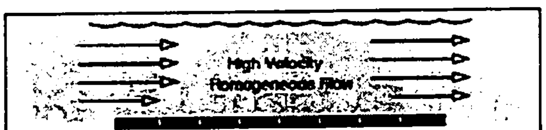
Upstream Barrier System

Upstream Barriers
Smith-Root Upstream Fish Barrier systems are designed to totally block the passage of all upstream migrating fish. The barriers use electric pulses designed to partially paralyze fish without causing physical injury. The pulsators are adjusted to produce an ascending electric field sufficient to gradually reduce the ability of fish to swim against the water flow. It is best to have upstream barriers located in areas of medium to high water velocity in order to sweep stunned fish clear of the electric field. Often an attraction flow is provided just below a barrier to lure fish into hatcheries, traps, fish ladders, etc.



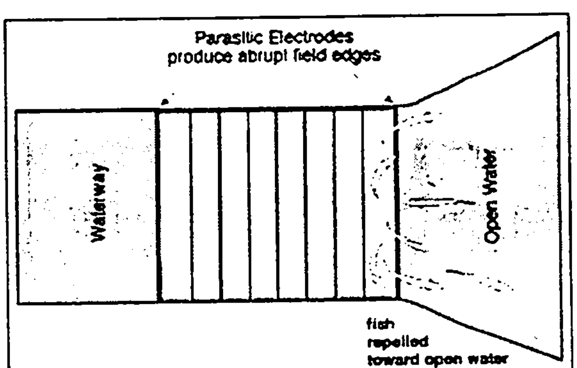
Upstream graduated field barrier with an attraction flow immediately below the barrier.

Upstream Barrier Hydraulics
For optimum design, it is important to maintain a uniform velocity and water depth across the entire water column. To do this, the bottom must be level and the sides should be contained. The bottom should also be smooth so that a velocity is maintained near the bottom. With high velocity and homogeneous flow throughout the barrier, inhibited fish are quickly swept clear of the electrified zone. For upstream migrating adult salmon and steelhead, our upstream electrical fish barriers have proven to work well in velocities ranging from 2 to 10 ft/sec.



For upstream barriers, the electrode array should be level and smooth.

Static Flow Barriers
Smith-Root static flow barrier systems are designed to startle and repel the advancement of migrating fish. The pulsator intensities are adjusted to provide a constant field strength across the array. The outputs are set to produce very narrow pulses with a slow repeating pulse rate. The narrow pulses do not tetanize or reduce fishes' ability to swim. The electrode array arrangement is similar to upstream barriers except parasitic electrodes are placed at each end to produce an abrupt field edge. The abrupt field edge causes fish to be startled toward open water. Tests have shown repelling efficiencies of nearly 100% in static flows when an open body of water is available for fish to return to.



Static flow barrier with open water return.

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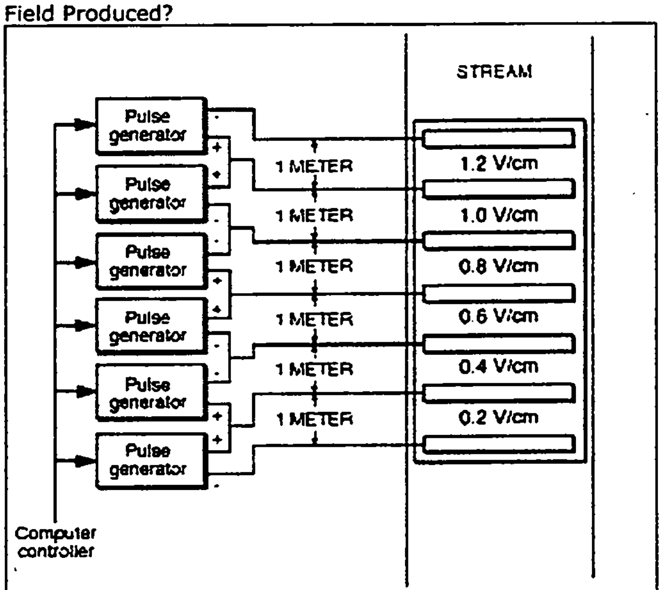
Graduated Fields

One of the most important features of the Smith-Root fish barrier design is the graduated electric field. As fish advance into a graduated field, they feel an increasingly unpleasant sensation. When the sensation is too intense, fish are unable to advance further and cannot keep their body orientated with the water flow. They turn perpendicular to the field, and are either swept clear by water flow or swim in the opposite direction from the increasing electric field.

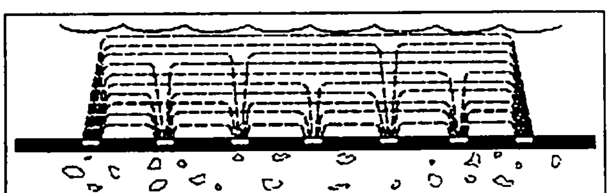
How Is The Graduated Field Produced?

Smith-Root barrier and guidance systems use from two to six pulse generators to provide ascending levels of field intensity. The pulsators (pulse generators) have their outputs connected to an array of evenly spaced electrodes placed across a stream bottom. Each pulsator can be adjusted to provide an increasing voltage between successive electrode pairs. This creates a gradually increasing electric field along the array. The pulsators are simultaneously triggered to cause the electric field lines to become additive and oriented with stream flow. Longer fish receive more head-to-tail voltage and are affected at an earlier stage, while smaller fish can penetrate the barrier further before being overcome or repelled.



Typical graduated electric field.

The figure at right shows a cross section of an electric field generated along a serially connected bottom-mounted electrode array. The oriented electric field causes the pattern to be distributed from the stream bottom to the surface.


An oriented electric field distributes evenly.

Flush-Mounted Electrodes

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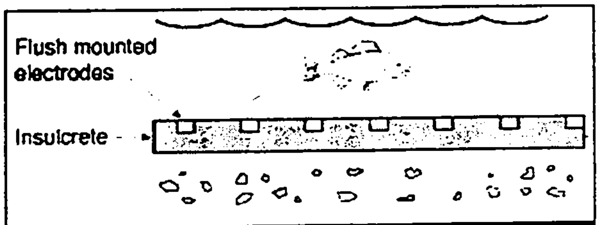

Flush-mounted electrodes do not trap debris.

Flush bottom-mounted electrode arrays do not alter normal water flow or catch debris. The electrodes are fixed into an insulating medium placed on the stream bottom. The insulating medium ensures that the electric current will flow through the water and not through the stream bottom.

For most permanent installations, the insulating medium is a special concrete mix called Insulcrete™. Site-specific designs include cast-in-place decks, pre-cast flat panels, and pre-cast culverts.

Plastic culverts are now also available. These provide the required insulation and allow flush-mounting of circular electrodes.

For site-evaluation we have portable canvas arrays that provide a temporary barrier system. The portable arrays are constructed of reinforced vinyl sheets with stainless steel cable electrodes attached to the top surface.

For More Information
Call 1-360-573-0202

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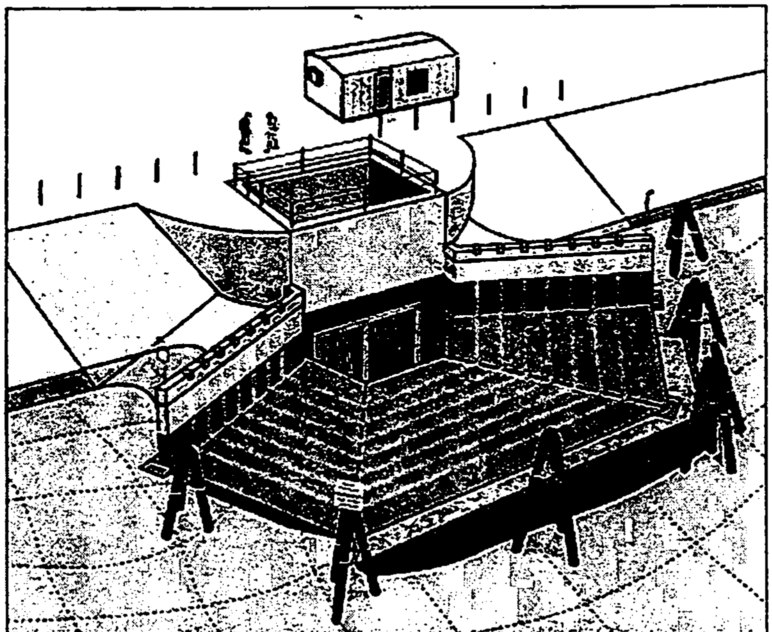
Intake Barrier

This fish barrier is designed to prevent fish being drawn into the cooling intake of a large steel mill. The old mechanical screens had to be cleaned regularly, and each cleaning required a costly plant shut-down. No cleaning is needed with the new Smith-Root electric fish barrier.

This barrier is powered by six pulsators housed in the IEB equipment building behind it. This building also contains FBTCS monitoring equipment.

In the river, pile-clusters are installed to protect the barrier from damage by passing ice-floes or ships.



Pump intake barrier.

Notice:

All Smith-Root, Inc. Electrical Field Fish Barrier systems are protected by patent. Ideas, arrangements, supplied drawings and specifications are the sole property of Smith-Root, Inc. and are intended for this specific project and shall not be used for any other purpose, without the written consent of Smith-Root, Inc. U.S. 4,750,451 Canada 1,304,442

Product Information

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Y2K Statement | Privacy Statement | Feedback

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Call 1-360-573-0202

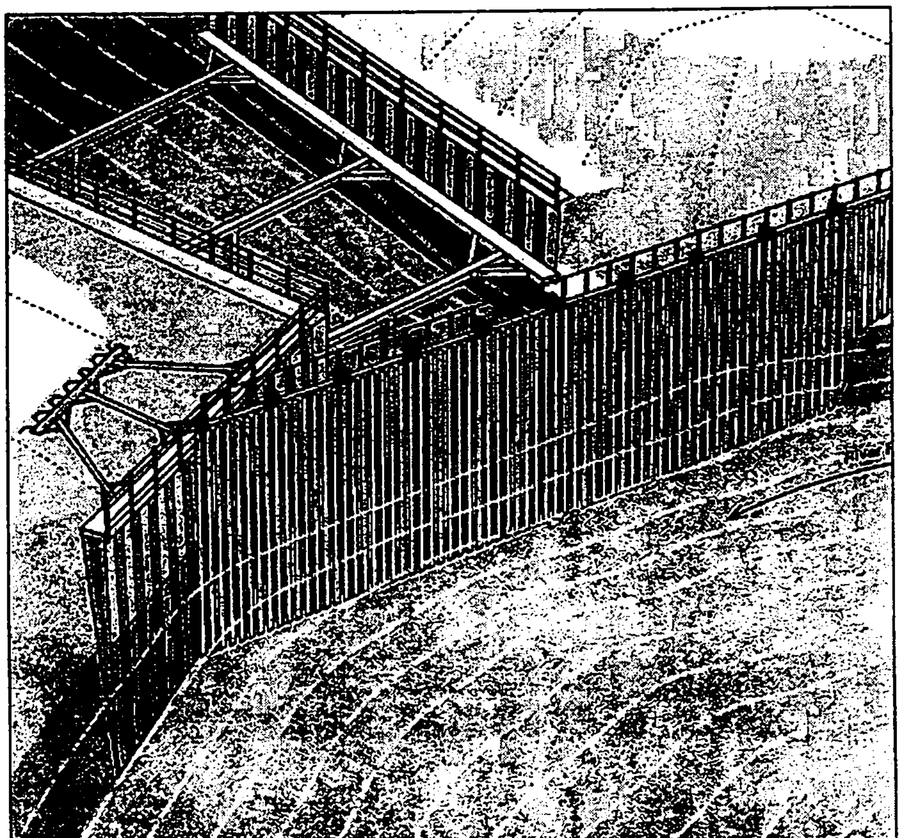
Louvered Intake Barrier

Our louvered barrier is designed for water intakes that have high-flows and big variations in water depth. Fish are thereby excluded from hydro-electric turbines or irrigation pumps.

Large increases in water depth do not reduce the effectiveness of this barrier because the electrodes are mounted vertically on the louvers.

High flows are made possible by spreading the flow over a large area. The electrodes are flush mounted to facilitate water flow between the louvers. (Patent Pending).

We are currently seeking opportunities to fine-tune this product. If you have a turbine or pump that you would like to protect, please contact us.



Louvered barrier for a large pump intake.

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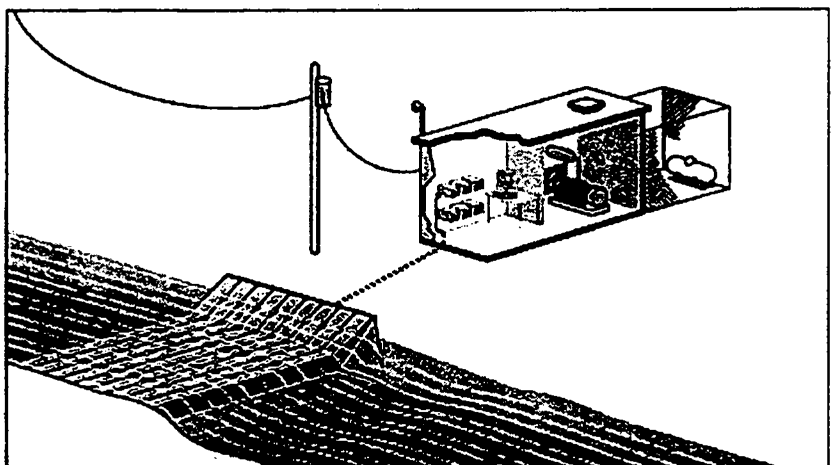
Barrier System & FBTCS Monitoring System

BP-6-9.0 BARRIER SYSTEM
The figure below shows a typical BP-6-9.0 large stream electric fish barrier system. The illustrated system includes six Programmable Output Waveform (POW) pulsators. The pulsators are serially connected to a plurality of submerged electrodes. The system uses our latest pulsator design, the BP-1.5-POW, with an input power of 1.5 kilowatts. Energy is stored in a large capacitor bank and is quickly discharged through water, much like a camera flash. Pulse width is adjustable between 0.15 and 1.0 milliseconds. The repetition rate is adjustable from 0.1 to 10 pulses per second. Other pulsator sizes available are the BP-1.0-POW, and the BP-0.5-POW for smaller streams and culvert barriers. Culvert barriers typically only require one or two pulsators. In the case of only one pulsator, the output can be split to energize up to three electrodes. All barrier systems include a monitoring system as described in the following section.



Typical BP-6-p barrier installation. Six pulse generators mounted in an environmental equipment enclosure. Wiring connects underground cables to the electrode array. Auxiliary power is provided, fueled by propane for quick starting and reliability.

FBTCS MONITORING SYSTEM
Each pulsator's waveform is controlled and monitored by the Fish Barrier Telemetry and Control System (FBTCS) via a fiber optic network. Pulsators are connected through a star concentrator so that should any pulsator in the system fail, the barrier will remain operational without disrupting communications with the remaining pulsators. A separate trigger loop keeps the pulsator's outputs synchronous as required by the BP-6-9.0 system.

The FBTCS system also has relay contacts for controlling external devices. The system can be expanded to monitor and/or control up to 256 devices by adding a custom interface board. The control system reports to remote monitoring locations via telephone modem or radio telemetry. Up to four telephone numbers can be programmed for it to call in the event of a problem.

The FBTCS can also receive remote commands to re-configure the pulsators outputs via telephone or radio modem link. When connected by modem to a computer, the FBTCS system presents equivalent menus allowing remote control and monitoring. Passwords can be employed to prevent unauthorized tampering. The system

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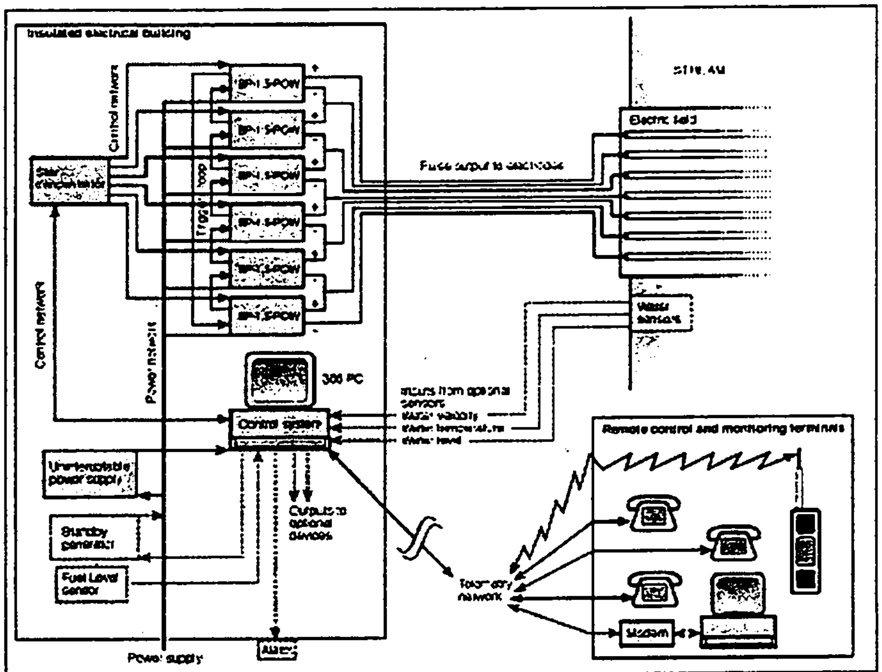
software provides a status display, and a keystroke calls up the menus to give access to all functions. An event-history is maintained to record error conditions. The system can be interrogated at any time from a standard touch-tone phone, in which case the system will respond in clear spoken voice.

In the illustration below the system monitors water velocity, temperature and level sensors which can automatically adjust pulse characteristics to respond to changes in water conditions. The system sends an alarm if pre-set water parameters go beyond set limits. The system is capable of monitoring up to 256 inputs.



A typical BP-6-12 schematic. Optional extensions are shown in dashed lines.

Notice:

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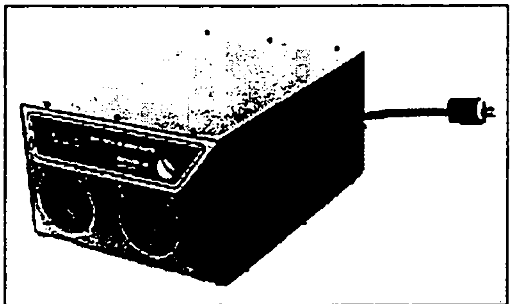
For More Information
Call 1-360-573-0202

P.O.W. Pulsators

Smith-Root offers three models of Programmable Output Waveform pulse generators. Pulsed waveforms and frequencies can be programmed for optimum fish blocking or repelling. They produce a wide range of DC pulse outputs to give more stopping power with less stress to fish. Pulsators are offered in three power ranges: 0.5, 1.0 and 1.5 kilowatts.

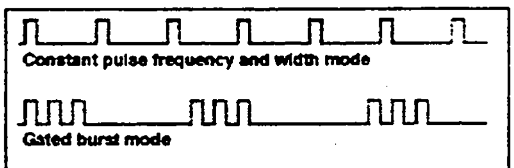


BP-0.5-P.O.W., BP-1.0-P.O.W. or BP-1.5-P.O.W.

Each POW pulsator includes a microprocessor to control width, frequency, and period of the output. A variety of wave forms can be generated: standard pulses, sweeping pulse widths, sweeping frequencies, and gated bursts. This allows generation of optimum waveforms that are effective with a wide range of species. The FBTCS telemetry and control system is required to set-up, monitor, and control the pulsators.

Standard Pulses: A regular pattern of on/off times. The width and period of the pulses are selected to produce the most effective pattern.

Gated Bursts: A group of pulses followed by a longer off-time. This is often just as effective as standard pulses, but less stressful to the fish.



Pulses can be created in a wide range of rates, widths and periods.

Other Waveforms: Sequences of pulses sweeping from wide-to-narrow width, or sequences sweeping from high-to-low frequency, can be implemented on special order.

Specifications	
Input voltage standard:	240 volts single phase AC
Input voltage special order:	120 volts single phase AC
Output voltage (Pulsed DC):	40, 80, 120, 160, 200, 240 V
Maximum input power:	500, 1,000 or 1,500 watts
Maximum output energy:	380, 1150 or 1525 joules
Output insulating rating:	5,000 volts
Output current maximum:	1,200 amps
Pulse width:	0.15 to 10.0 millisec
Output pulse frequency:	0.1 to 10.0 Hz
Dimensions:	16.5"W x 10.5"H x 21"D
Weight:	60, 80 or 100 pounds
Operating temperature:	0-35¼C (32-95¼F)
Capacitor bank:	11,000, 16,000, 27,000 μfd

Product Information
Introduction
Graduated Fields
Upstream Barriers
Downstream Barriers
Safety
Barrier Monitoring
Pulsators
Cast Culvert Barrier
Plastic Culvert Barrier
Portable Array Barrier
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Tailrace Barrier
Canal Barrier
Intake Barrier
Louvered Intake Barrier
Strobe Light Guidance
Sonic Barrier

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COANDA PROPOSAL

Proposal No. __

Description

Proposal No.__ Coanda Screens

- Proposal Description: Provide Coanda Screen along downstream face of existing diversion dam. Approximately 600 ft. of screen length is required to provide the 600 ft^3/s delivery. This screen could be located anywhere along the diversion dam, but preferable as far upstream as possible to maximize the available head. Based on preliminary hydraulic analysis, an 8-ft. diameter pipe on a 0.005 slope is required to convey this capacity. However, given uncertainties, further feasibility analysis is required to further develop this proposal.

- Critical Items to Consider:

- In river construction at low flow conditions.
- Winter construction.
- Hydraulic feasibility analysis.
- Access for maintenance and repair.

- Ways to Implement: Install on downstream face of existing dam.

- Excavate to bedrock.
- Form and place concrete flume and delivery pipe.
- Install screens.

- Changes from the Baseline Concept: Not included in baseline.

Advantages	Disadvantages
· Low maintenance · Passive cleaning · Reduces diversion through GVIC head gates · Reduces maintenance · Ensures adjudicated water right since diversions can be made by existing protocol during emergency shut down of the screens if they become damaged or excessively fouled.	· May be difficult to provide all of the required flow during low-river flow conditions. · Potential for silt deposition and plugging · In river construction required. · Requires additional flow over diversion dam to provide passive cleaning. · Cannot be operated during low river flow periods when additional sweeping flow cannot be provided. · May require raising diversion dam to provide sufficient head for full delivery of required flow rates. · Limited access for cleaning or repair during high river flow conditions.

Proposal No. __

Potential Risks

- Winter construction in the river requiring extensive 404 permitting and construction sequencing. At the mercy of the weather, possibility of high water event while under construction.
- Subject to screen fouling and seasonal removal for cleaning.
- Impingement potential for fish?
- Requires detailed feasibility analysis to determine if the concept is viable for this application.

Cost Items	Nonrecurring Costs
Original Baseline Concept	$0
Value Concept	$0
Savings	$0
Value Study Costs	$20,000
Implementation Costs	$0
Net Savings	**$(20,000)**

==

OPEN CHANNEL FLOW ANALYSIS: FLOW IN A PIPE
COMPUTER MODEL: UDCHANNEL : PIFLOW 12-06-1993

==

EXECUTED BY:
J. Kubitschek..
ON DATE 02-17-2000 AT TIME 16:55:15

** PROJECT TITLE: Pipe Flow Analysis, Coanda Screen Delivery, GVIC Fish Screens

- Pipe Diameter computed from discharge requirements and available head.

** DESIGN INFORMATION

PIPE (EQUIVALENT) DIAMETER	(INCHES)	=	84.270
PIPE ROUGHNESS MANNING N		=	0.014
PIPELINE SLOPE	(FT/FT)	=	0.0100
DESIGN FLOW RATE	(CFS)	=	600.000

** NORMAL FLOW CONDITIONS:

FLOW CENTRAL ANGLE	(DEGREE)	=	360.00
FLOW DEPTH	(FEET)	=	7.02
FLOW AREA	(SQ FEET)	=	38.74
FLOW VELOCITY	(FPS)	=	15.49
SPECIFIC ENERGY	(FT)	=	10.75
SPECIFIC FORCE	(KLB)	=	26.33
FLOW FROUDE NUMBER		=	0.00

NOTE: FROUDE NUMBER=0 MEANS FLOWING FULL.

** CRITICAL FLOW CONDITIONS :

FLOW CENTRAL ANGLE	(DEGREE)	=	283.483
FLOW DEPTH	(FEET)	=	6.27
FLOW AREA	(SQ FEET)	=	36.50
FLOW VELOCITY	(FPS)	=	16.44
MINIMUM SPECIFIC ENERGY	(FT)	=	10.47
MINIMUM SPECIFIC FORCE	(KLB)	=	26.49
SLOPE	(FT/FT)	=	0.0089

□NERGY (FT) = 10.47
MINIMUM SPECIFIC FORCE (KLB) = 26.49
SLOPE

```
================================================================================
    OPEN CHANNEL FLOW ANALYSIS: FLOW IN A PIPE
    COMPUTER MODEL: UDCHANNEL : PIFLOW 12-06-1993
================================================================================
    EXECUTED BY:
    J. Kubitschek.....................................................
                        ON DATE 02-17-2000  AT TIME 17:07:02

**  PROJECT TITLE: Pipe Flow Analysis, Coanda Screen Delivery, GVIC Fish Screens
  • Pipe Diameter computed from discharge requirements and available head.

**  DESIGN INFORMATION

PIPE (EQUIVALENT) DIAMETER(INCHES) =    95.970
PIPE ROUGHNESS MANNING N           =     0.014
PIPELINE SLOPE           (FT/FT)   =    0.0050
DESIGN FLOW RATE         (CFS)     =   600.000

**  NORMAL FLOW CONDITIONS:

FLOW CENTRAL ANGLE       (DEGREE)  =   360.00
FLOW DEPTH                 (FEET)  =     8.00
FLOW AREA               (SQ FEET)  =    50.24
FLOW VELOCITY               (FPS)  =    11.94
SPECIFIC ENERGY              (FT)  =    10.21
SPECIFIC FORCE              (KLB)  =    26.29
FLOW FROUDE NUMBER                 =     0.00
    NOTE: FROUDE NUMBER=0 MEANS FLOWING FULL.

**  CRITICAL FLOW CONDITIONS :

FLOW CENTRAL ANGLE       (DEGREE)  =    247.958
FLOW DEPTH                 (FEET)  =     6.23
FLOW AREA               (SQ FEET)  =    42.01
FLOW VELOCITY               (FPS)  =    14.28
MINIMUM SPECIFIC ENERGY      (FT)  =     9.40
MINIMUM SPECIFIC FORCE      (KLB)  =    25.30
SLOPE                     (FT/FT)  =     0.0055

ENERGY      (FT)     =     9.40
MINIMUM SPECIFIC FORCE      (KLB)  =    25.30
SL
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FAX TRANSMISSION RECORD

US BUREAU OF RECLAMATION
PN REGIONAL OFFICE
1150 NORTH CURTIS ROAD
BOISE ID 83706-1234

FAX NUMBER (208) 378-5171

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TO: Dennis Hawkins FROM: Steve Montague

CODE: CODE:

FAX No. 970-248-0601

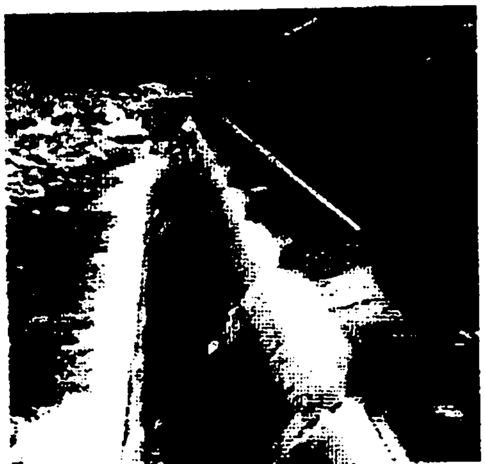
WE ARE SENDING 14 PAGES, INCLUDING THIS COVER SHEET. IF THE FAX IS NOT RECEIVED IN GOOD ORDER PLEASE CALL THE NUMBER LISTED ABOVE.

Dennis, following is the information I have on Coanda screens. It is essentially from two web sites. One is Aquadyne, Inc. The other is Tony Wahl's web page. Tony works for the Bureau in the hydraulics lab in Denver. I would give Tony a call for any questions on Coanda Screens. His phone number is: (303) 445-2155. If you have access to the internet, the addresses for these two sites are at the top of the following pages. Call me if I can be of any further help.

Steve

AQUADYNE, INC.

Aqua Shear
Static Intake Screen



Click photo to see larger image

Bear Creek Power Diversion

California

Installed 1984

Engineer - Ott Water Engineers

Owner - TKO Power

70 cfs

FEATURES AND ADVANTAGES
- No moving parts
- Simple and inexpensive to install
- No electricity required
- High capacity -- 1½ cfs per foot of weir length
- Profile wire stainless steel
- Capable of removing solids as small as 0.5 mm

APPLICATIONS
- Hydroelectric turbine intakes
- Irrigation Diversions
- Municipal and industrial diversions
- Wildlife refuges
- Fish Hatcheries
- Fish barriers
- Screening wherever fish protection and liquid/solid separation are required

The Aquadyne Aqua Shear Screen utilizes a combination of shear and Coanda Effect. As the water flows across each horizontal wire, a portion is sheared or "sliced" at each slot to be passed to the useful purpose of the diversion. Solids larger than the slot are flushed past the screen. The standard slot opening is 1.0 mm. Screens with larger or smaller openings can be manufactured on special order. Liquid/solids separation is further enhanced by the Coanda Effect; that is , the phenomenon whereby fluids tend to follow a solid surface. A specially designed acceleration plate provides for both an even distribution of flow across the screen and an increase in velocity of the fluid for more effective liquid/solid separation.

If you desire additional information about this product or any other Aquadyne products see our Additional Information Page.

More Screens➤

Home Page - Additional Information Page
Aqua Shear Screens - Overshot Aqua Screen -Undershot Aqua Screen- Flat Plate Screen

Last modified: November 10. 1997

AQUADYNE, INC.

Aqua Shear
Static Intake Screen


Click photograph to see large image

Forks of Butte Power Diversion

California

Originally Installed 1991

Owner - Energy Growth Partnership I

220 cfs

The Forks of Butte Diversion structure is constructed on a variation of a side channel weir. Fish, debris, etc. pass directly down stream. Screened water flows through a penstock directly to the turbines. This installation was damaged by the over 100 year flood of December 1996. Aquadyne provided screens for the repaired structure.

Lost Creek Power Diversion

California

Installed 1989

Owner - Mega Renewables

60 cfs


Click photograph to see large image

The Lost Creek Diversion diverts water from the stream to a channel, from which water is released over the screen. Water, fish and debris passing the screen flow through a smaller constructed channel back to the stream.

< Back More Screens >

AQUADYNE, INC.

THIS PAGE IS UNDER CONSTRUCTION

Aqua Shear


Click photograph to see large image

Nyklemoe Wildlife Refuge

Installed 1989

Engineer - Owner

Owner - Minnesota Dept. of Natural Resources

55.8 cfs

The Forks of Butte Diversion structure is constructed on a variation of a side channel weir. Fish, debris, etc. pass directly down stream. Screened water flows through a penstock directly to the turbines. This installation was damaged by the over 100 year flood of December 1996. Aquadyne provided screens for the repaired structure.

Wahianoa Intake

New Zealand

Installed 1991

Engineer - Owner

Owner - Electricity Corp.

50 cfs


Click photograph to see large image

The Lost Creek Diversion diverts water from the stream to a channel, from which water is released over the screen. Water, fish and debris passing the screen flow through a smaller constructed channel back to the stream.

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Prepared for:
The First International Conference on Water Resources Engineering
American Society of Civil Engineers
San Antonio, Texas
August 14-18, 1995

Hydraulic Testing of Static Self-Cleaning Inclined Screens

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Abstract

Several configurations of static, self-cleaning, inclined screens were tested in the hydraulics laboratory of the Bureau of Reclamation. The screens were tested in an overflow weir configuration with potential for fish exclusion and fine debris removal applications at water intakes and diversion structures. Similar screens are used in the mining industry, primarily in coal-handling applications, and this type of screen has been successfully used for debris and fish exclusion at several prototype sites (Ott et al., 1987). This paper describes the testing program and results, and discusses how the Coanda effect may contribute to the high flow capacity of the screens.

Introduction

There is a growing need on Bureau of Reclamation projects to screen water for very fine debris and small aquatic organisms. Unfortunately, as screen openings are reduced, maintenance effort required to keep screens clean is increased. One screen design that offers potential for screening fine debris with minimum maintenance is the static inclined screen (fig. 1). A concave wedge-wire screen is installed in the downstream face of an overflow weir. Flow accelerates down the face of the weir and across the screen. Clean water drops through the screen while debris is discharged off the downstream end of the screen. A small bypass flow ensures that debris is carried off the screen. The nature of the flow across the screen face makes the screen largely self-cleaning. This screen has been successfully used for debris and fish exclusion at several prototype sites (Ott et al., 1987), but there is little detailed design information available. Installations similar to those tested here have been reported to have screening capacities of 0.09-0.14 $m^3/s/m$ (1.0-1.5 $ft^3/s/ft$).

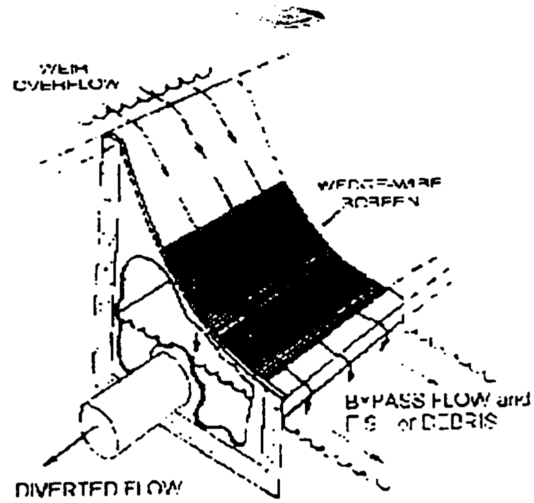


Figure 1. - Typical static inclined screen used for water diversion (after Ott et al., 1987)

To develop design data for possible Reclamation use of static inclined screens, several screen configurations were tested in Reclamation's hydraulics laboratory. Objectives of the testing were to establish the flow capacity of a typical configuration and to qualitatively assess the tendency of the screens to clog with debris.

The high capacity of the static screens tested by Reclamation is due primarily to a tilted-wire construction in which each wire is tilted so that its upstream edge is offset into the flow. A thin layer of the flow is sheared off the bottom of the water column and directed through the screen. This shearing action may depend somewhat on a phenomenon known as the Coanda effect. Past literature concerning these screens has attributed their high capacity to the Coanda effect, but the mechanism by which the effect improves the capacity has not been fully explained.

The Coanda effect is familiar to most hydraulicians, although perhaps not by name. The effect was first observed in 1910 by Henri-Marie Coanda, in connection with exhaust flow from an experimental jet engine (Stine, 1989). The Coanda effect is the tendency of a fluid jet to remain attached to a solid boundary. When a jet is discharged along a solid boundary, flow entrainment into the jet is inhibited on the surface side. For the jet to separate from the surface there must be flow entrainment into the jet on the surface side beginning at the separation point. However, the close proximity of the surface limits the supply of flow to feed such entrainment. Thus, the jet tends to remain attached to the surface. If the surface deviates sharply away from the jet, separation will occur, but if the surface curves gradually away, the flow may remain attached for long distances. Primary applications of the Coanda effect have been in aeronautics; wings and engines using the effect have achieved increased lift and thrust. Reba (1966) describes experimental work on propulsion systems using the Coanda effect, including hydrofoils, jet engines, and a levitating vehicle. The Coanda effect has also been used in the design of improved nozzles for combustion applications.

Figure 2 shows the flow over a flat-wire screen and over a tilted-wire screen as it would occur with and without the Coanda effect.

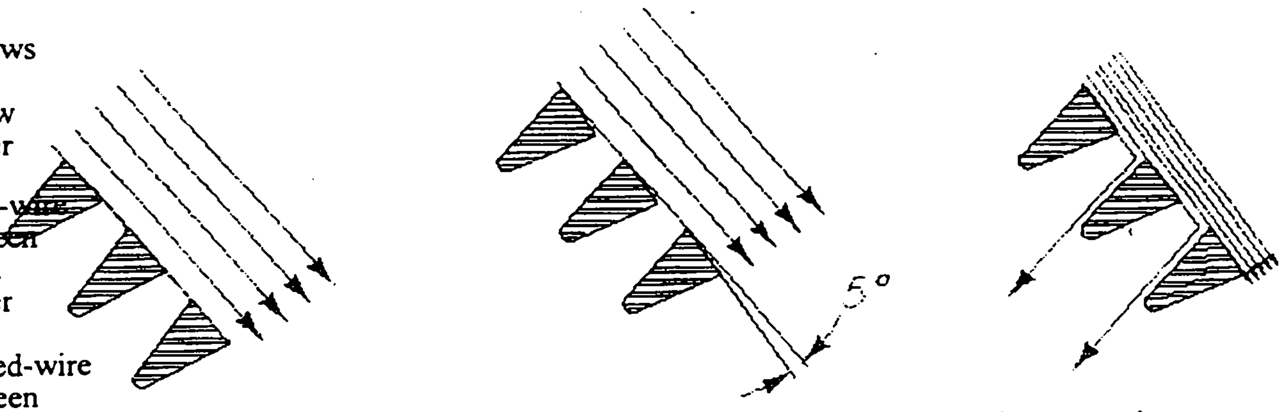


***Figure 2.** - Schematic representation of flow over flat-wire and tilted-wire inclined stati screens, with and without the Coanda effect.*

The flow is shown as it would appear near the top of the screen, where the flow direction has been established by the ogee crest. Without the Coanda effect, the flow separates off the high point of each wire and skips to the next wire, with essentially no flow being sheared off. Gravity, pressure forces and the curvature of the screen panel will force a small amount of flow through the screen, and as the flow continues down the screen the flow field will begin to deviate toward the screen. Once this deviation matches the tilt angle of the wires, the flow will be similar to that shown at the right of figure 2.

The Coanda effect causes the flow to remain attached to the screening surface of each wire, directing the flow into the offset created at the next downstream wire. A thin layer of the flow is sheared off by the next wire, which is offset into the flow due to the tilted-wire construction. The incremental discharge through the screen at any wire is a function of the flow velocity and the thickness of the sheared water layer. The elevation drop from the crest to the screen produces high velocity flow over and through the screen. Since the Coanda effect keeps the flow in contact with the screening surface of each wire, even near the top of the screen, it helps produce high capacity flow over the full length of the screen. The significance of this benefit is uncertain.

Testing Program

Two concave, stainless steel, wedge-wire screen panels were tested in the laboratory facility in three different configurations shown in Table 1. Both screens were constructed with a 254-cm (100-inch) radius and covered a 25 arc, producing a total length of 1.11 meters (3.64 ft) in the flow direction. Each screen was installed on the downstream face of an ogee crest spillway in a 30.5-cm (1-ft) wide flume. A 19-mm (0.75-inch) wide support beneath the screen restricted the flow-through width of the screen to 28.6 cm (11.25 inches).

***Table 1.** — Test screen configurations.*

Test	Screen Type	Dimensions
A	Tilted wires	• Crest designed for flow of 0.116 m^3/sec/m (1.25 ft^3/s/ft) • 0.366 meter (1.2 ft) drop to start of screen • 60° starting angle at top of screen (from horizontal)
B	Flat wires, parallel to flow	

The first screen used V-shaped wires oriented perpendicular to the flow direction. The wires were 1.52 mm wide, with a clear spacing between wires of 1 mm. The wires were tilted 5 from the normal orientation (fig. 2). This configuration is capable of screening out debris smaller than the 1-mm clear spacing, depending on screen inclination, flowrate, and debris characteristics. This screen was tested in two different crest configurations, with the upstream edge of the screen set into the downstream face of the crest at 60 and 50 angles from horizontal, tangent to the ogee profile.

The second screen was constructed with the same V-shaped wires and wire spacing, but the wires were run parallel to the flow direction and were not tilted. This configuration was tested because of the possibility that it would be a preferable design for use in applications involving fish; this wire orientation would likely cause less descaling of fish and less abrasion of fish eggs passing over the screen. This screen does not take advantage of the Coanda effect.

All quantitative testing was done with clean water. To qualitatively evaluate clogging potential, each configuration was also tested with debris consisting of saturated sawdust and wood chips from model construction activities.

Screen A was installed on the downstream face of an ogee crest spillway designed for a flow of 0.116 m^3/s/m (1.25 ft^3/s/ft). This screen was initially tested with the full length of the screen open to flow, but it was quickly apparent that the screen capacity was much greater than the design flow rate of the test facility. To permit testing at a flowrate that would produce bypass flow, covers were constructed so that the open screen length could be limited to the upper 0.457 meters (1.5 ft), or 0.61 meters (2 ft). To permit testing the full-length screen A to full capacity, a new crest was constructed and the screen was retested as configuration C. Screen B was installed in the same crest configuration as screen A. The capacity of screen B was relatively low, permitting all testing to be done with the full screen length open to the flow.

Data recorded for each test flowrate were the inflow to the screen (measured with laboratory venturi meters), and the flowrate through the screen (measured with a suppressed rectangular weir). The bypass flow off the screen was determined from continuity. For flowrates that produced no bypass flow, the flow distance down the screen was recorded.

Results

Table 2 shows the capacity of the full-length screens and the partially covered screen sections at the zero-bypass condition. Screens A and C both had much higher capacities than those previously cited in the literature. Screen A had the highest capacity due to its steeper inclination angle (60 vs. 50 for screen C) and greater head drop that produced higher velocities across the screen face.

Table 2. — Screen capacities with zero bypass flow.

Screen	Length of Open Screen meters (ft)	Screened Flow with Zero Bypass Flow $m^3/s/m$ ($ft^3/s/ft$)
A	0.457 (1.5)	0.116 (1.25)
	0.787 (2.58)	0.260 (2.80)*
B	1.086 (3.56)	0.048 (0.519)
C	0.457 (1.5)	0.106 (1.14)
	1.086 (3.56)	0.334 (3.59)

* *Largest flowrate tested did not reach the end of screen A. Extrapolating data from lower flowrates suggests a zero-bypass screening capacity of about 0.37 $m^3/s/m$*

Figure 3 shows the results of tests on screen A, with the cover in place to limit the open screen length to 0.457 m. The maximum screened flow shown in Table 2 was reached when flow was observed down the full length of the open screen. As the inflow was increased further the bypass flow increased as shown in the figure.

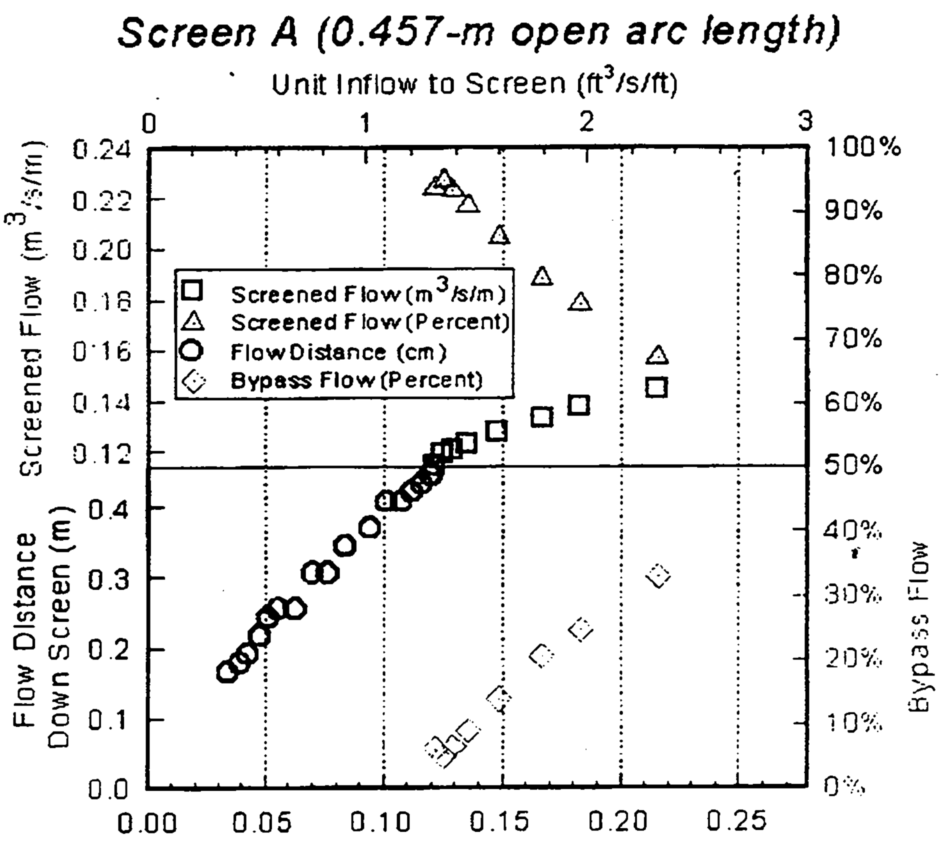


***Figure 3.** - Results of screen A tests with cover limiting open screen length to 0.457 meters.*

Figure 4 shows the screening capacities of the unmodified screen A and the shortened sections of screen A tested with the cover plate in place. The capacity is expressed in terms of the flow per unit screen area, and is plotted as a function of the specific energy input to the screen at the upstream edge. The specific energy was calculated 2 meters upstream of the crest, referenced to the elevation of the upstream edge of the screen. The figure shows that within the range of conditions tested, the discharge per unit area through screen A is a single function of the input energy for both the fully open screen and the partially covered screens. This indicates that the Coanda effect is influencing the flow through the screen. If the Coanda effect were not a factor, the upstream portion of each screen would be less efficient, and there would be a significant reduction in the screened flow per unit area when the lower portions of the screen were covered.

Testing with debris showed that all screen configurations were resistant to clogging. Screen B in particular showed no debris buildup on the screen face; the orientation of the wires parallel to the flow allowed the flow to easily sweep debris off the screen. Screens A and C did exhibit some clogging and an increased bypass flow when debris was initially introduced, but most debris was quickly dislodged and carried down the screen face. Generating turbulence in the flow near the crest seemed to accelerate the self-cleaning process; a paddle wheel or other device that generates turbulence at the crest might prove beneficial.

Testing of screen C revealed a very loud, high frequency noise emanating from the screen at flow rates above about 0.28 $m^3/s/m$ (3 $ft^3/s/ft$). This noise was likely due to some form of flow-induced screen vibration, although the exact source could not be determined during the tests. This is a condition that requires further study as it may affect long-term screen durability.

References

Ott, R.F., E. Boersma, and J. Strong, "Innovative Intake Protects both Aquatic Life and Turbine Equipment", *Waterpower '87*, Portland, Oregon, Aug. 19-21, 1987.

Pankratz, T.M., *Screening Equipment Handbook*, Technomic Publishing Co., Lancaster, Pennsylvania, 1988.

Reba, I., "Applications of the Coanda Effect", *Scientific American*, June 1966.

Stine, G.H., "The Rises and Falls of Henri-Marie Coanda", *Air & Space Smithsonian*, Sept. 1989.

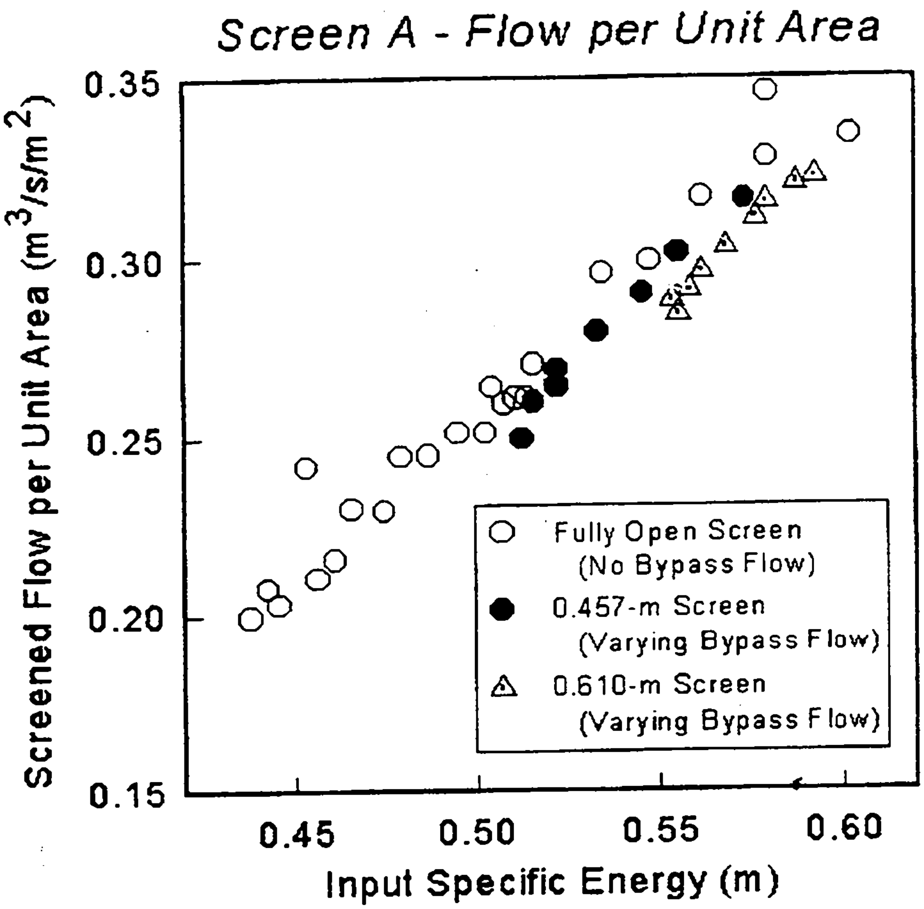
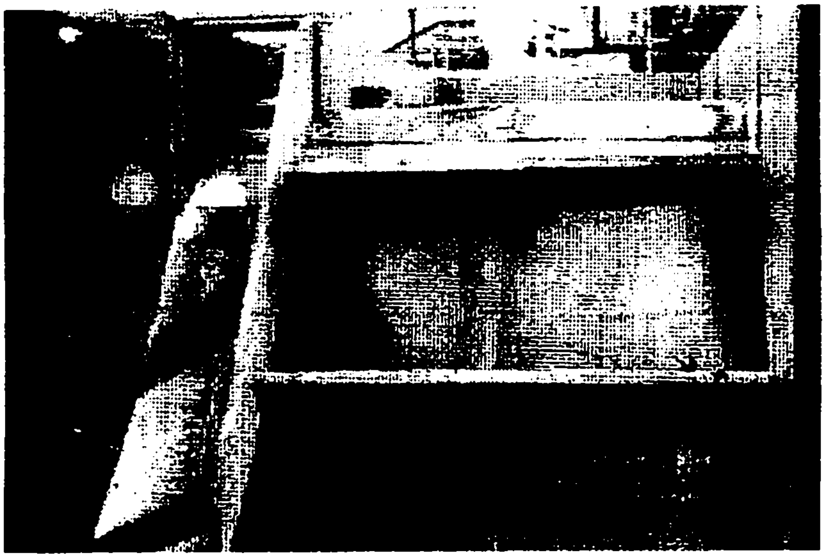


Figure 4. - Results of screen A tests with and without covers to limit open screen length.

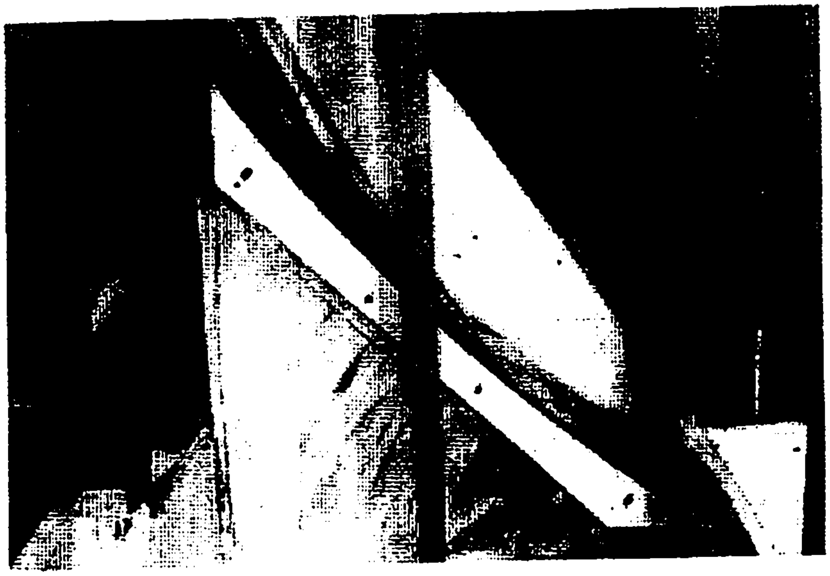
Photographs

The following photographs did not appear in the original paper due to space limitations.

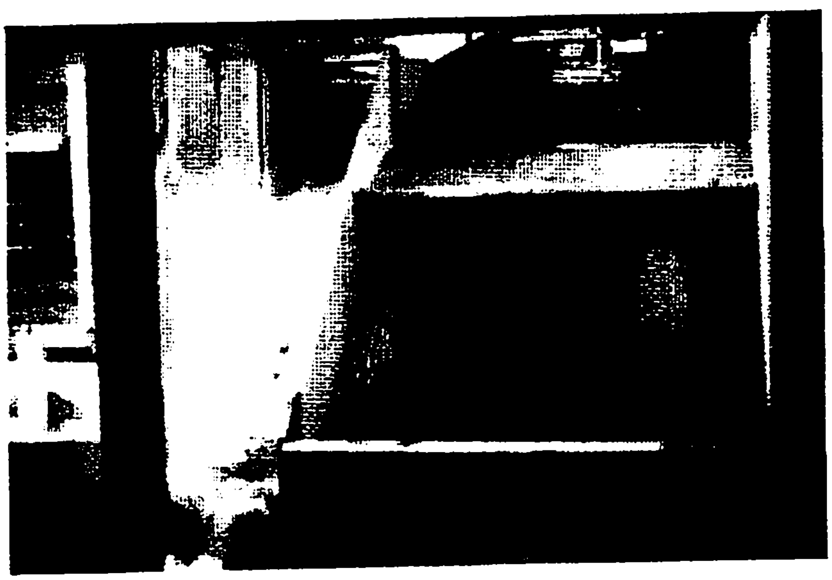


Screen configuration C in the dry (same as screen A, but with lower crest that permitted testing at higher flowrates). This view shows a 5-ft wide screen installed in the flume, with the test section narrowed to the 1-ft wide section on the left side. The test section was narrowed because the screen capacity was much higher than anticipated, and the lab pump capacity would not allow testing the screens to full capacity using the 5-ft wide section.

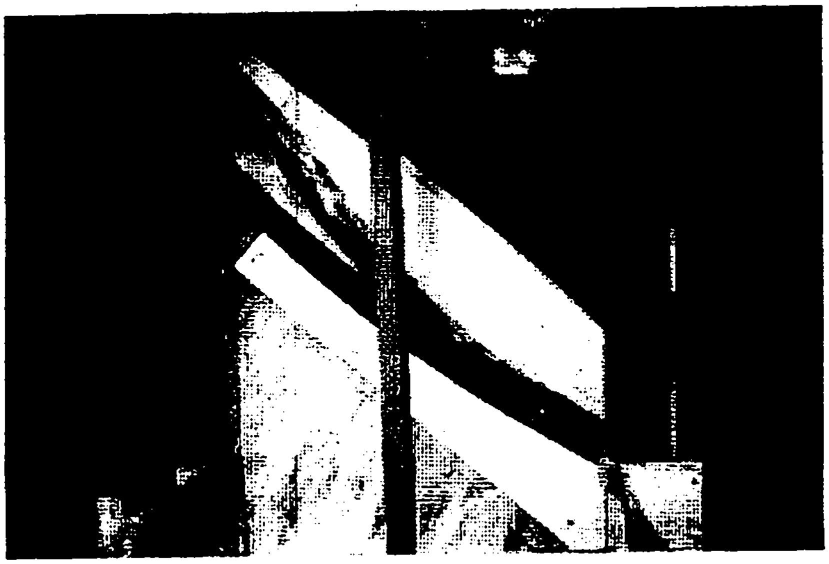
Screen A under test. Note that all flow passes through the screen before reaching the bottom edge. Screen wires run horizontally across the face of the screen. The vertical lines in the photo are the screen support rods underneath the wires.



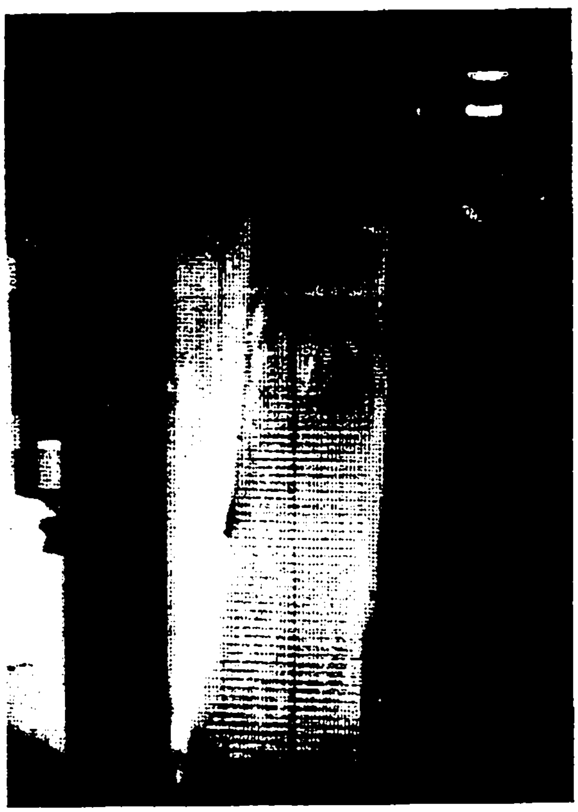
Side view of screen A under test. Note how the flow is turned nearly 90 degrees and exits out the bottom of the screen in a direction nearly perpendicular to the screen face. This screen uses wedge-wire oriented perpendicularly to the flow (wires run horizontal across screen face).



Screen C under test. At this flowrate, some flow does pass off the bottom edge of the screen.



Side view of screen C under test. Again note the perpendicular exit flow out of the screen.



Front view of screen B under test. Nearly all flow passes over the screen and off the downstream edge. This screen's wires run parallel to the flow direction. The horizontal lines visible in this photo are the underlying support rods, which run horizontally across the screen.

Side view of screen B under test. Notice that for this screen the flow that does go through the screen simply falls into the exit channel. It is not forcefully ejected perpendicularly out of the bottom of the screen as with screens A and C.

Return to Tony Wahl's USBR Home Page
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If you have questions or comments regarding this page, please send e-mail to: twahl@do.usbr.gov

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