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Marble Bluff Dam
Fish Passage Concept Study
June 1995

Technical Service Center

BUREAU OF RECLAMATION

WATER RESOURCES RESEARCH LABORATORY

DRAFT

MARBLE BLUFF DAM
FISH PASSAGE CONCEPT STUDY

Investigations by

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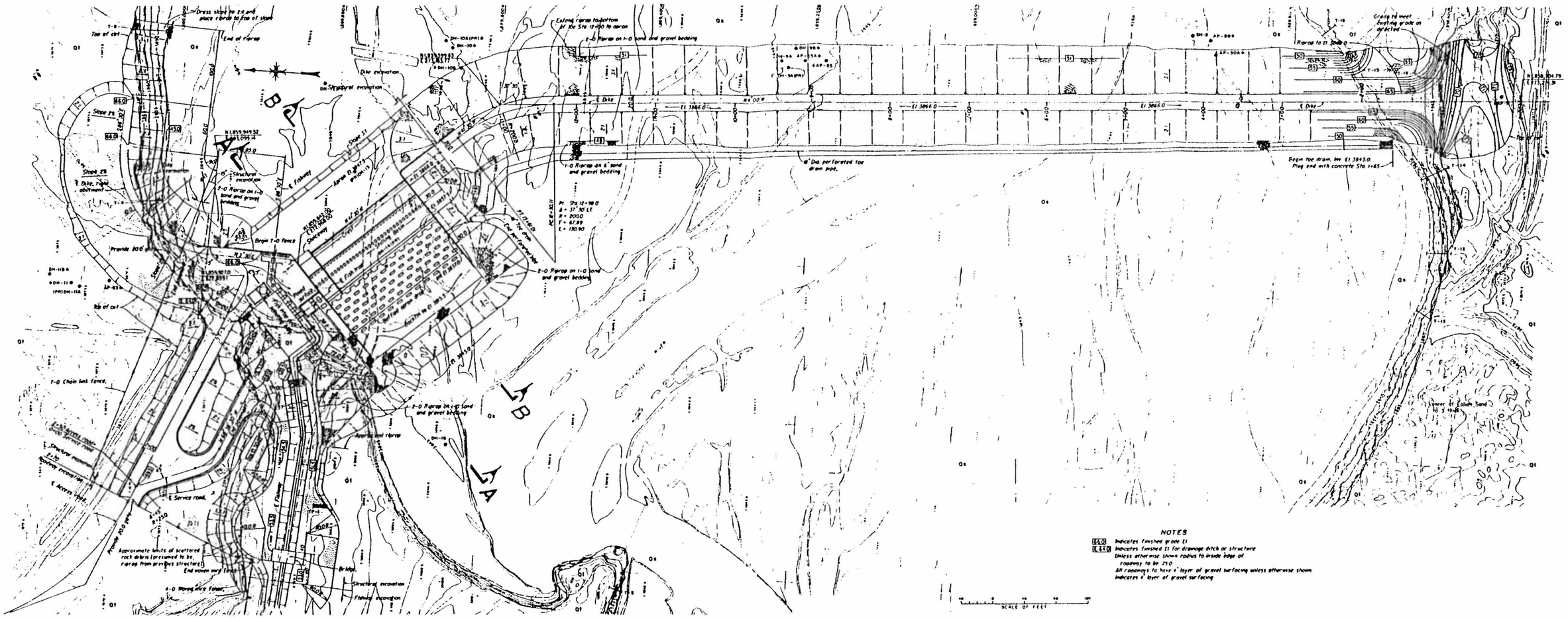
Marble Bluff Dam Fish Passage

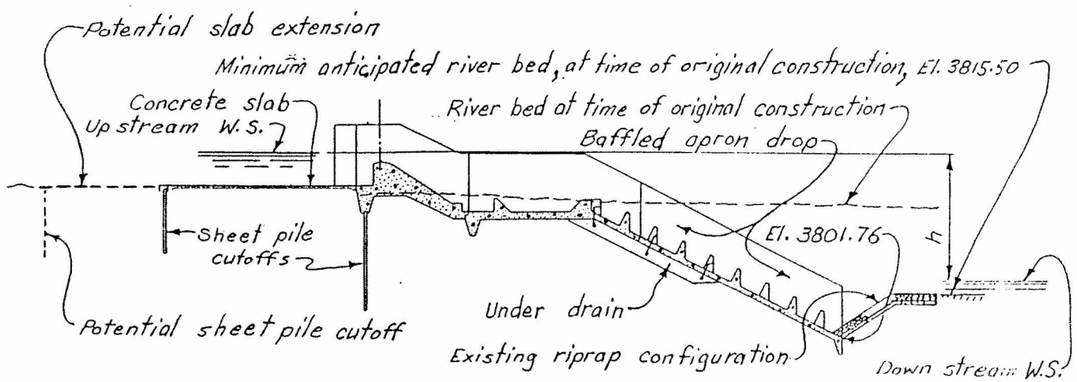
Background

The Lahontan Basin Area Office requested the Technical Service Center (TSC), Denver, Colorado, conduct a concept design study focused on improving fish passage at Marble Bluff Dam near Reno, Nevada. Marble Bluff Dam and fish passage facilities are located on the Truckee River, approximately 3 miles upstream of Pyramid Lake, near Reno, Nevada. Figure 1 shows a general plan of the structures as originally designed in 1973. The dam is actually a grade control structure for the Truckee River. Lake levels have declined up to 80 ft due in part to Truckee River water diversions since white settlers started farming in the region. Currently the lake is about 72 ft below the pre-diversion level. Declining lake levels initiated a steepening gradient in the lower river and exposed a large flat delta area at the mouth of the lake. The lake supports several fish species including endangered cui-ui and the threatened Lahontan cutthroat trout. Both species migrate up the Truckee River to spawn during high spring flows. The steepened river gradient and the presence of shallow braided flow over the delta have greatly reduced spawning runs in the river.

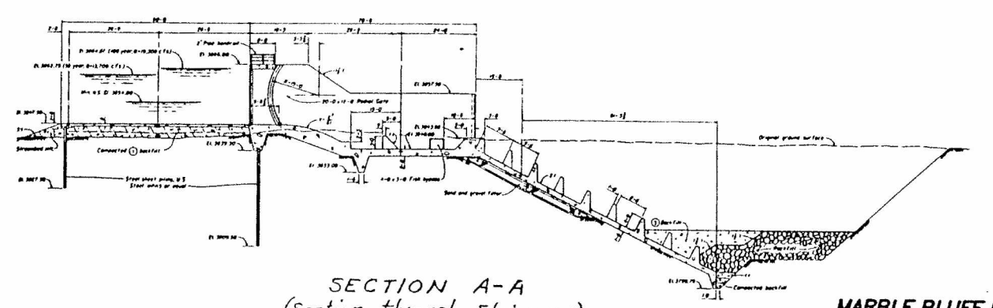
The first major effort to improve fish migration up the lower Truckee River was started by the Corps of Engineers in 1942 when the lake elevation was 3820. A diversion dam and fishway channel were started near the site of the present facilities. World War II interrupted the construction and the dam washed out during flood flows in 1950. In 1976 the Bureau of Reclamation constructed Marble Bluff Dam and fish passage facilities for the U.S. Fish and Wildlife Service (FWS). The facility was designed to aid fish passage and stabilize the rapidly degrading river channel. The dam provides water to the Pyramid Lake fishway, which starts at Marble Bluff Dam and extends northerly about 3 miles to Pyramid Lake. The existing fishway follows the 1942 fishway channel alignment entering the lake about 0.75 miles NE of the river delta. The fishway was built to bypass the dam and the shallow river delta. The fishway channel has five combination weir/orifice style fish ladders along its length.

The dam is a zoned, earth-fill embankment with a 150-ft-long, uncontrolled concrete ogee crest spillway, crest elevation 3854.5. To the right of the spillway is a 20-ft-wide, gated sluiceway, floor elevation 3847.5. Spillway and sluiceway flows pass down a baffled apron drop to the downstream river channel. The river channel upstream of the dam is silted in to about the elevation of the sluiceway invert. At low flows there is no storage behind the dam. Prior to construction the river channel was at about elevation 3844. The down stream end of the baffled apron drop was constructed to elevation 3801.76 to protect the dam against channel degradation, leaving much of the baffled apron buried below the original streambed elevation. Currently the downstream river channel bed is at about elevation 3815.5, lying just above the top of the spillway toe riprap placed during construction.





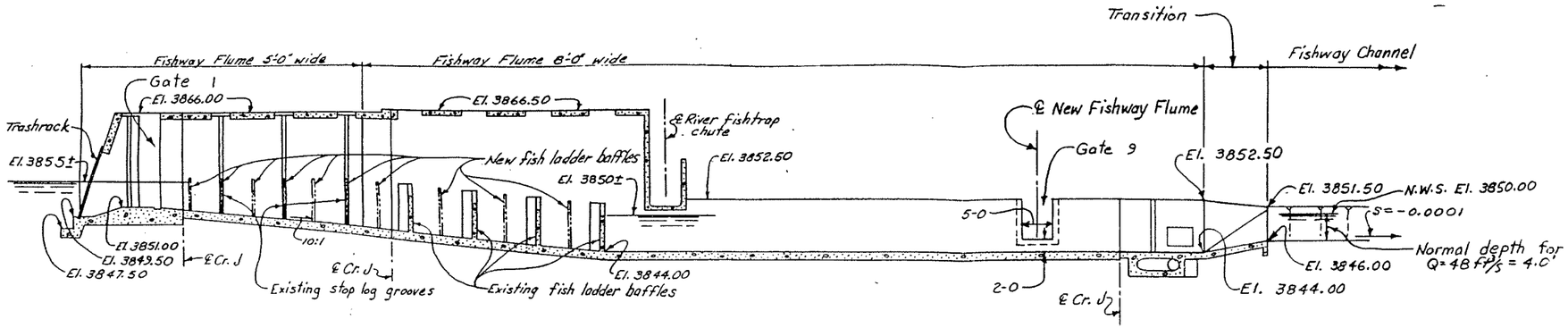
SECTION B-B
(Section through spillway)



SECTION A-A
(Section through sluiceway)

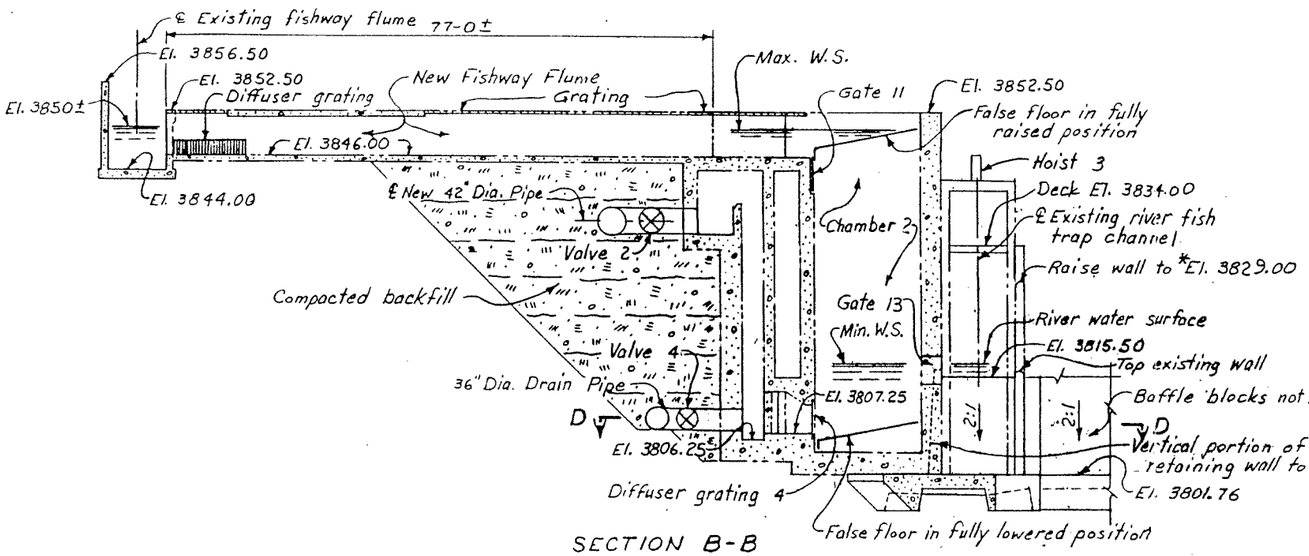
MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
GENERAL PLAN OF EXISTING FACILITIES

FIGURE 1

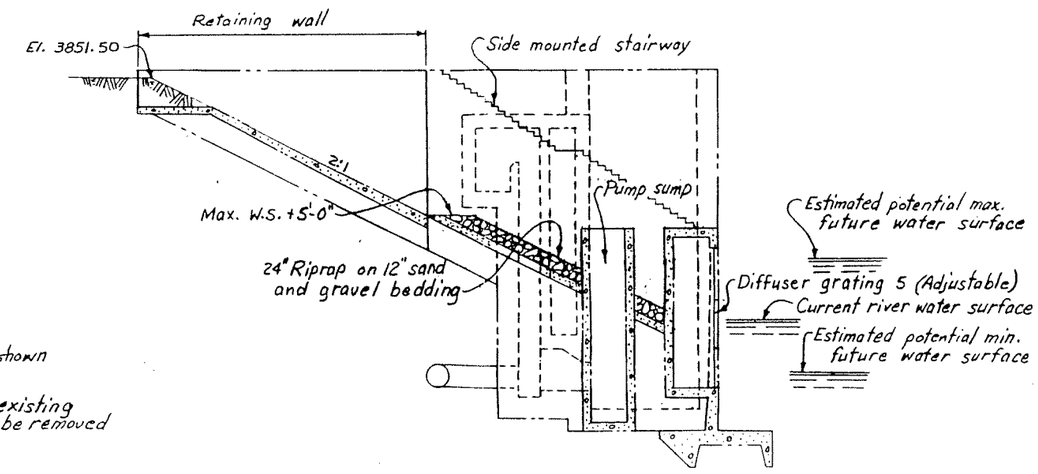


SECTION A-A

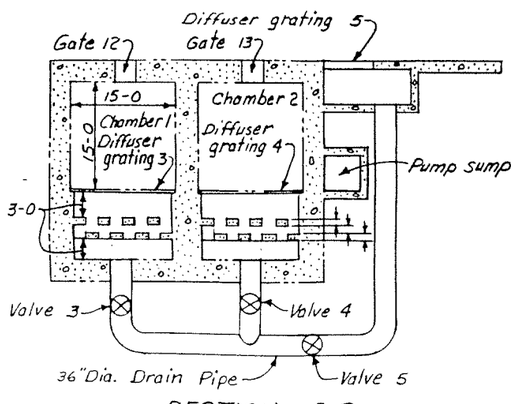
(Existing structures unless otherwise denoted)



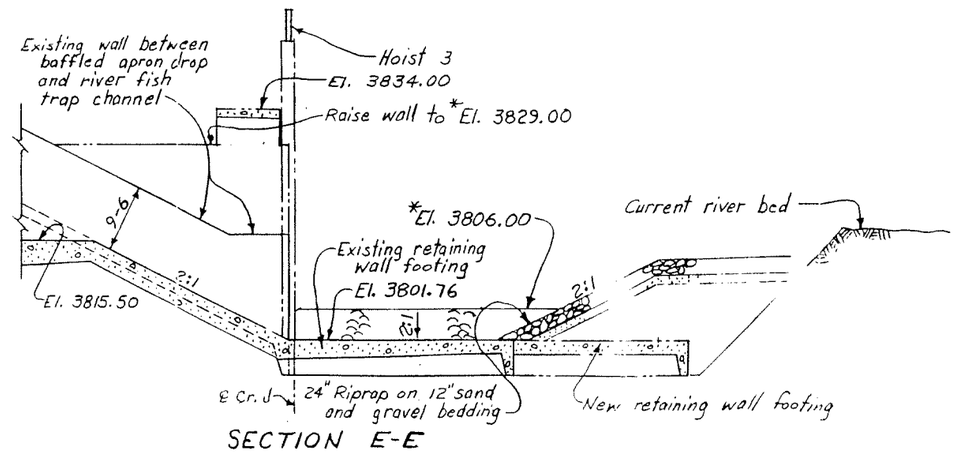
SECTION B-B



SECTION C-C



SECTION D-D



SECTION E-E

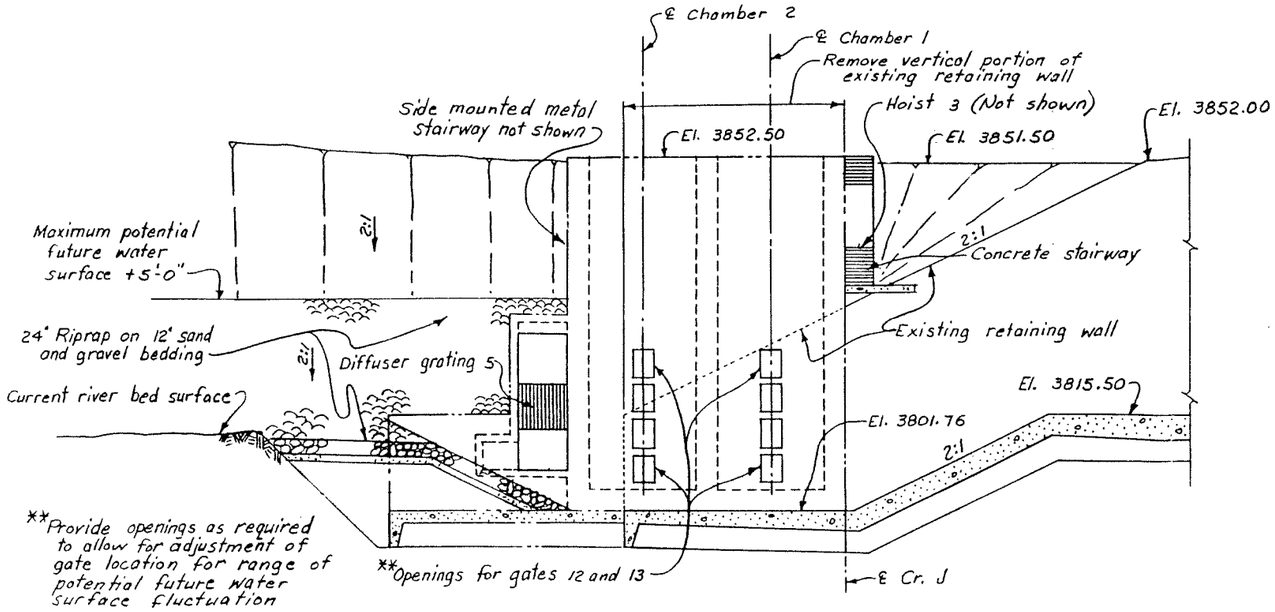
MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

NEAR-DAM DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT

SHEET 2 OF 3

FIGURE 9b



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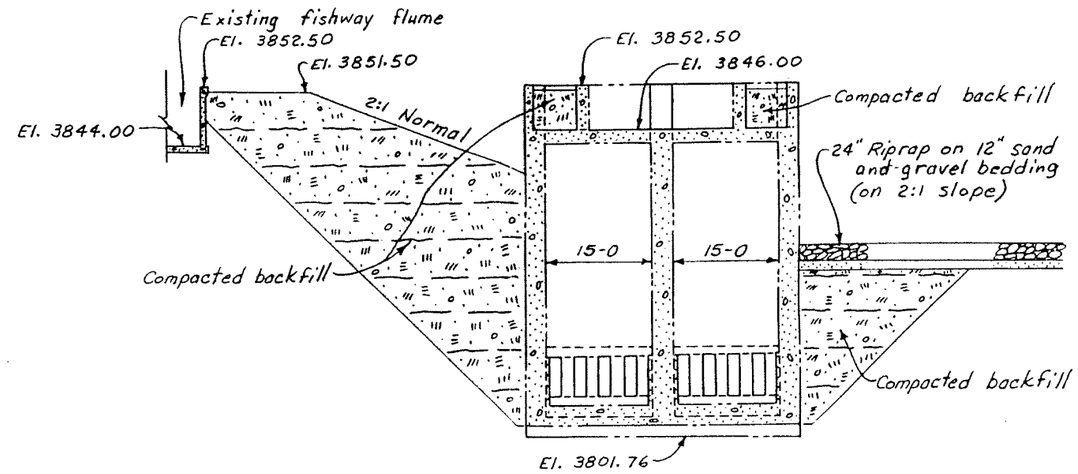

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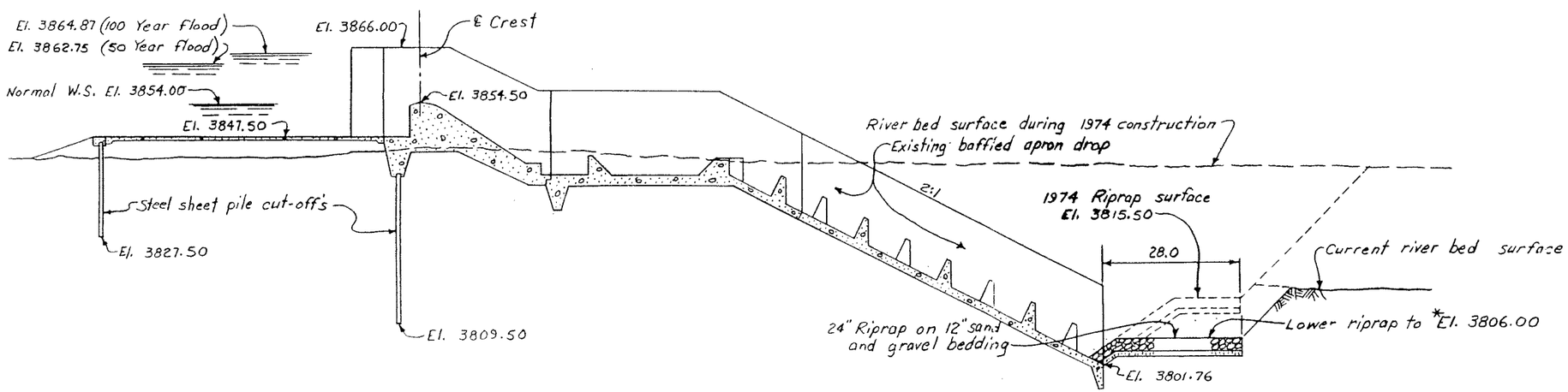
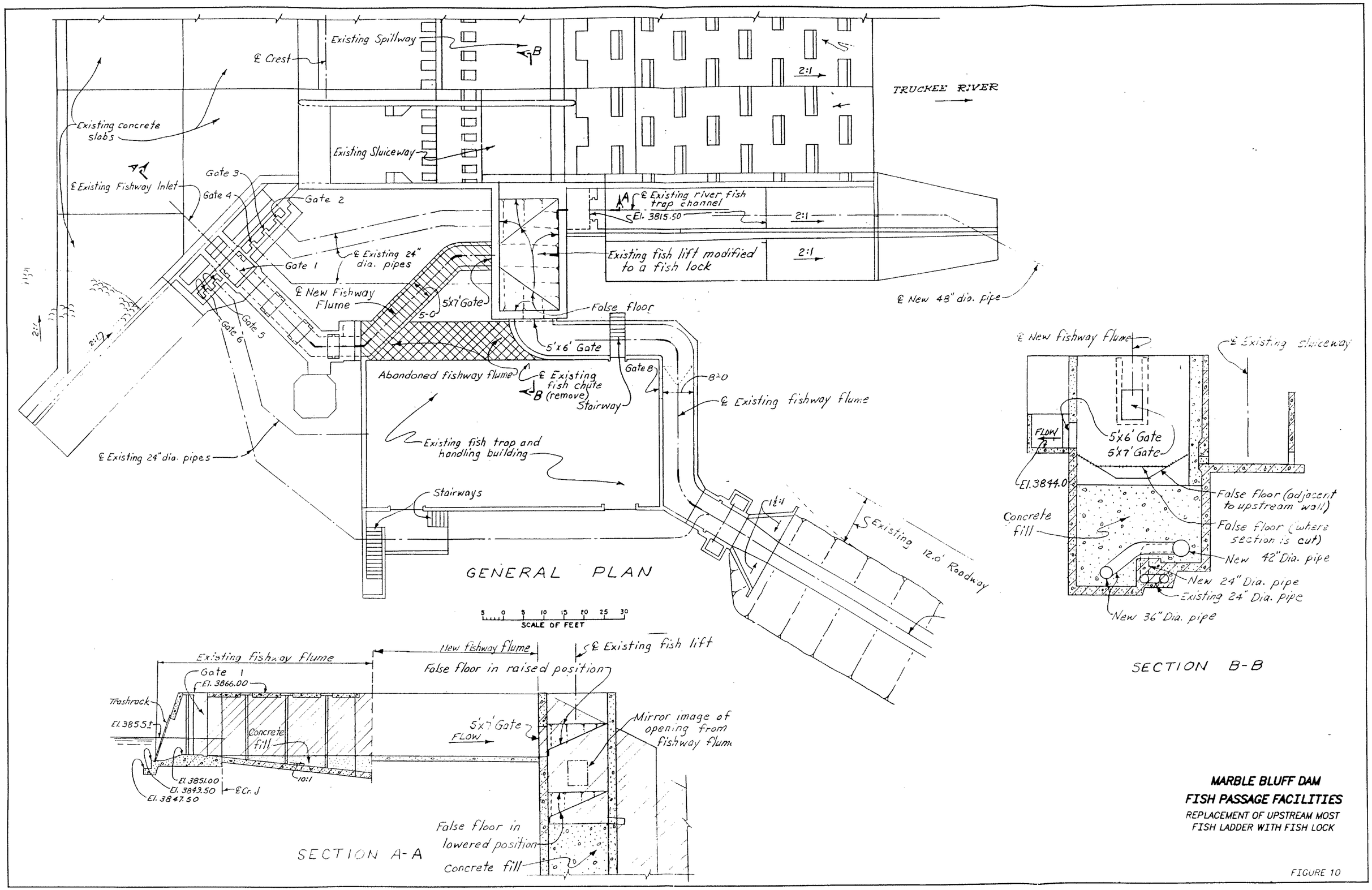


SECTION H-H

MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
NEAR-DAM DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT
SHEET 3 OF 3

FIGURE 9c

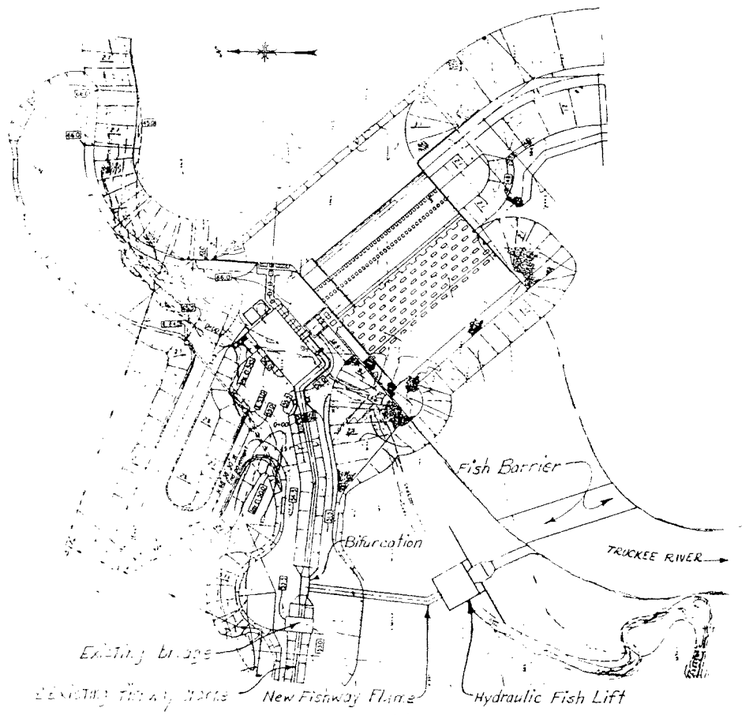


MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

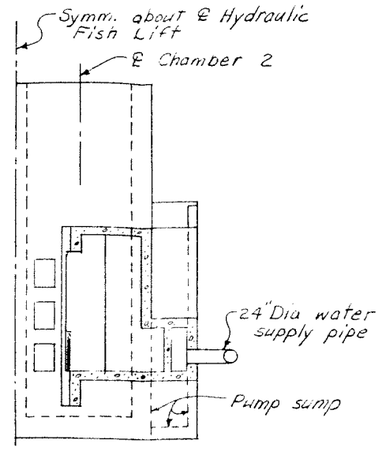
REPLACEMENT OF UPSTREAM MOST FISH LADDER WITH FISH LOCK

FIGURE 10

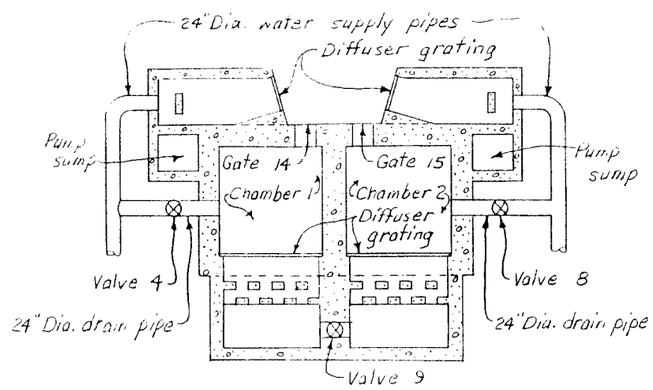


GENERAL PLAN

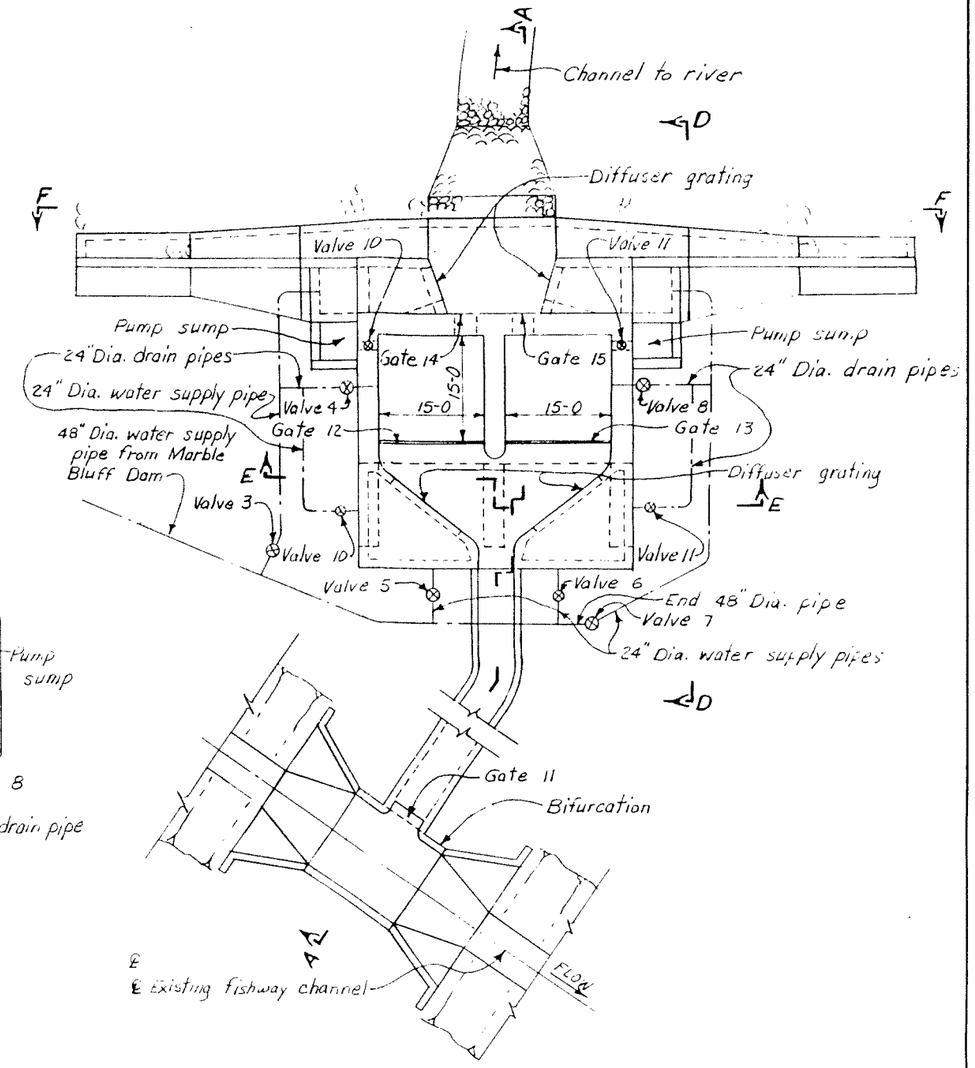
80 0 80 160 240
SCALE OF FEET



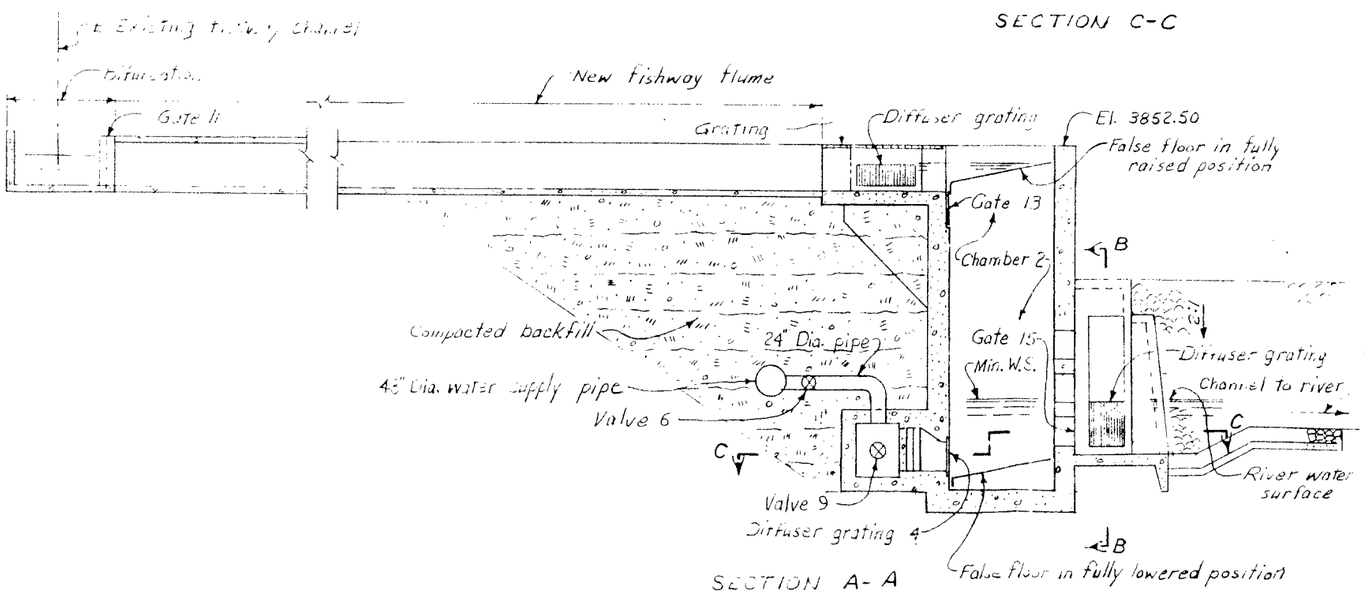
SECTION B-B



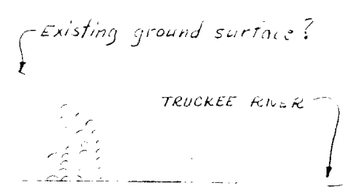
SECTION C-C



PLAN-HYDRAULIC FISH LIFT



SECTION A-A



5 0 5 10 15 20 25 30
SCALE OF FEET

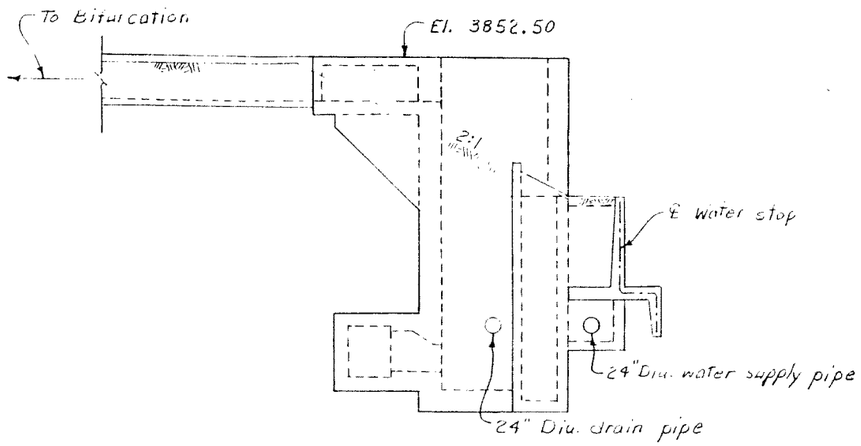
MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

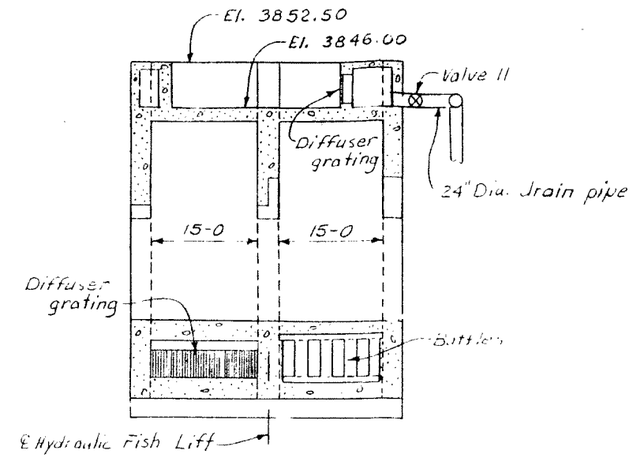
DOWN RIVER DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT

SHEET 1 OF 2

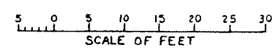
FIGURE 11a

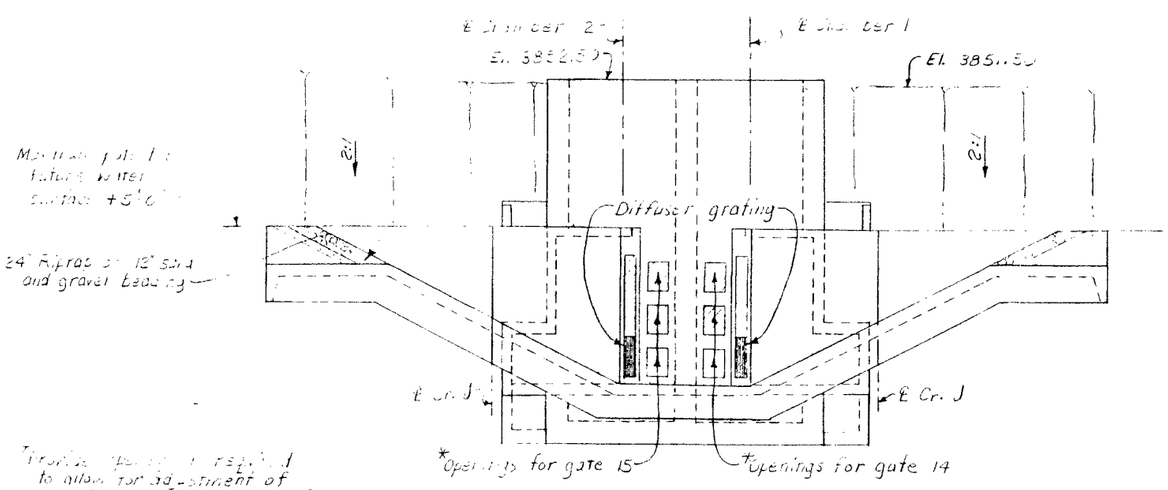


SECTION D-D



SECTION E-E





SECTION F-F

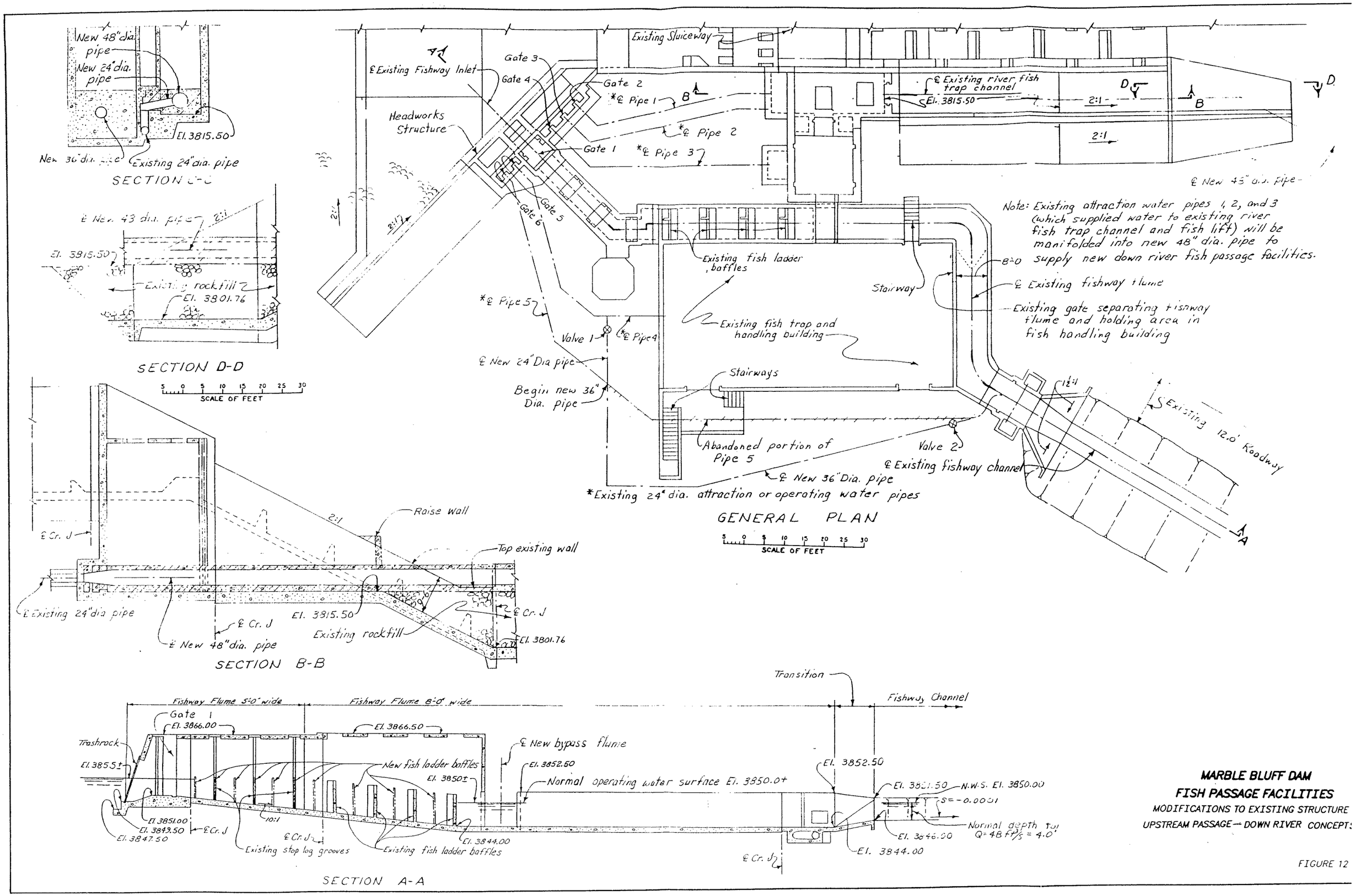
MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

DOWN RIVER DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT

SHEET 2 OF

FIGURE 11b



MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
MODIFICATIONS TO EXISTING STRUCTURE
UPSTREAM PASSAGE — DOWN RIVER CONCEPTS

FIGURE 12

In addition to the fishway bypass channel, a mechanical hoist type fish lift was designed to provide passage for fish migrating up the river to the toe of the dam. Neither of the fish passage facilities has functioned as intended. Cui-ui were found to be incapable of passing the fishway ladders as designed. The ladder design, figure 2, was based on then typical salmonid style ladders and available studies (Koch 1972, 1973, 1976; Ringo and Sonnevil 1977; U.S. Fish and Wildlife 1976, 1977, 1978) of the cui-ui physical and behavioral attributes. The mechanical fish lift, figure 3, has also had numerous operational problems and limitations that have been identified during use. Both structures have been progressively modified by FWS since their initial construction. Modifications have been made in response to a better understanding of the fish physical and behavioral needs and facility limitations. However, fish passage (both upstream and downstream passage) for the cui-ui and the Lahontan cutthroat remains a significant problem.

In accordance with the Cui-ui Recovery Plan (U.S. Fish and Wildlife, 1992) this concept-level study focuses on improving fish passage at Marble Bluff Dam and does not directly address improved functionality of the fishway. However, data on the fishway ladders were used to foster ideas and design requirements for implementing a ladder concept at the dam. This information is applicable to future improvements in the fishway ladders.

Figure 2 - A Marble Bluff Dam fishway ladder. As shown, the ladders were modified by adding intermediate baffles within each pool.

Study Scope

The Lahontan Area Office provided the following Purpose and Requirements that guided the scope of this study.

Purpose

Prepare alternative conceptual designs and cost estimates for improving passage of fish over or around Marble Bluff Dam in large numbers as required by the Cui-ui Recovery Plan. Based on the evaluation of the designs and estimates provided through this action, the Bureau of Reclamation will initiate final designs for

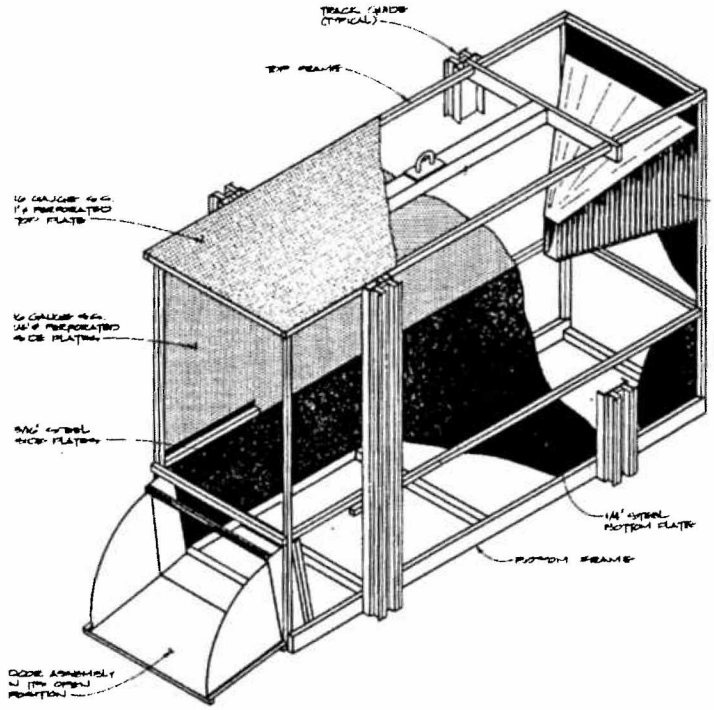


Figure 3 - Fish trap used for lifting fish over Marble Bluff Dam, FWS.

construction of modifications to Marble Bluff Dam and appurtenant facilities necessary to provide more efficient passage of fish at the facilities.

The modifications established through this process may not fully meet the needs and requirements for cui-ui recovery and may serve as interim measures only. Evaluation of the modifications designed and constructed through this process by the Lower Truckee River Restoration Steering Committee and the Cui-ui Recovery Team may indicate that further modifications will be required to integrate the operation of Marble Bluff Dam into the overall restoration plan.

Requirements

The work to be performed under this contract shall include development of at least three alternative feasibility-level designs for improvements to Marble Bluff Dam and related fish facilities with estimates of construction cost. The designs shall be developed through the following:

1. Review existing engineering drawings of the facilities construction and any modifications completed.

2. Visit Marble Bluff Dam a minimum of two times, one prior to development of alternatives and at least one time during the design process to assure that alternatives are reasonable for construction.

3. Meet a minimum of two times with appropriate representatives of Reclamation, the Fish and Wildlife Service, the Pyramid Lake Paiute Tribe, the Corps of Engineers, and the Lower Truckee River Restoration Steering Committee. The Cui-ui Recovery Team will be represented by and have input into the process through representatives of the Fish and Wildlife Service. At least one meeting shall occur prior to initiation of designs, one intermediate meeting, and one meeting when designs are nearly complete.

4. Plans shall consider both upstream passage and out migration of spawners from multiple fish species and return of fry back to the lake.

5. The goal of the design is to achieve the ability to pass up to 300,000 spawning fish upstream during a 3-day spawning run with as low a mortality rate as possible in accordance with the Cui-ui Recovery Plan. Estimates of mortality rates or limits should be prepared for each design alternative.

6. Designs must consider water velocity, water turbulence, oxygen content of the water, attraction flows, and other items which may be an impediment to cui-ui.

7. The design shall, to the greatest extent possible, provide for operational simplicity and minimized labor requirements.

8. A final report shall be prepared providing the designs, cost estimates, and enough detail to effectively compare the designs.

If possible the designs prepared should incorporate redundancy of equipment or facilities to prevent failure of one item from curtailing the operation of the facility.

The total estimated amount of funding available for the modifications is approximately $1.5 million.

Background on the Cui-ui[1]

Description

Lakesuckers (genus Chasmistes) are differentiated from other members of the family Catostomidae by thin lips, the lobes of which are separated and may lack papillae, and by a large terminal, oblique mouth. The four recognized species are residents of three distinct drainage basins: cui-ui (C. cujus) in the Truckee River basin of western Nevada (Pyramid Lake); shortnose sucker (C. brevirostris) in the Klamath River basin of Oregon and California; June sucker (C. liorus) in Utah Lake; and the recently extinct Snake River sucker (C. muriei) of the upper Snake River in Wyoming (Miller and Smith, 1981).

Cui-ui is a large, robust sucker with a long, broad, and deep head. The dorsal side of its coarsely-scaled body is blackish-brown with a bluish-gray cast which fades to a creamy-white belly. Breeding males develop tubercles on the anal and caudal fins (LaRivers, 1962; Miller and Smith, 1981). Larvae were described by Snyder (1983). Cui-ui is probably the largest of the living species of Chasmistes, weighing up to 7.72 lb (Snyder, 1917; Miller and Smith 1981). Female cui-ui have been documented exceeding a length of 27.6 in (Buettner, personal communication, 1991) with males attaining 26.1 in (Rissler, personal communication 1991).

At the beginning of the 20th century, cui-ui inhabited Pyramid and Winnemucca Lakes. Obligate stream spawners, cui-ui congregated near the mouth of the Truckee River in spring and migrated as far as 25 miles upstream (to the vicinity of Wadsworth, Nevada) to spawn (Snyder, 1917). The species was eliminated from Winnemucca Lake when it dried up in the 1930' following unrestricted diversion of water from the Truckee River and a severe drought.

Cui-ui is now restricted to Pyramid Lake and the lower Truckee River (downstream from Derby Dam). Pyramid Lake elevation is nearly 80 ft lower than at the turn of the century, and there are now structural impediments (e.g., Marble Bluff and Numana Dams) to fish passage. Adult and juvenile cui-ui inhabit Pyramid Lake year-round. Adults utilize the lower 12 miles of the Truckee River only during the spawning season (ranging from as early as April to as late as June) and only in years in which there are sufficient attraction flow and passage above or around the delta (Scoppettone, et al., 1986). Most spawners utilize the 10-mile reach between Marble Bluff and Numana Dams; as the fish ladder at Numana Dam is not conducive to passage of cui-ui.

---

[1] Material extracted from the U.S. FWS Cui-ui Recovery Plan, Second Revision

Life History and Habitat

Cui-ui is a large, long-lived and omnivorous sucker. Pyramid Lake provides rearing habitat for larvae, juveniles, and adults. The lower Truckee River provides primary spawning habitat. Adults, eggs, and larvae may be present in the river for a maximum of several weeks. Spawning has been observed at freshwater interfaces and springs within Pyramid Lake (Koch, 1973).

Lake Habitat

Pyramid Lake is the terminus of the Truckee River. It is saline (>4.1ppt), alkaline (pH = 9.1-9.3) and categorized as oligotrophic to mesotrophic. From 1981 to 1990 the maximum depth has ranged from 365 to 390 ft. Average annual evaporative loss is approximately 440,000 acre-feet, which creates a vertical drop of 4 ft. Pyramid is a monomictic lake and may stratify as early as May; it usually remains stratified until December. Depth of the thermocline varies from 35 to 85 ft (Galat, et al., 1981). As of November 1991, the lake elevation was 3800.3 ft.

For much of the year adult and juvenile cui-ui inhabit the littoral zone at depths of 60 to 100 ft. Juveniles appear to concentrate at the north and south ends of the lake. They are most active during summer and fall; however, a seasonal migration pattern has not been demonstrated (Scoppettone, personal communication, 1991).

River Habitat

The lower Truckee River is a low- to moderate-gradient stream descending at a rate of approximately 7.9 ft/mile. The banks are composed of unstable sedimentary material which is vulnerable to severe erosion. The stream channel has changed significantly during this century. Lowering of Pyramid Lake and artificial straightening of the river for flood-control purposes (Gregory, 1982) have created a shallow, braided, and unconfined channel network, and formed a broad delta at the mouth (Born, 1970; Glancy, et al., 1972). Marble Bluff Dam functions as a hydraulic control to reduce upstream erosion, and has also created several miles of habitat suitable for cui-ui spawning immediately upstream.

Discharge in the lower Truckee River is highly variable between seasons and years, depending, in part, on upstream storage and diversions at Derby Dam. Average annual inflow to Pyramid Lake for the period 1918-1970 was approximately 250,000 acre-feet (Matthai 1974). Runoff, a function of snowmelt, generally peaks in late spring (average of 56,000) acre-feet in May) and is lowest in late summer (average of less than 1,000 acre-feet in August).

Spawning

Adult cui-ui congregate in March and April near the mouth of the river prior to migration. Spawning runs begin in April or May, depending upon timing of runoff, river access, and water temperature. There is evidence that a high volume spring runoff attracts more spawners and promotes egg ripening (Sonnevil, 1981; Buchanan and Strekal, 1988). Most spawners migrate less than 6 miles upstream, but some may travel up to 12 miles. While most spawners spend only a few days in the river, some may remain up to 16 days. Spawning runs may continue for 4 to 8 weeks, but most fish migrate during a 1- to 2-week period (Coleman 1986).

Current Status of Fish Passage at Marble Bluff Dam

Upstream fish passage is achieved by mechanically hoisting a fish trap. The trap-and-release channel back to the river has been extensively modified since 1978 to improve operation. During attraction, the trap sits in a well at the head of a concrete approach channel along the right bank of the downstream river channel, figure 4. Fish move up the approach channel following attraction flows and pass into the fishtrap, figure 3. Operators judge when to raise the trap. Fish caught in the fish trap can be released into the fish evaluation building, or when raised higher, released into the head end of the fishway channel that skirts the evaluation building. The fish trap basket is then lowered back into attraction position in the well.

Deficiencies of the Existing System

The major areas of concern for improving fish passage are:

Attraction zone - Hydraulic conditions at the base of the baffled apron spillway are extremely turbulent and varied. The spillway baffles within the tailwater zone produce a series of high velocity jets between baffles alternating with wake zones behind baffles. The complicated flow at the spillway and tailwater interface likely causes disorientation and delay of fish seeking a migration path over the dam. Attraction of fish to the fish trap approach channel apparently has not been identified as a major problem for the current trap system. However, a more efficient fish passage method will be limited by the poor attraction zone.

Passage efficiency - The original system was designed such that all fish entering the lift must pass through the fish evaluation facility. The system was modified in 1987 to allow fish to be lifted and released directly to the river via the fishway channel. This modification included designing a new trap basket, raising the elevation of the hoist, and adding a new high elevation release channel. Although improved, during large runs the modified system has proved too slow to handle the large numbers of fish encountered and has caused unacceptably high mortality due to fish over-crowding in the fish trap basket. Comments expressed

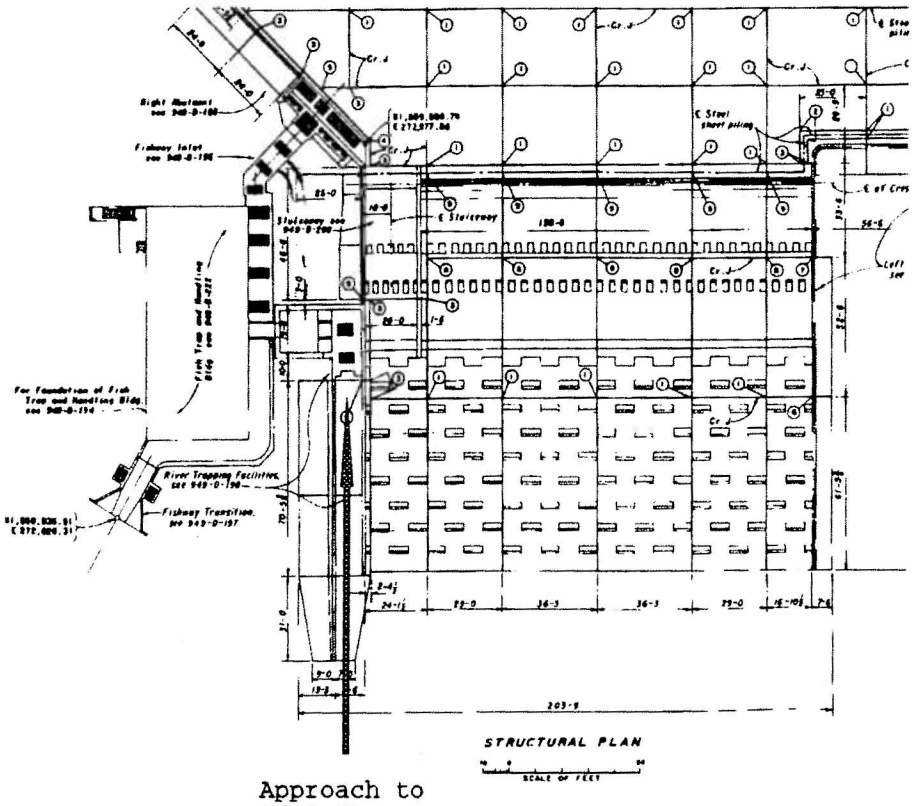


Figure 4 - Plan view of Marble Bluff Dam showing the approach channel to the river fish hoist/trap.

by FWS personnel and the Paiute Indian Tribe, who help operate the facility are: the system is slow due to operating problems with the release gate; the time required to submerse the lifting basket to the bottom of the attraction well after each cycle is too long; the system is too labor intensive; and the system requires considerable judgement by the operators. As cited by the requirements of the study, a goal of passing 300,000 fish in a 3-day period is needed to accommodate the unique nature of the large numbers of cui-ui that may run for a short duration.

System backup/simplicity - A point frequently mentioned is the lack of a backup system and the need for simplicity of operation. Past experience has shown a relatively minor breakdown of the hoist mechanism can result in a significant reduction in total fish passage at the dam due to the short time fish tend to run. The present system also requires too much human interface to properly complete its function. During cui-ui runs the facility requires 24-hour staffing.

Fishway flow inlet conditions - Short circuiting, defined as fish exiting the fishway and passing back downstream over the dam, is a suspected problem. The river inlet to the fishway channel is about 35 ft to the left of the spillway. The sluiceway gate is closed during fishway operation. As shown on figure 1, the dam is located on a bend in the river. The fishway exit lies on an upstream angled wingwall on the outside of a river bend. The cui-ui and the Lahontan cutthroat both run in the spring during high river flows, which coincide with high sweeping velocities along the wingwall. Flow velocities near the fishway exit may be sufficiently high to carry weak swimmers back downstream over the spillway.

Downstream passage - The only downstream fish passage paths are over the dam's baffled apron spillway or through the fishway channel when operating. Fish and Wildlife Service estimates a mortality rate of fry passing over the spillway's baffled drop of about 10 percent. Mortality or delayed mortality as a result of adult fish passing over the spillway is largely unknown. The fishway channel diverts only about 20 to 50 ft^3/s of the river flow, has no guidance structures to the inlet, and has an imposing trashrack covering the inlet. When operating, fishway diversion flows likely contribute little to downstream fish passage.

Depth of the fish trap attraction channel - The stream channel bed below Marble Bluff Dam has degraded from about elevation 3844 in the 1970's to about elevation 3815.5 today, figure 1 section B-B. Elevation 3815.5 is the top of the downstream protective riprap and the attraction channel invert. Continued degrading of the downstream channel will result in the riprap forming a drop or being undermined and failing, which will result in a drop in water level below elevation 3815.5. The uncertainty of future river channel degradation below the dam is a major design concern for fish passage.

Fish Passage Concept Development

Substantial experience and data exist on fish passage at Marble Bluff Dam. The FWS has, over a period of many years, studied spawning of the cui-ui and the Lahontan cutthroat. They have worked steadily to understand and improve the fish passage facilities constructed at the dam and fishway in 1978. This knowledge base and a literature review of other non-salmonid fish passage facilities were used to develop concept level fish passage designs for Marble Bluff Dam. Several organizations have participated as an advisory group providing fish passage ideas, data, and peer review during concept meetings held in Carson City, Nevada. The FWS, Pyramid Lake Paiute Tribe, U.S. Bureau of Indian Affairs, Truckee Nature Conservancy, and Reclamation participated.

Types of Fish Passage

Fish passage problems at Marble Bluff Dam are complicated by both a degrading stream channel and the unique spawning behavior of the cui-ui lake sucker. The difficult issues of fish passage at the site lead to numerous methods of fish passage being investigated during the concept study. The main fish passage methods investigated were:

- Meandering channel from the dam to the lake.
- Meandering channel from the dam to the river below the dam.
- Channel and drop fishway.
- Replacing the mechanical fish lift with a lock type fish lift.
- Adding a separate lock type fish lift.
- Vertical slot and orifice fish ladder.
- Improving the existing mechanical fish lift.

Each fish passage method was investigated to demonstrate general feasibility. Those methods which were deemed feasible were further developed toward achieving the goals set in the study scope.

Meandering Channel to the Lake

Several members of the advisory group who have experienced the problems of river delta passage and past operational problems with the existing lift favored moving toward an improved fishway channel diverting flow directly to the lake. The idea was raised to construct a meandering channel of sufficient length so fish ladders would not be needed along its course. The operating water surface elevation upstream of Marble Bluff Dam is 3854 and the current lake water surface elevation is about 3794, a difference of 60 ft.

The Manning formula can be used to design channels assuming steady uniform flow.

$$Q=\frac{c}{n}AR^{\frac{2}{3}}S^{\frac{1}{2}} \qquad (1)$$

where,

Q = discharge, ft^3/s
c = Manning coefficient, 1.49 (English units)
n = roughness coefficient
A = channel area, ft^2
R = hydraulic radius, A/P where P = total length of wetted perimeter, ft
S = energy grade line slope

Assuming a target design velocity (V = Q/A), equation 1 can be rewritten as:

$$\frac{V}{S^{\frac{1}{2}}c} = \frac{R^{\frac{2}{3}}}{n} \qquad (2)$$

This form of equation 1 gives insight for meeting design objectives. Ideally, one would like to minimize the quotients of equation 2. This says a rough, wide and shallow channel will provide the greatest energy loss for the given velocity and discharge constraints.

For example, a trapezoidal channel with 1½:1 side slopes designed with the same capacity, velocity, and depth criteria as the existing fishway channel will have the following properties:

Capacity (Q) = 48 ft^3/s
Velocity (V) = 1 ft/s
Depth of flow (d) = 4 ft
Bottom width (b) = 6 ft
Mannings "n" (n) = 0.035, riprap lined
Bottom grade (s) = 0.000178
Length of channel (L) = 63.8 miles

The channel length can be reduced by designing for higher velocity and shallower depths. Increasing the design velocity to V = 2 ft/s, and reducing the depth to 2 ft gives:

Q = 48 ft^3/s
V = 2 ft/s
d = 2 ft
b = 9 ft
n = 0.035
s = 0.00131
L = 8.7 miles

A fishway channel would have to have a seepage liner covered with coarse riprap the entire length. In addition to length, there are several other deterrents to a meandering channel fishway at the site. The channel would act as a trap for wind blown sands. Sand material would both flush with operation and deposit within the riprap lining. Significant quantities of sand within a lengthy fishway could reduce the design roughness and result in higher than desired velocities in some sections. Secondly,

a fish ladder would be needed as a terminal structure to provide for any future decline in the lake elevation.

Meandering Channel from Marble Bluff Dam to River

If a riprap lined channel were constructed from the dam to the river just below the dam, the drop in water surface would be a maximum of 34.5 ft. Assuming design parameters similar to the previous case, a channel slope of 0.00131, the channel would be about 5-miles long. The problems of wind blown sand deposition and possible degradation of the river channel are again major concerns.

Fishway Channel with Small Drops

A channel with a series of 6-in drops was also investigated. Table 1 gives the maximum and minimum water depths and velocities for a variety of conditions given a channel with low sill drops similar to the channel shown on figure 5. A long channel with a uniform bottom grade reaches normal depth for a given capacity. When drops are added at regular intervals along the same channel, backwater will develop with varying water depths. The backwater will stabilize when a "steady-state" situation is reached. The water depths in the steady-state backwater will always be less than normal depth.

Table 1 - Backwater calculations for fishway with small drops

Run No.	Q Discharge (ft^3/s)	b width (ft)	POOLS		CHUTES		STEADY STATE			
			Slope (ft/ft)	Length (ft)	Slope (ft/ft)	Length (ft)	Depth max (ft)	Vel. min (ft/s)	Depth min (ft)	Vel. max) (ft/s)
1	125.4	25.35	0.00012	480	0.0250	20	2.33	1.87	1.81	4.46
2	117.2	11.50	0.00010	560	0.0125	40	3.45	2.04	2.97	2.47
3	96.0	10.00	0.00034	480	0.0250	20	3.02	1.59	2.50	2.75
4	57.7	7.88	0.00040	560	0.0125	40	2.87	1.65	2.87	2.12
5	48.0	9.00	0.00010	560	0.0125	40	2.43	1.56	1.94	2.07
6	48.0	6.00	0.00017	480	0.0250	20	2.71	1.76	2.20	2.35
7	60.0	6.00	0.00017	480	0.0250	20	3.02	1.88	2.51	2.45

e channel lengths from the dam to river downstream of dam (34.5-ft drop in water surface) for each channel and drop ernative are given below. A set of pools is one pool plus one chute.

n No.1 - Length set = 500 ft, drop/set = .5576 ft sets required 34.5/.5576 = 62 sets = >Lt =31,000 ft = 5.87 miles.
n No.2 - Length set = 600 ft, drop/set = .5560 sets required 34.5/.556 = 62 sets = > Lt = 37,00 ft = 7.05 miles.

Run No.3 - length set = 500 ft, drop/set = .666 ft sets required 34.5/.666 = 52 sets = > Lt = 26,00 ft = 4.92 m
Run No.4 - Length set = 600 ft, drop/set = .724 ft sets required 34.5/.724 = 48 sets = > Lt = 28,00 = 5.45 mi
Run No.5 - Same as Run No.2.
Run No.6 - Length set = 500, drop/set = .5854 ft sets required 34.5/5854 = 59 sets = > Lt = 29,500 ft = 5.59 m
Run No.7 - Same as Run No. 6.

As an example, figure 5 shows the steady state backwater profile for the following channel, when 6-in drops are added every 480 ft:

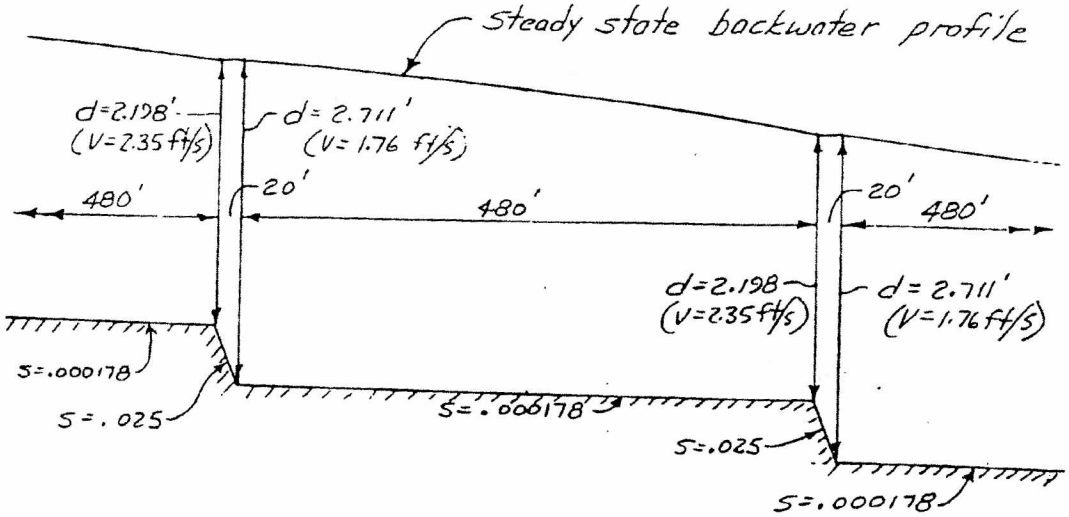
Q = 48 ft^3/s
b = 6 ft
s = 0.000178
side slopes = 1-1/2:1
n = .035
normal depth, d = 4 ft
Velocity at normal depth = 1 ft/s

The maximum and minimum steady state water depths are 2.71 and 2.20 ft, respectively, which are significantly less than the desired 4-ft depth. Runs 6 and 7 show water depth can be increased by increasing the capacity; however, the velocities will also increase. Simply said, low sill structures will not provide the desired backwater. Weirs with elevated sills or contracted sections are required to control the flow to achieve deep pools and low velocities between drops.

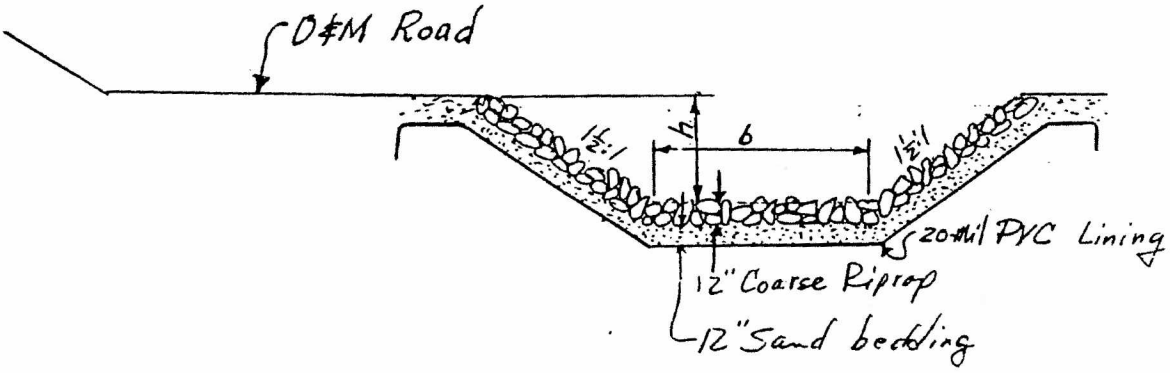
Modify Existing Fish Hoist to a Fish Lock

The existing mechanical fish trap and hoist could be abandoned in place of a fish lock concept. A fish lock is simply a water elevator which operates similar to a boat lock. Locks can be used to move fish over dams of nearly any height. Locks are often used where multiple species passage is required. By lifting fish, locks are as efficient at passing weak swimmers as strong. There are a large number of fish locks in use, however, only a few in the U.S. The oldest and simplest lock design is the Borland lock, developed in Scotland, figure 6. The Borland is a closed chamber design. Closed chamber designs have been shown to deter fish entry, probably due to decreasing light. Open well type locks like the Ardnacrusha Fish Lock in Ireland, figure 7, have generally performed better. Locks lift fish over dams with very low physiological stress. Locks typically require monitored operation and provide lower fish passage capacity than ladders.

The existing fish trap chamber could be modified to work as a fish lock. The mechanical fish lift structure operates in a 15-ft by 15-ft vertical shaft with a 7-ft-deep sump below the entrance, figure 8. A large single chambered lock could be incorporated within the existing well. The attraction channel and entrance to the lock would be unchanged from the existing fish trap conditions. Entrance to the lock will become un-passable for cui-ui if the river channel near the entrance degrades below



EXAMPLE STEADY STATE BACKWATER
Q = 48 cfs
b = 6 ft
Side slope 1½:1
n = .035



TYPICAL CHANNEL SECTION

Figure 5 - Example of a fishway channel with small drops.

El. 3815.5. After being lifted and moved from the lock, fish could be passed into the existing fishway just downstream of the final ladder or upon raising the walls of the well, fish could be lifted to the river elevation and passed directly into the fishway inlet channel.

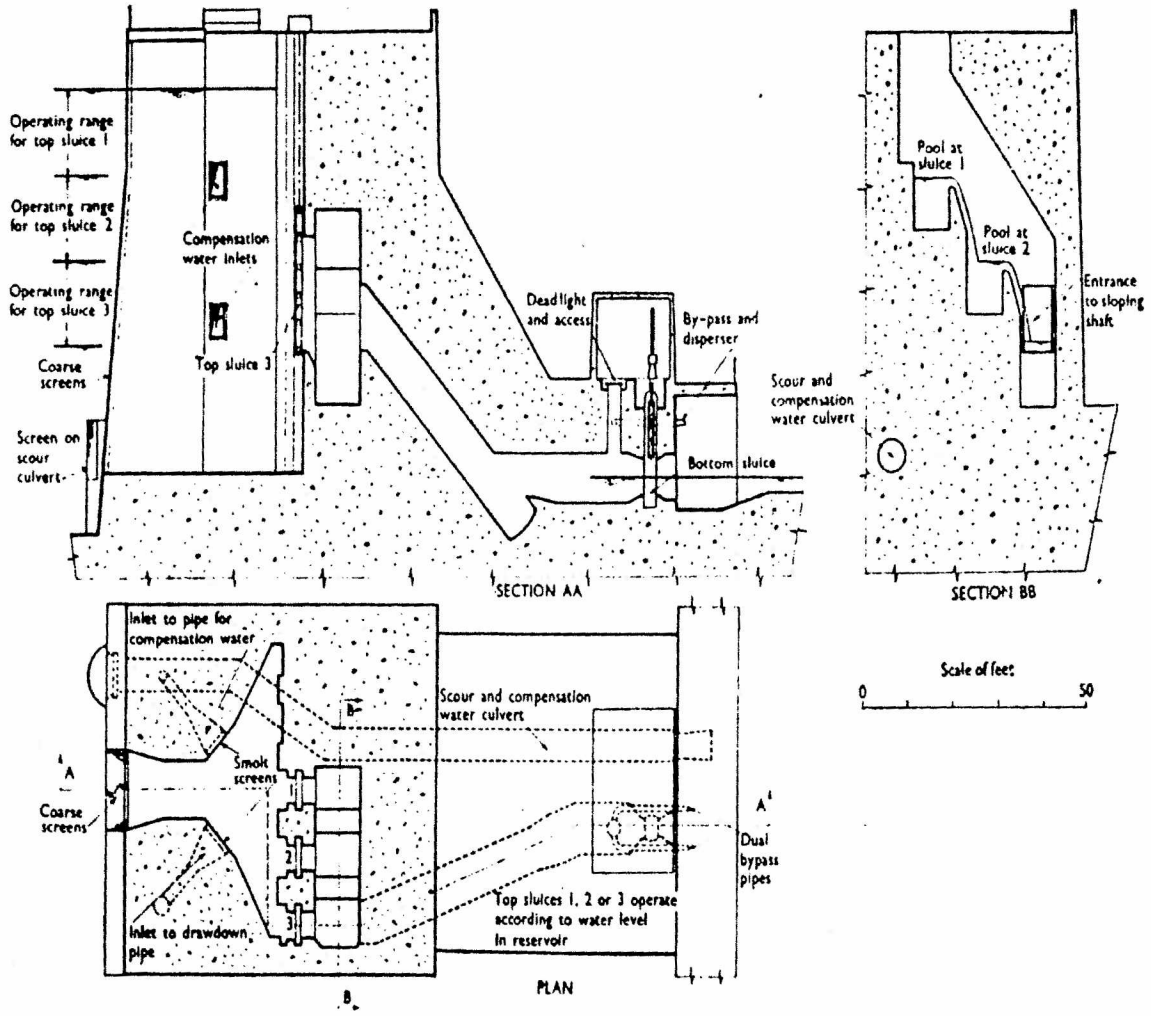


Figure 6 - Borland style fish lock, Aitken 1966.

As identified by the project objectives, an estimated fish passage capacity of 300,000 fish during a 3-day period is needed at Marble Bluff Dam to prevent migration delays at the dam. Estimating fish passage capacity is difficult for any fish passage structure as fish behavior and physical attributes are involved. For this concept study, generic guidelines published by the FWS were used to estimate fish passage capacity for lock

and ladder options (source for guidelines - National Biological Service, S.O. Conte Anadromous Fish Research Laboratory).

FWS guidelines define peak fish passage capacity for a lock as:

Peak capacity = total cycle time * volume of attraction pool * number of fish per unit volume

Total cycle time = attraction + filling + flushing fish + emptying

- Attraction times vary widely depending on the species and attraction conditions, based on prior experience from the Marble Bluff Dam fish trap assume 30 minutes.

- Filling time is proportional to the differential elevation between the water level in the well and the river elevation. As the well is supplied water from the river at the fishway headworks, the chamber filling rate progressively slows as the water surface rises in the well. The well takes about 7-10 minutes to fill using the two existing 24-in-diameter pipes.

- The fish flushing period is assumed to be about 5 minutes for a lock with a crowder to force fish from the well.

- The time required to empty the lock will be about 30 minutes. A slow emptying rate is necessary because flow must be discharged back into the attraction channel. Exit velocities must be maintained below about 3 ft/s to prevent flushing fish from the channel that are waiting to enter the lock. The excavation needed to add a new pipe to empty the lock downstream would be extremely difficult at the existing site. A pipe to waste flow could be hung above the attraction channel at about elevation 3825 and then waste flow into the downstream spillway. This approach would allow rapid emptying of the lock to elevation 3825 after which the remaining volume would have to be released slowly through a low level valve. Total peak cycle time is therefore limited to about 1 cycle per 1.25 hours, or 0.8 cycles per hour.

Volume of attraction pool = depth of attraction pool * area

- Depth of attraction pool = sump depth + river stage above 3816.5 - 3 ft for crowder. Attraction pool depth is equal to 5 ft assuming a river stage of 3917.5 in the attraction channel.
- Area of well = 225 ft^2.
- Volume of attraction pool = 1125 ft^3. FWS guidelines recommend reducing attraction pool volumes by 15 percent for unusable space or non-target species; therefore, the attraction pool volume is 956 ft^3.

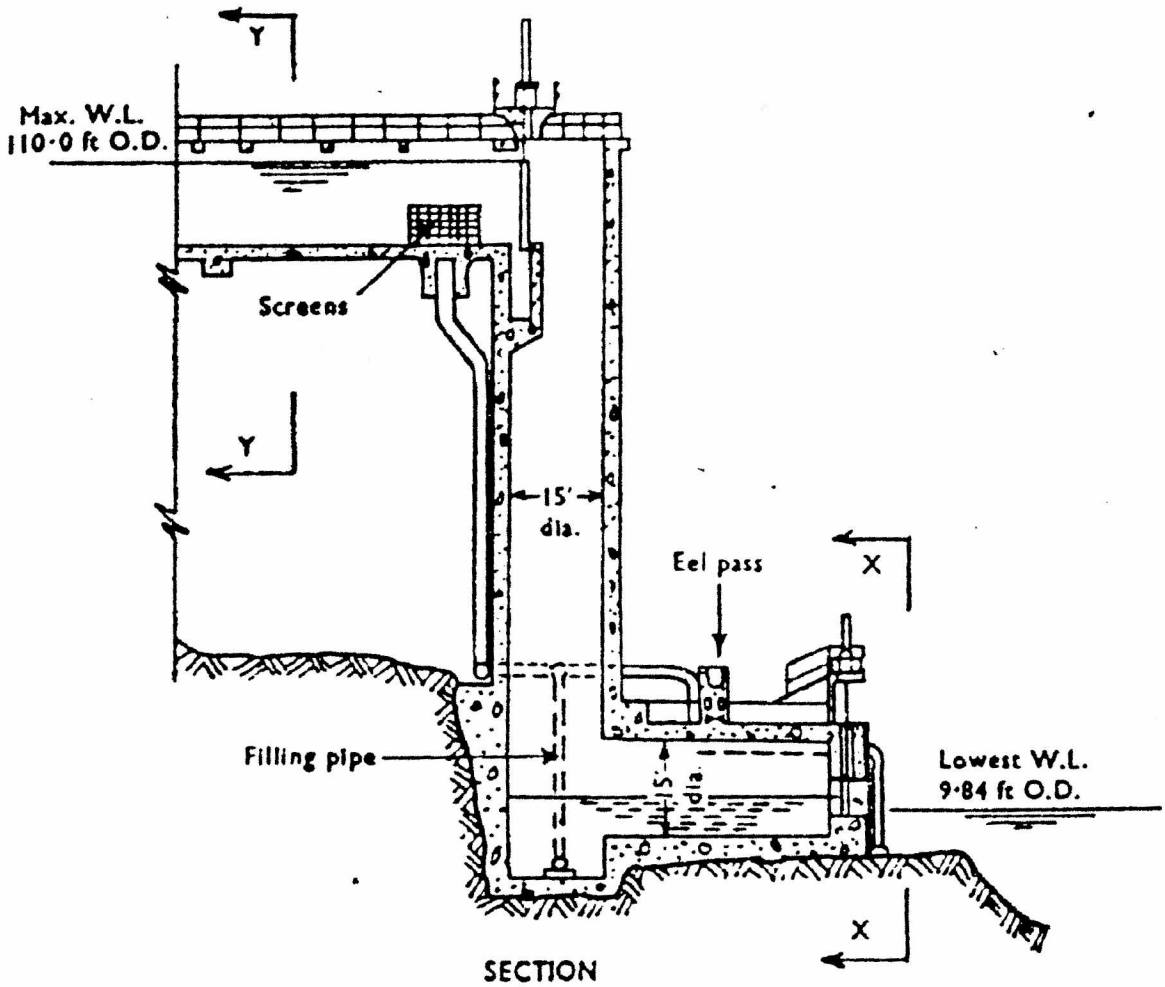


Figure 7 - Vertical lift fish lock at Ardnacrusha, Ireland, Aitken, 1966.

Number of fish per ft^3 = for cui-ui we assumed 1 fish per ft^3 (this value will be lower for larger average sizes of fish).

Peak capacity per hour = 764 fish/hour (956 ft^3*1 fish/ft^3*.8 cycles/hour). If the concentration of fish migrating up the river was constant for 3 days, approximately 55,000 fish could be passed through the lock. However, peak daily capacity would likely be significantly less due to the randomness of migrating fish populations approaching the attraction area. Despite the uncertainty associated with estimating peak fish passage capacity, peak capacity values do provide a good basis of comparison between various fish passage alternatives.

<u>Pros and cons of converting the fish trap/lift to a single chamber lock concept</u> -

Positive aspects of this fish passage concept are:

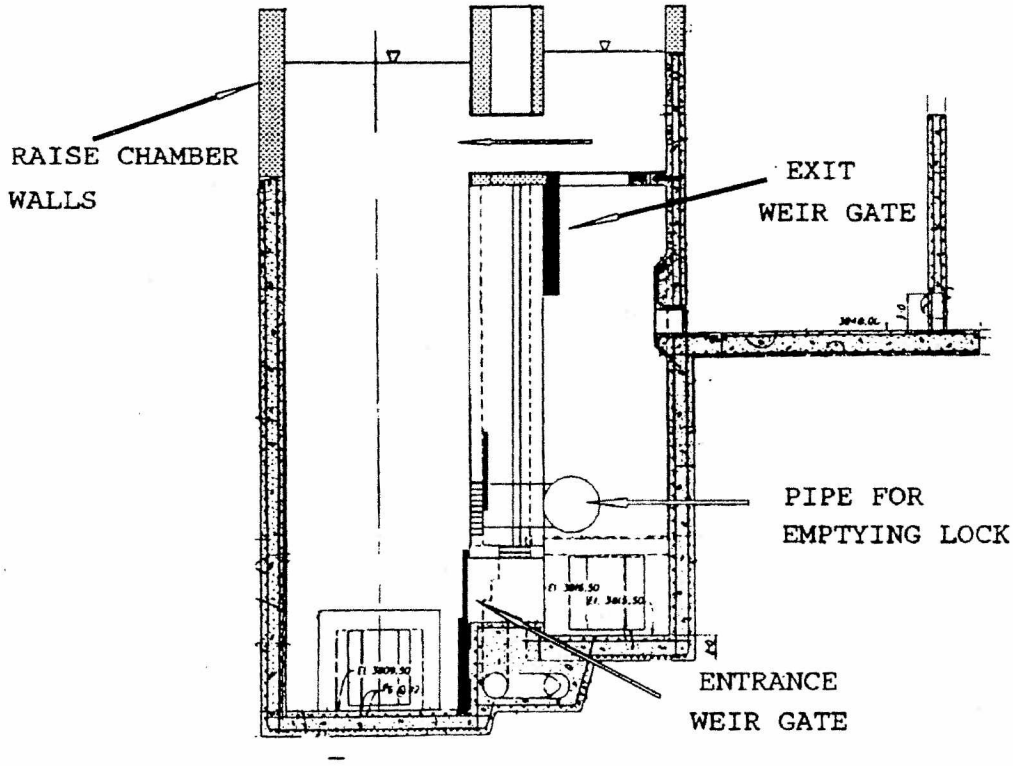


Figure 8 - Mechanical fish hoist/trap modified to a lock concept.

1. Requires minimal construction
2. Will pass fish over the dam with low physical stress
3. Can be designed to pass fish to the fishway inlet channel, bypassing all existing fish ladders.

Negative aspects of concept:

1. The elevation of the attraction channel floor, 3815.5 is a concern. Continued degradation of the river channel below the dam may limit or prevent fish entry into the channel.
2. Peak fish passage capacity is estimated to be about 55,000 fish over a three day period.
3. Attraction conditions are poor. Spillway flow will inhibit or delay fish from finding the entrance to the lock.
4. Requires automated or manual operation of a sequence of valves to complete each cycle.
5. A single lock design would not provide a backup system.

Due to the low estimated capacity, a full concept design and cost estimate was not pursued.

Dual Chambered Fish Lock

Two conceptual designs were developed for a dual chambered fish lock. The first is a near-dam design with the structure located at the entrance to the existing river fish trap attraction channel and a similar lock design moved about 200 ft downstream of the dam. Each concept is discussed.

Near-dam lock - The near-dam dual chambered lock is shown in figures 9a, 9b, and 9c. The design incorporates a new vertical lock structure, a modified headworks providing for a new water supply pipe, a short section of fishway channel intersecting the existing fishway, and modification or replacement of fishway ladder located adjacent to the evaluation building, figure 9a.

Fish enter the lock adjacent to the existing river fish trap channel. The lock lifts fish to approximately elevation 3846 where they are moved out of the lock into a short channel that intersects the existing fishway channel downstream of the fish evaluation facility. From the intersection point upstream, fish from the river lock would be combined with fish moving up the fishway. At the evaluation facility, fish could be diverted into the facility or continue move up the fishway channel toward the fishway headworks. The concept of combining fish moving up the river with fish moving up the fishway will require an efficient method of passing fish directly to the river. There remains about a 4 ft elevation difference between the entrance to the evaluation facility and the fishway headworks, El. 3851. The original fishway design provided a short ladder at a 10:1 slope similar in design to the down channel fishway ladders. The ladder proved ineffective for cui-ui passage and has been largely abandoned in favor of moving all fish through the fish evaluation facility. Problems with flow conditions within the ladder have been complicated by the manual stoplogging required to adjust for changing river stage. The evaluation facility was not designed to handel the total fish passage capacity of the fishway, therefore the present method of operation is difficult and has created migration delays.

Two concepts were considered in this study to provide fishway passage from the fishway directly to the river. One option is to modify the old fishway ladder. Peak flow velocity in the ladder could be reduced to about 3.4 ft/s (a drop of 0.36 ft across each baffle) by modifying the ladder to include 14 fish ladder baffles at 5-ft centers, figure 9b, section A-A. Baffle design should be determined by model and field testing.

The second concept studied proposes replacing the upstream most fishway ladder with a second fish lock, figure 10. A concept similar to the previous proposal for replacing the existing mechanical fish lift with a single chamber fish lock is proposed.

The floor of the existing well would be raised to about elevation 3840 to reduce the lock cycle time and provide sufficient attraction area to handel the large numbers of fish that could be moving up the fishway.

Fish passage capacity for the dual lock design is improved over a single lock by having two locks operating out of phase. While one lock is filling and emptying, the other is setting in the attraction phase. Capacity of the dual lock design is estimated as:

Total peak cycle time = attraction + filling + flushing fish + emptying

- Attraction time - With a dual lock design, attraction time is concurrent with filling and emptying of the adjacent lock. Therefore, the system is not delayed awaiting fish to move into the attraction chamber. Attraction time can be considered zero.

- Filling time is similar to the dam-lock design, 7-10 minutes to fill.

- The fish flushing period is about 5 minutes for a lock with a crowder to force fish from the well.

- The time for emptying is about 10 minutes. Water can be wasted away from the attraction area, thus allowing high velocity release.

Total peak cycle time is about 25 minutes, resulting in about 2.4 cycles/hour.

Volume of attraction pool = depth of attraction pool * area

- Depth of attraction pool = sump depth + river stage above entrance - 3 ft for crowder. Assuming a river stage of 3817.5 and a sump invert elevation of 3805, the useable depth of the attraction pool is 9.5 ft.

- Area of well = 225 ft^2.

Volume of attraction pool = 2137 ft^3. Reducing the volume by 15 percent for unusable space or non-target species gives a useable volume of 1816 ft^3.

Number of fish per ft^3 = for cui-ui we assumed 1 fish per ft^3. This value will be lower for larger average sizes of fish.

The estimated peak capacity/hour for a dual lock system is about 4350 fish/hour (1816 ft^3*1 fish/ft^3*2.4 cycles/hour). Assuming peak fish passage capacity could be achieved for a 3-day period, a total of about 300,000 fish could be passed.

Problems related to the near-dam location - Ideally, a new fish passage facility should be capable of operating within downstream river water surface elevations of 3810 to 3827. Elevation 3810 was chosen assuming continued degradation of the river below the dam could occur. Several problems were identified for constructing a facility close to the dam that is capable of operating at the desired minimum water surface. Dewatering and shoring to protect existing structures would be very costly. Discussions with the construction engineer for the original construction and construction memos in the Marble Bluff Dam SEED report indicate dewatering was a major problem during the construction when lake bed slit deposits were encountered. The actual dewatering effort will be dependent on the presence and elevation of the lake bed sediments. Geologic drill holes are needed at the construction site. If the sediments are not encountered, the dewatering will become simplified and therefore will be less costly. If lake bed sediments are encountered, increased numbers of dewatering well-points will have to be used. In conjunction with dewatering for excavation, extensive sheet pile shoring would be required to protect the existing structures during construction.

More importantly, if the future minimum riverbed elevation becomes lower than the existing riprap elevation of 3815.5, the increase in the value of "h" (the difference between upstream and downstream water surfaces shown on section B_B, figure 1.) could create an instability in the baffled apron drop. This could occur because the existing under-drainage system does not provide for pressure relief below El. 3815.5. In addition, the concrete footing and riprap at the toe of the dam would have to be modified to allow fish passage through a low level attraction channel, figure 9b, section E-E.

Pros and cons of the near-dam dual chamber lock concept - Positive aspects of this fish passage concept are:

1. Good fish passage capacity.
2. Fish incur low physical stress during passage.
3. Fish passage from the fishway downstream of the evaluation facility to the river can be achieved by modifying the existing ladder or converting the existing fish trap/lift to a low lift lock. An improved fish passage facility at the head of the fishway will benefit both river and fishway operation.

Negative aspects of this fish passage concept are:

1. The close proximity to the existing structures requires extensive shoring and dewatering during construction.
2. Future river degradation could block fish access to the lock.
3. Attraction conditions are poor. Spillway flow will inhibit or delay fish from finding the entrance to the lock.
4. Requires automated or manual operation of a sequence of valves to complete each cycle.

Estimated construction costs for the near-dam lock concept are $2.4 millon. Complete cost summary estimates for the near-dam lock concept are given in Appendix A, Near-Dam Lock Concept.

During review of the dual-chamber fish lock concept we felt the facility could be improved by moving the lock downstream. Moving the structure downstream would allow for future river degradation, improving ease of construction, and improving fish attraction conditions. The dual-chamber lock concept revised for a downstream location is called the down river lock concept.

Down River Fish Lock Concept

The river lock concept incorporates a vertical dual-chamber lock, similar to the near-dam dual-chamber lock design, located approximately 200 ft downstream of the dam toe, figures 11a and 11b. In addition to the lock the concept features a fish barrier in the river adjacent to the lock, a section of new fishway flume, a new fishway bifurcation structure at the intersection between the new fishway flume and the existing, and modifications to the 24-inch-diameter fishway supply piping and fish trap attraction flow piping. The development of this concept precludes the use of the existing mechanical hoist as a backup system due to placement of a fish barrier across the river below the dam and use of the existing attraction flow piping to supply water to the new lock structure.

Improved attracti conditions - A riprap or roller-compacted concrete fish barrier will be placed in the r /er adjacent to the new fish passage facilities, as shown on figure 11a. The barrier would guide fish to the attraction channel leading to the fish lock facility and prevent movement of fish to the base of the dam. The barrier would also stabilize the river grade at the toe of spillway, thus preventing future potential erosion problems should the river continue to degrade. The extent of a barrier needed to prevent cutthroat trout from passing remains in question.

Excavation and dewatering - Excavation and dewatering are simplified by moving away from the immediate location of existing structures. It is likely that the dewatering effort could be reduced by about 50 percent over that needed for the near-dam location. Again, the absence or presence of lake bed silts will need to be determined before dewatering needs can be estimated with certainty. Although shoring and dewatering costs are reduced for the river-lock location, excavation quantities for the river site may be greater due to location of existing ground surface and a reduced need for shoring. Discussions with the construction engineer for the original Marble Bluff Dam construction indicated the soils at the site may require 1-1/2:1, or flatter excavation slopes for stability during construction.

Modifications to existing structures - Modifications to the existing facilities for the river fish lock concept are as shown on figure 12. Attraction and filling flow and for the locks are supplied utilizing the three existing 24-in-diameter pipes, supplied by gates 2, 3, and 4. These pipes will be manifolded together to supply the new 48-in-diameter supply pipe running to the downstream fish lock location.

Additional flow will also be needed in the existing fishway channel down to the new bifurcation structure. This reach of the fishway channel will be enlarged to accommodate the increased flow. The additional flow will be supplied by teeing pipes 4 and 5 together as shown in figure 12. A new 36-in-diameter pipe would then carry flow to the existing fishway flow control structure. The remaining portion of pipe 5 will be abandoned.

Operation of the river lock fish passage facility - The new fish passage facilities would be integrated into the existing system so the current operating mode of the existing fishway channel to the lake is not disturbed. Currently, the water surface in the existing fishway channel to the lake (shown as El. 3850.00), just downstream of the transition in figure 12, section A-A is based on a 4-ft normal depth for a flow of 48 ft^3/s. Backwater will develop in the 8-ft-wide existing fishway flume to an elevation slightly higher than 3850.0 at the end of the 10:1 sloping drop. Fish would leave the river lock following a fishway flume that intersects the existing fishway at a new bifurcation structure located downstream of the fish evaluation building. Fish would move up the fishway and pass through the evaluation building or pass up the fishway via a modified ladder or a second fish lock (figure 10) as previously discussed.

Operation of a lock should be automated with a manual backup system. The following is an outline of the operation of the river dual-chamber fish lock:

Initial startup each year -

1. Make sure all gates and valves are closed prior to startup (weir gates are considered closed when they are in their up position).

2. Open gates 1, 5, and 6, shown on figure 12 and establish flow into the existing fishway flume and fishway channel.

3. Open gates 2, 3, and 4, figure 12, to supply operational water for the fish lock.

4. Open gate 11, figure 11a, to flood the new fishway flume.

5. Open river gate 14, figures 11a and 11b, to flood chamber 1.

6. Adjust valve 5, figure 11a, to provide desired flow capacity through river gate 14 opening.

7. Open valves 3 and 7, figure 11a, to establish the desired attraction flows into the river channel.

Cycling of the fish lock-

1. Once the desired number of fish are present in chamber 1 or a set cycle time has past, close chamber 1 river gate (No. 14) and open river gate 15 and valve 6, figure 11a. When the chamber water surface reaches its maximum position, close valve 5.

2. Begin to raise fish crowder 1 (this may be done concurrently with step 1).

3. Lower gate 12 (weir gate, figure 11a) while crowder is raising.

4. When the crowder reaches its fully raised position and all the fish have evacuated chamber 1, raise gate 12, figure 11a. Open valve 4, figure 11a, to dewater chamber 1 (water could also be wasted from one chamber into the other using valve 9).

5. Repeat similar steps to cycle chamber 2.

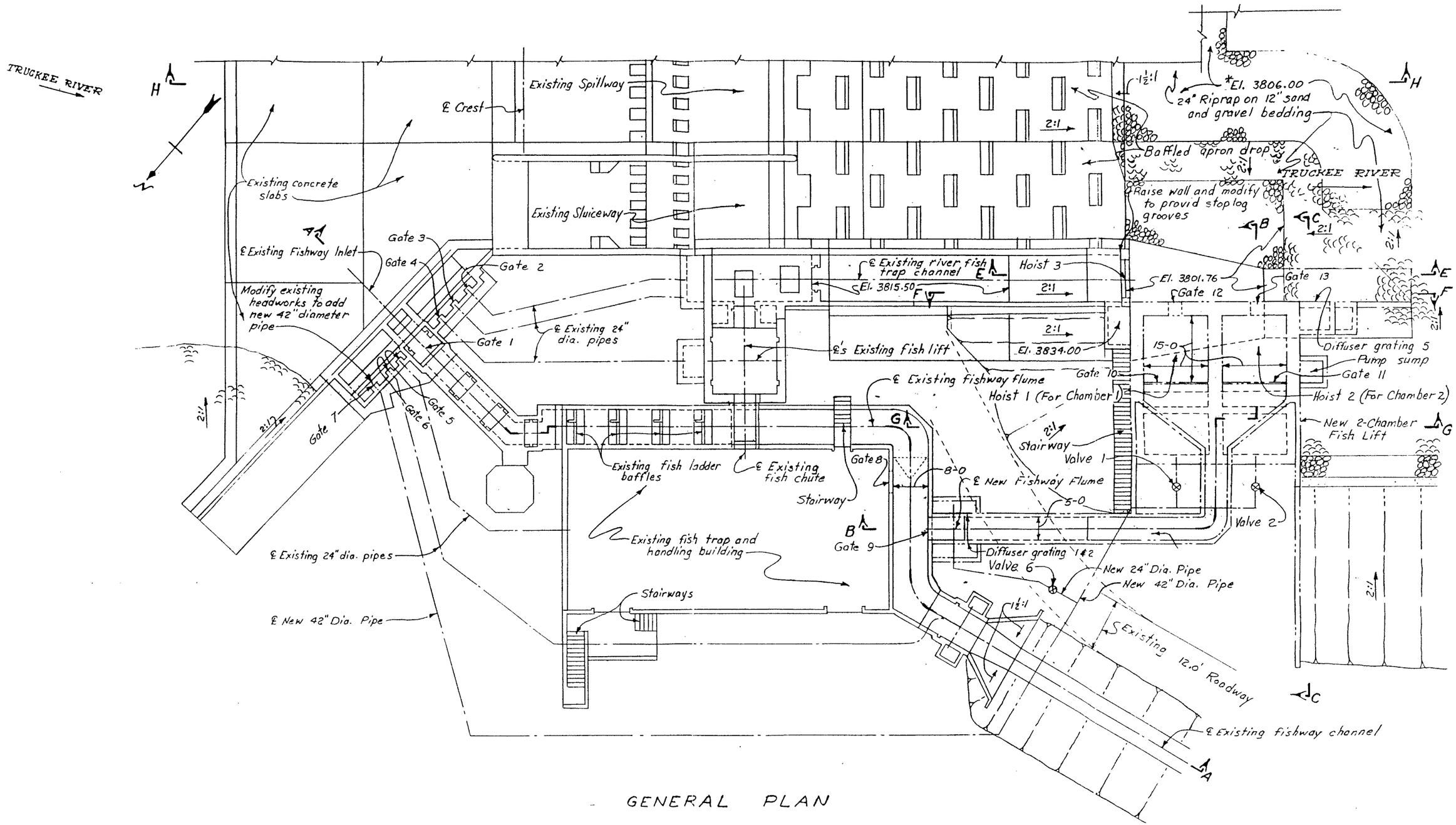
<u>Pros and cons of the river location for a dual chamber lock concept</u> - Positive aspects of this fish passage concept are:

1. Good capacity.
2. Requires low physical stress for passage.
3. Improves attraction conditions to the lock.
4. Fish passage from the fishway downstream of the evaluation facility to the river can be achieved by modifying the existing ladder or converting the existing fish trap/lift to a low lift lock. An improved fish passage facility at the head of the fishway will benefit both river and fishway operation.

Negative aspects of the river lock concept:

1. Requires automated or manual operation of a sequence of valves to complete each cycle.
2. The existing mechanical fish lift is abandoned.

Estimated construction costs for the river lock concept are $2.2 million (Note: cost of replacing the upstream most fish ladder with a second lock are not included). Complete cost summary for the river lock concept is given in Appendix A, River Lock Concept.



GENERAL PLAN

*Designs will be based on a minimum potential future river bed surface elevation (shown as El. 3806.00) and a maximum potential future water surface elevation plus 2'-0" (shown as El. 3829.00). These elevations may change during final design.

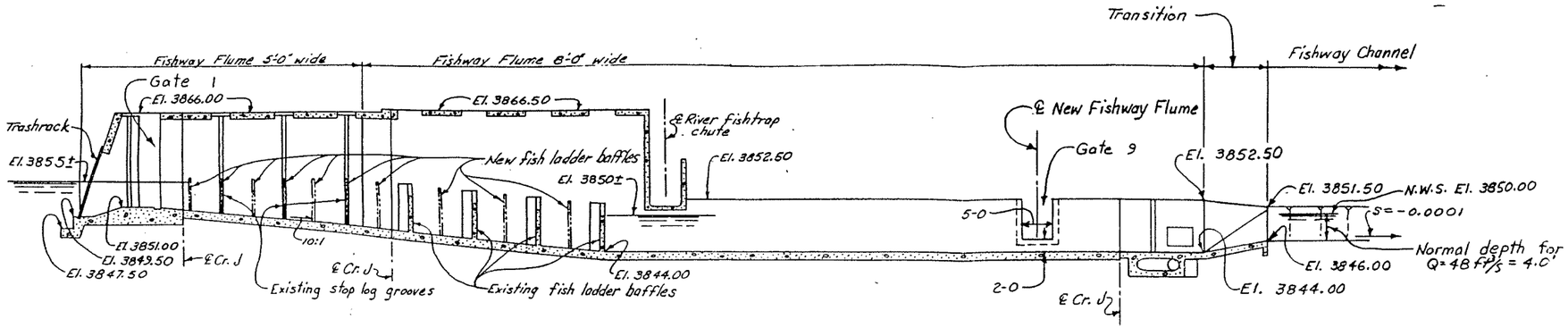
MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

NEAR-DAM DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT

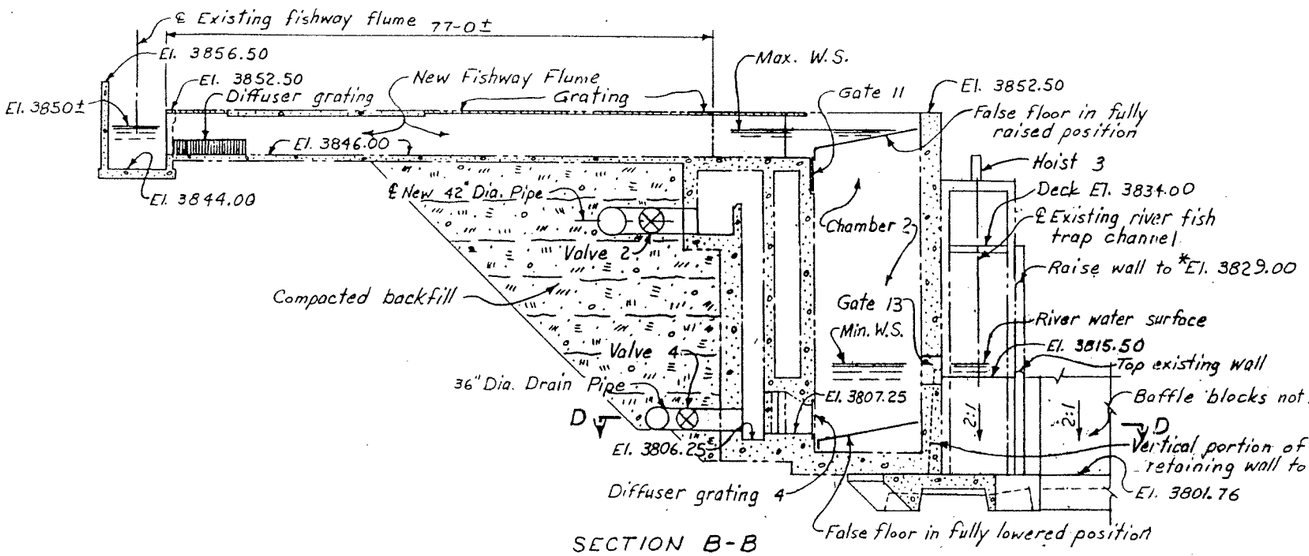
SHEET 1 OF 3

FIGURE 9a

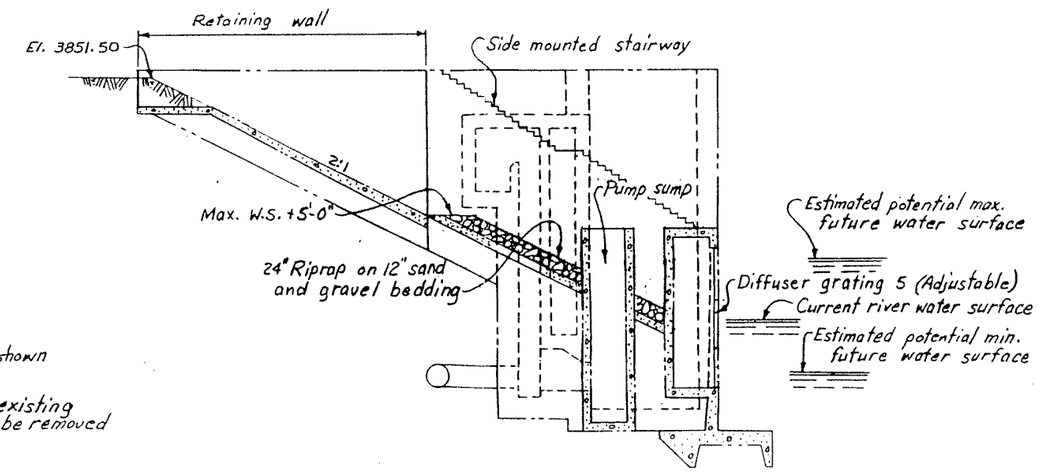


SECTION A-A

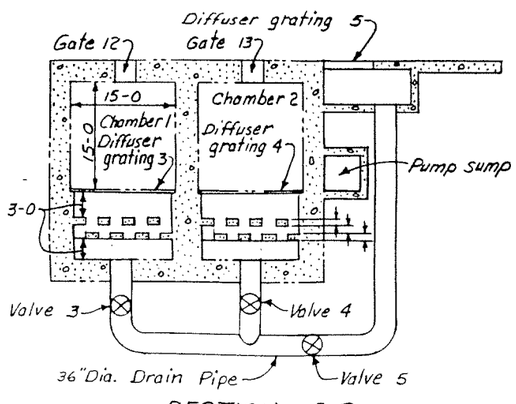
(Existing structures unless otherwise denoted)



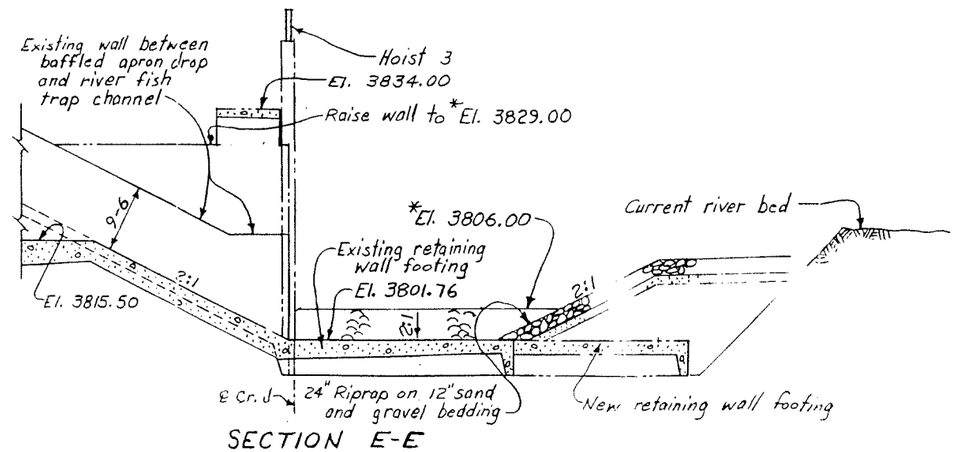
SECTION B-B



SECTION C-C



SECTION D-D



SECTION E-E

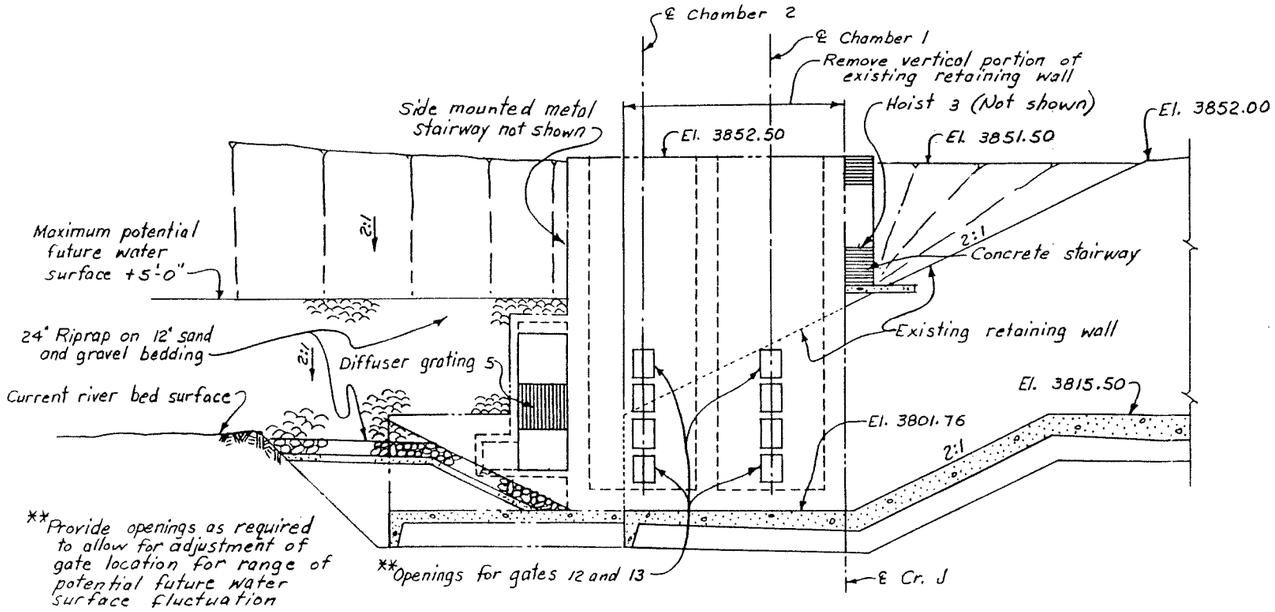
MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

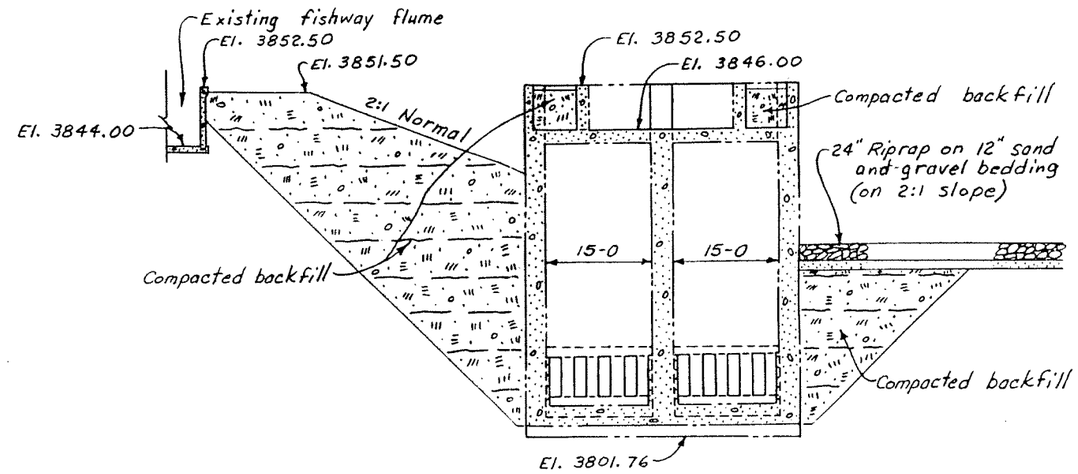
NEAR-DAM DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT

SHEET 2 OF 3

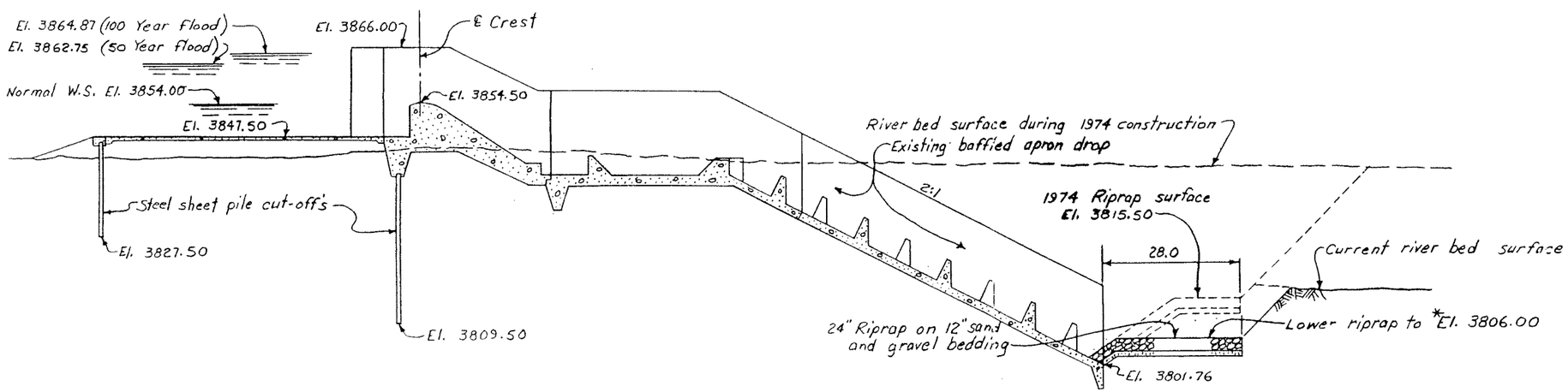
FIGURE 9b



SECTION F-F



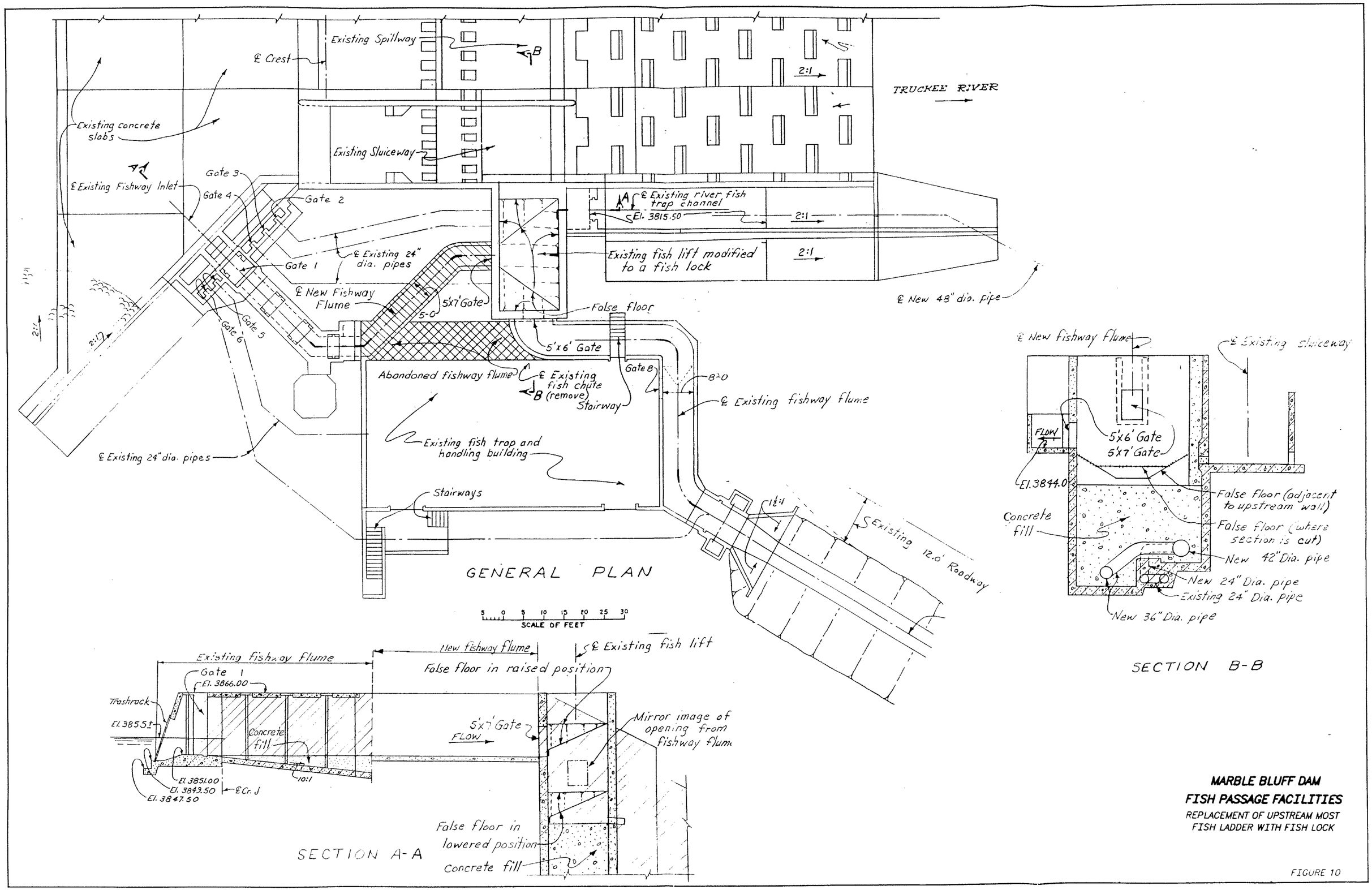
SECTION G-G



SECTION H-H

MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
NEAR-DAM DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT
SHEET 3 OF 3

FIGURE 9c

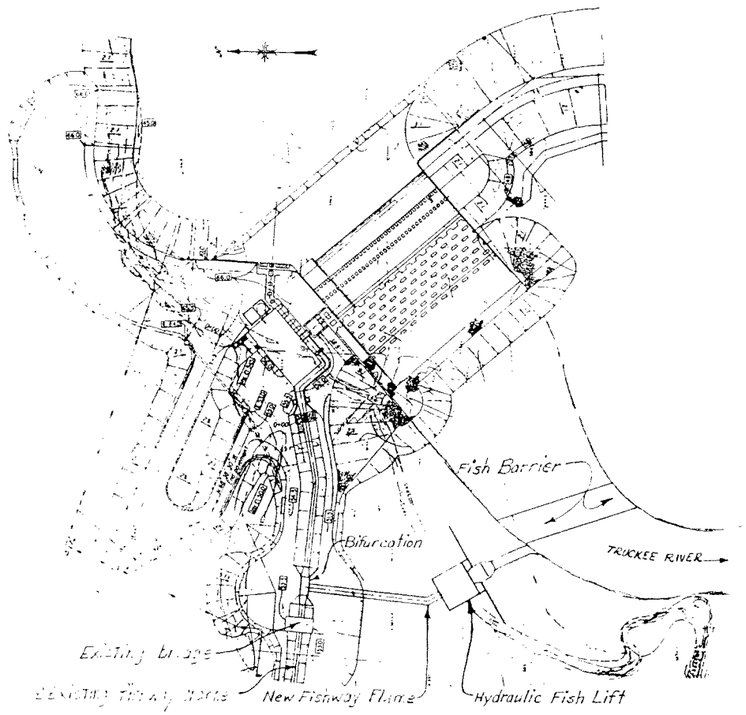


MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

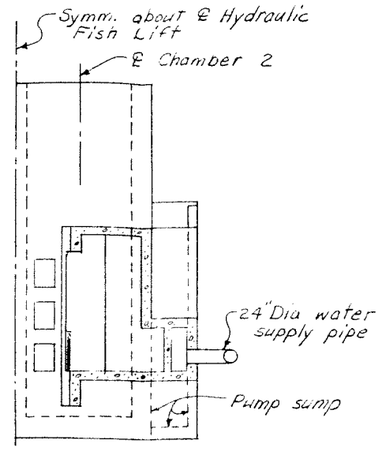
REPLACEMENT OF UPSTREAM MOST FISH LADDER WITH FISH LOCK

FIGURE 10

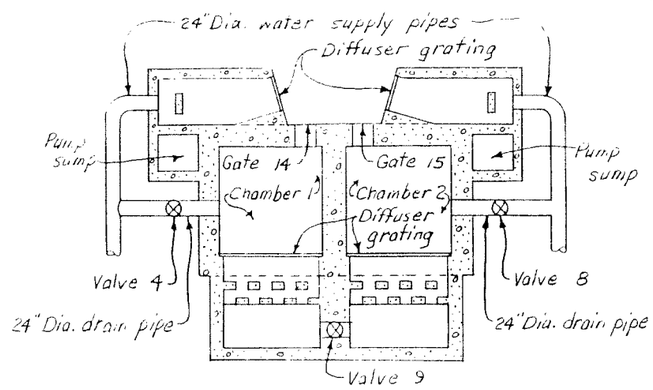


GENERAL PLAN

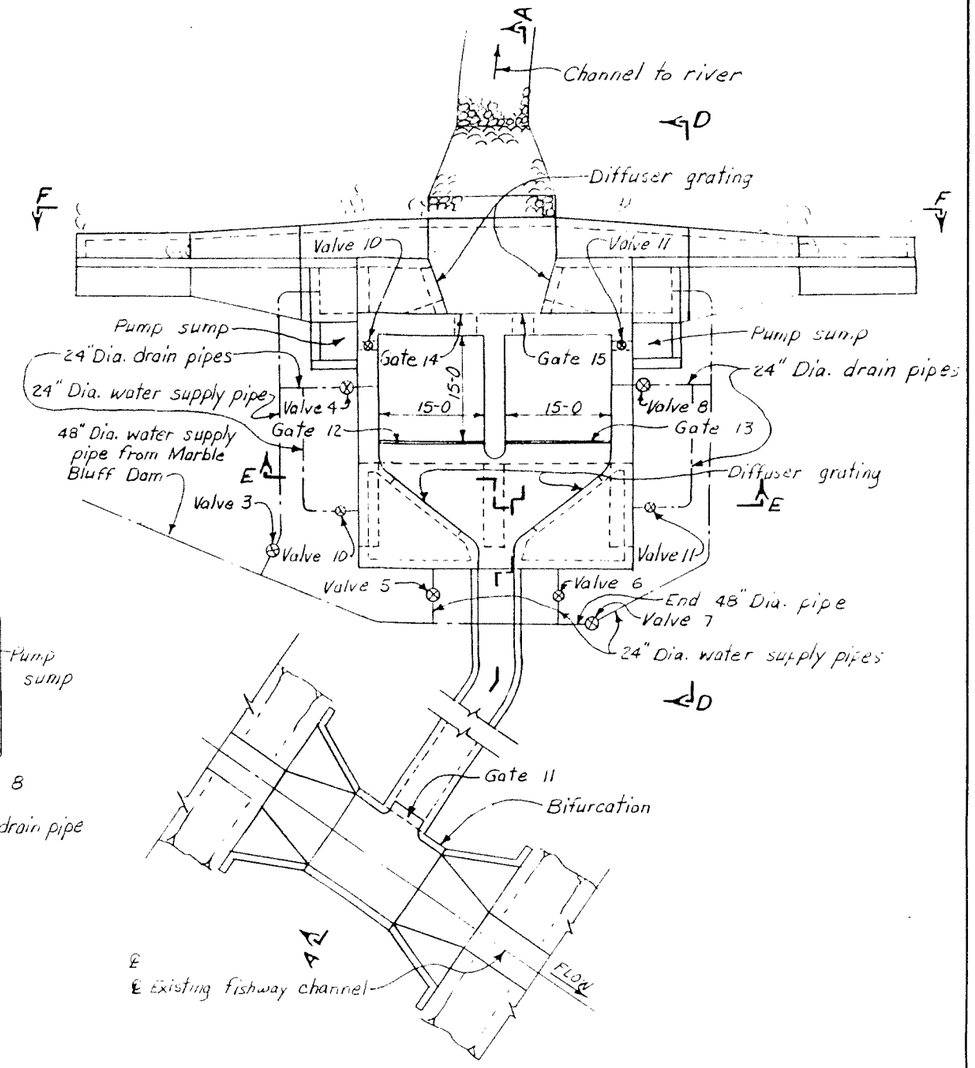
80 0 80 160 240
SCALE OF FEET



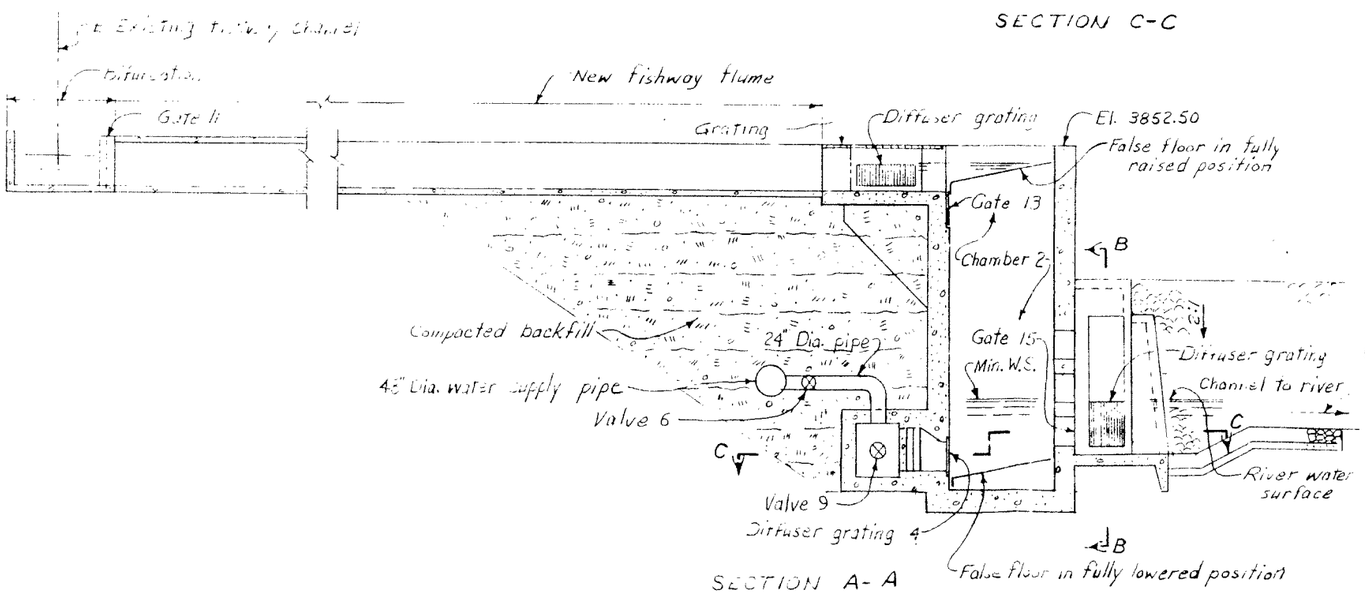
SECTION B-B



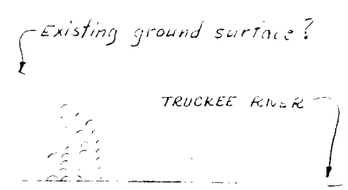
SECTION C-C



PLAN-HYDRAULIC FISH LIFT



SECTION A-A



5 0 5 10 15 20 25 30
SCALE OF FEET

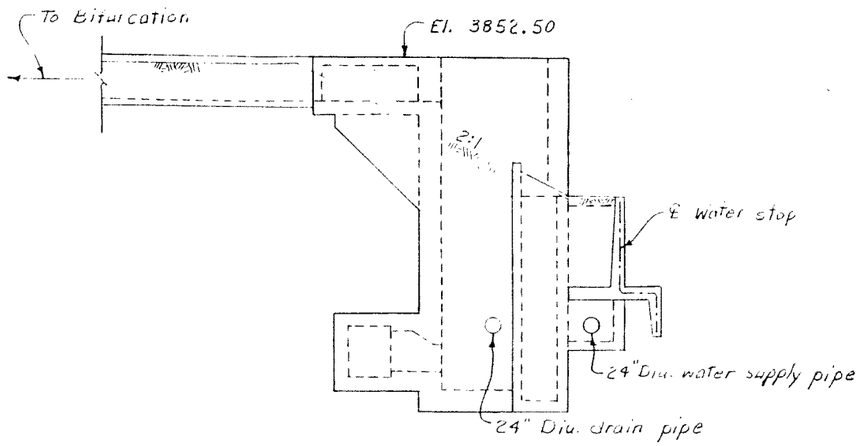
MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

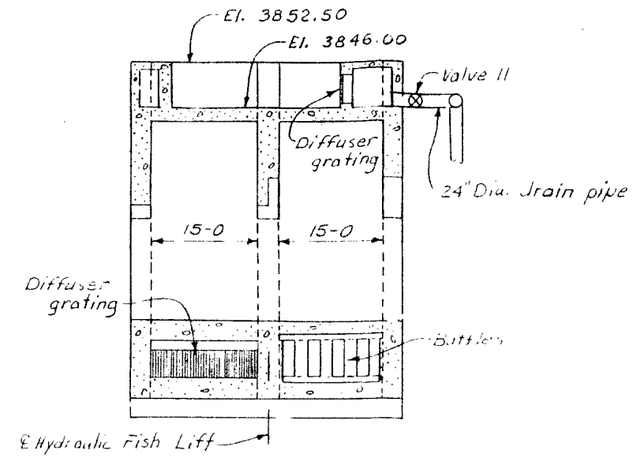
DOWN RIVER DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT

SHEET 1 OF 2

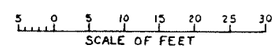
FIGURE 11a

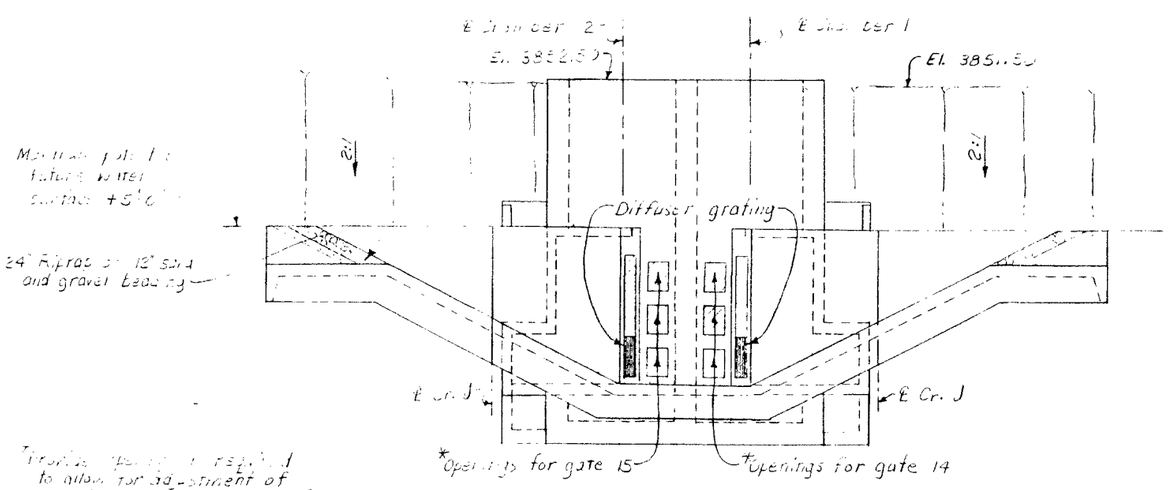


SECTION D-D



SECTION E-E





SECTION F-F

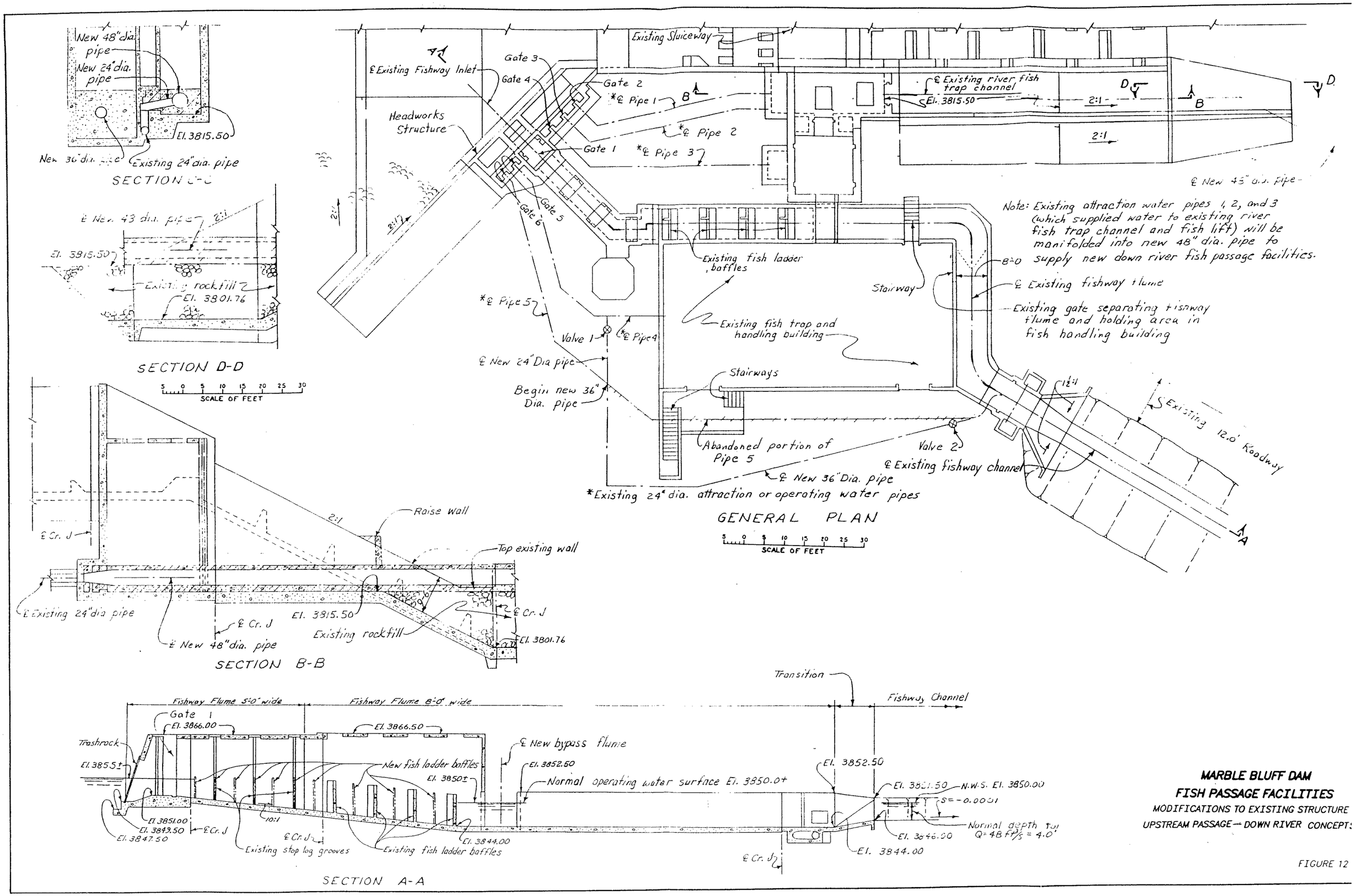
MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

DOWN RIVER DUAL-CHAMBER FISH LOCK
UPSTREAM PASSAGE CONCEPT

SHEET 2 OF

FIGURE 11b



MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
MODIFICATIONS TO EXISTING STRUCTURE
UPSTREAM PASSAGE — DOWN RIVER CONCEPTS

FIGURE 12

Fish Ladder Concept

The Marble Bluff fishway provides valuable experience for designing new fish ladders for cui-ui and Lahontan cutthroat. The Marble Bluff fishway was designed with five ladders along its length. These ladders were designed based on "then" standard ladder criteria derived mostly from experience with adult salmon. The ladders are on a 10 percent slope with combination weir/orifice baffles spaced every 10 ft of run. The head drop over each baffle was about 1 ft which corresponds to an orifice passage velocity of about 5.6 ft/s assuming a loss coefficient of 0.7. The as-built design had the bottom passage orifices aligned from baffle to baffle down the ladders. For this baffle geometry, approach velocity head must be considered as the flow moves down the ladder. The bottom orifice openings are 1.5 square which is equivalent to a circular orifice of 1.69 ft diameter. Decay of the centerline velocity downstream of each orifice can be estimated as given by Albertson;

$$\frac{V_{max}}{v_o}\frac{x}{D_o}=6.2 \qquad (3)$$

where, V_{max} = core velocity a distance x downstream of orifice, ft/s
v_o = initial orifice core velocity, ft/s
D_o = orifice diameter, ft

Equation 3 applies to x/D_o ratios greater than 6.2. For x/D_o values less than 6.2, the core velocity of the jet at the jet centerline has not started to decay. The ratio of x/D_o between baffles for the original design is about 6. Therefore, the centerline velocity exiting the upstream baffle orifice is not decreased prior to encountering the next downstream baffle orifice. Accounting for velocity head increases the theoretical orifice velocity to about 7.0 ft/s. Experience has shown that the cui-ui is not capable of negotiating these velocities. Through field experimentation FWS closed off all the orifices and added intermediate weirs to improve fish ladder passage. By installing intermediate and alternating weirs the drop across each weir was reduced to about 0.5 ft. Fish passage has improved using the modified weir ladder. However, video records of migrating cui-ui indicate flow velocities through the weirs remain too high for efficient passage. The video show cui-ui confronting the weirs several times before ascending and on occasion falling back over the weirs. A second uncertainty with the present ladder design is the absence of bottom passage. The present weir-only ladders force cui-ui to move up the ladders by staying high in the water column to pass over the weirs.

Ladder gradient and baffle spacing - Experience gained with the existing ladders helps define the upper velocity limit for effective cui-ui passage. The modified ladder contains 0.5-ft drops between weirs with 5-ft pool lengths. The peak weir passage

velocity is about 4.5 to 5 ft/s. In 1994, almost 35,000 cui-ui passed up the modified fishway, (FWS 1994). However, the fish moving up the fishway were predominately stronger swimming males. Experience has shown peak velocities in a fishway must be less than 4.5 ft/s, how much less is unknown.

In general, fish ladder velocity criteria for non-salmonids are very limited. However, several ladders have been designed specifically for non-salmonid species and studies have found many salmonid ladders are used by non-salmonids.

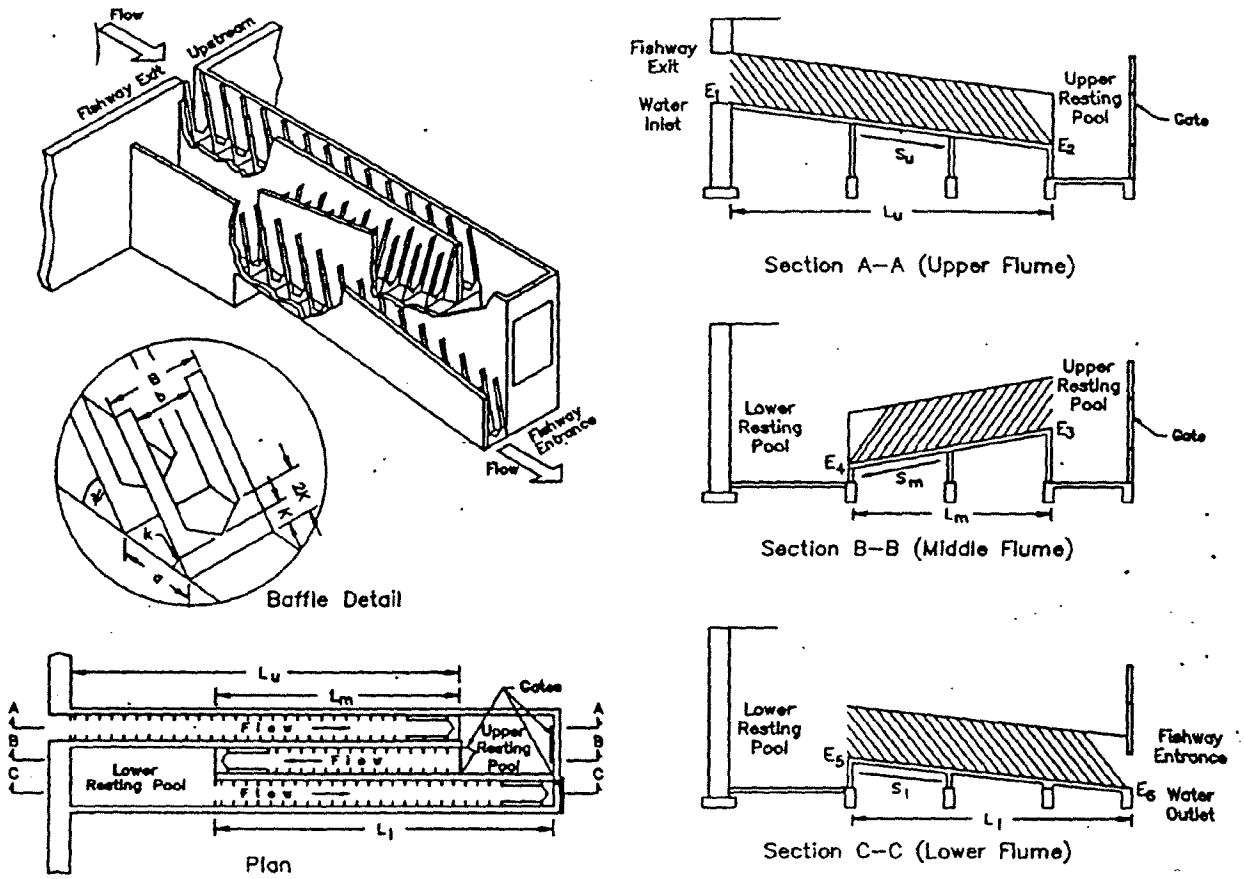


Figure 13 - Denil fishways installed at Fairford and Cowan, Canada.

Prototype studies of two Denil ladders on the Fairford River, Manitoba and Cowan Lake, Saskatchewan (Katopodis et al., 1991) found the ladders provided effective passage for sauger, walleys, white suckers, and other resident fish species. The Denil ladders are designed at a 12 percent slope with run lengths of between 15 and 30 ft, figure 13. However, the ladders have a total elevation drop of only about 7 ft. At Fairford, velocities in the weir chutes varied from about 4.5 ft/s at 0.6 depth to about 2.3 ft/s at 0.2 depth. Slightly higher velocities were measured at Cowan. The velocities are above reported critical swimming velocities of many species using the

ladders. However, velocities were below burst swimming speeds. Weak swimmers were assumed to pass up the Denil ladders by holding close to the bottom in the lowest velocity zone. The study did not compare ladder usage to downstream migrating fish populations. Therefore, the study results do not clearly show the overall effectiveness of the ladders. A previous Canadian study by Schwalme and Mackay (1985), of two Denil ladders and a vertical slot ladder, figure 14, found similar results to Katopodis's. The Schwalme and Mackay study also found the vertical slots provide slower passage velocities compared to a Denil. Although the data are not conclusive, juveniles and weaker swimmers appeared to prefer the vertical slot ladder.

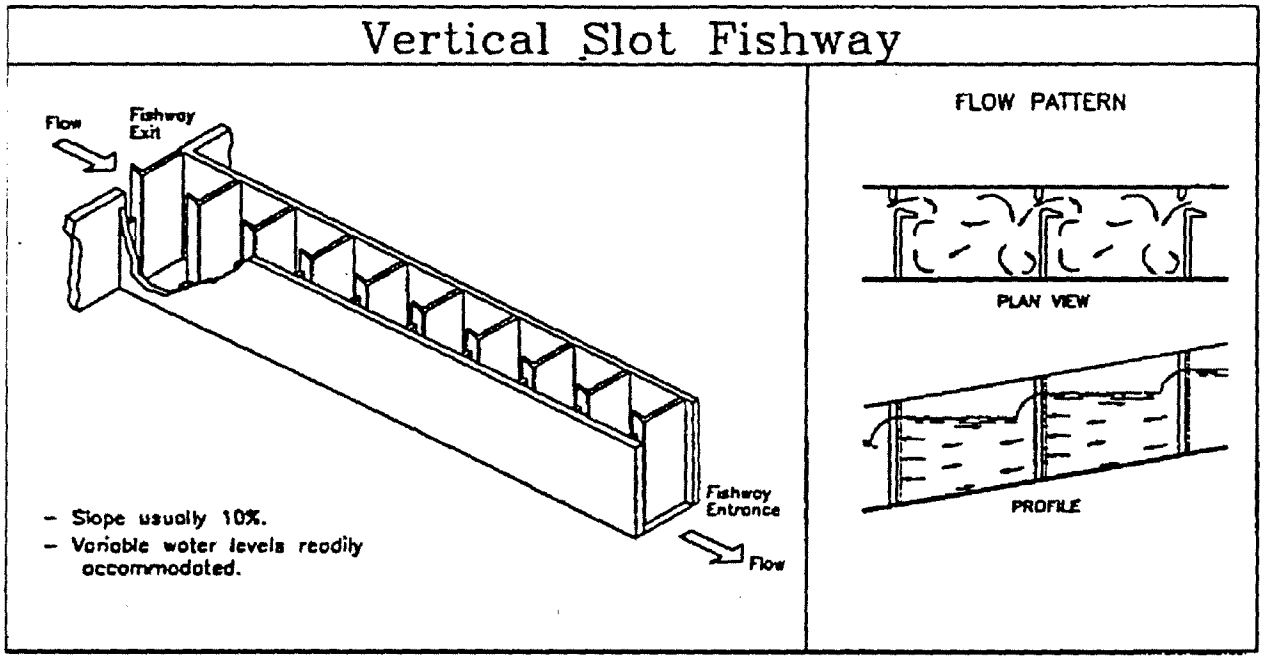


Figure 14 - Typical vertical slot fishway, Katopodis 1991.

Another example of a ladder design for non-salmonids is the proposed Redlands Diversion Dam fish ladder near Grand Junction, Colorado. The proposed (final design is currently under review) Redlands Fish Passageway is a combination vertical slot and bottom orifice ladder designed for the Colorado squawfish and razor back sucker in the Gunnison River, figure 15. The ladder will provide fish passage around Redlands Diversion Dam, which has a hydraulic height of about 10 ft. The ladder has two runs at a 3.75 percent grade. Aluminum baffles are spaced along the fishway at 6-ft intervals. The head drop across each baffle is about 0.22 ft. The fishway will have a normal flow depth of about 5 ft and will pass 11 to 17 ft^3/s. The fishway is designed to achieve average velocities through the baffles of about 2.2 ft/s. The rather low design velocity is required to meet a reported burst swimming speed of 2.0 ft/s for the razorback sucker. The proposed design of the fishway allows baffles to be removed and adjusted to optimize passage. The chosen vertical slot and orifice

baffle design is shown in figure 16. The Redlands ladder is an example of designing in flexibility to allow for field optimization of a fish ladder to adjust for the uncertainty of the swimming ability of the razorback sucker.

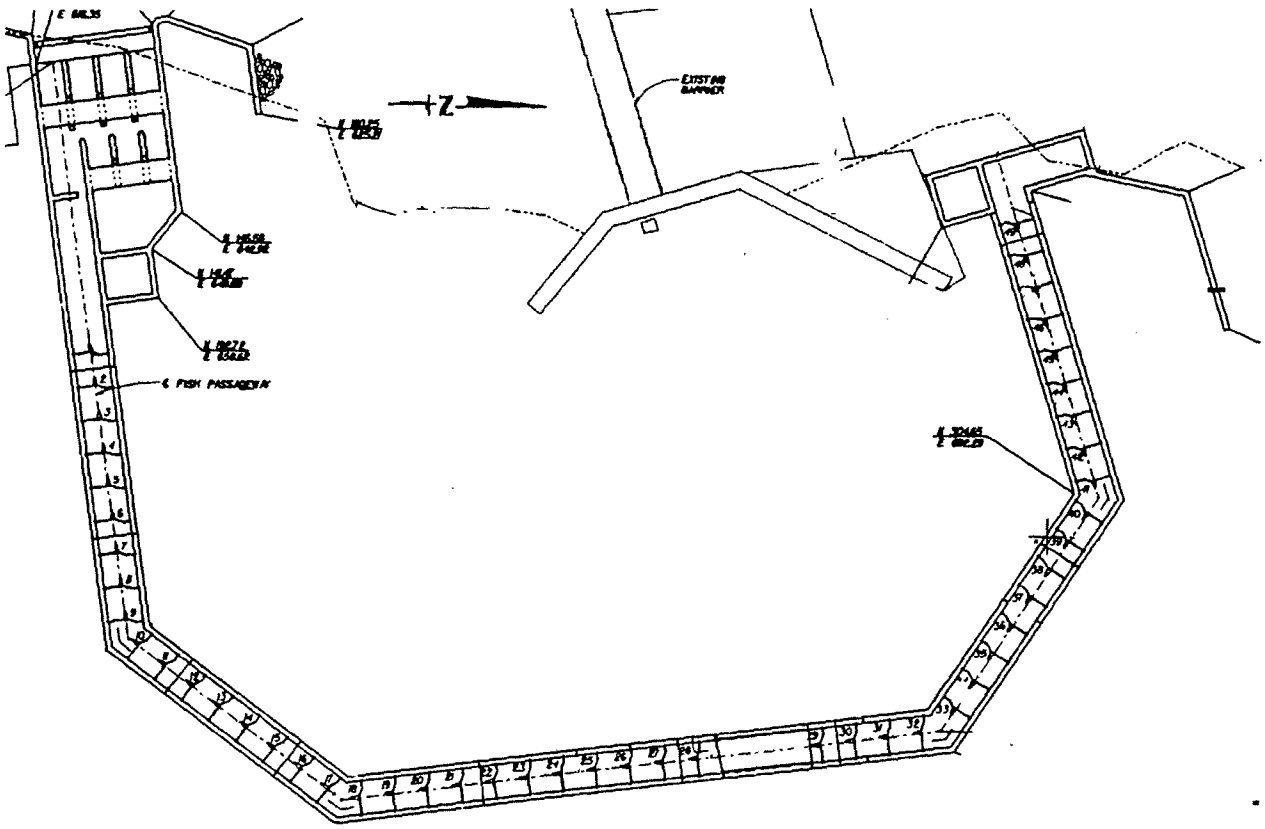


Figure 15 - Proposed Redlands Diversion Dam fishway.

Marble Bluff Dam fish ladder design objectives - During the Marble Bluff Dam concept study, key ladder design objectives were prioritized as: achieve flexibility in peak passage velocity within the range of 3.0 to 4.0 ft/s, minimize structure size, and maximize fish passage capacity.

Peak passage velocity - A peak velocity range of, 3.0 to 4.0 ft/s was targeted. Assuming a slot or orifice loss coefficient of 0.7, these velocities correspond to baffle drops of about 0.28 ft and 0.5 ft, respectively.

Structure size - The minimum structure length is achieved by maximizing fish ladder gradient. A comparison of ladder length and baffle spacing is given in table 2.

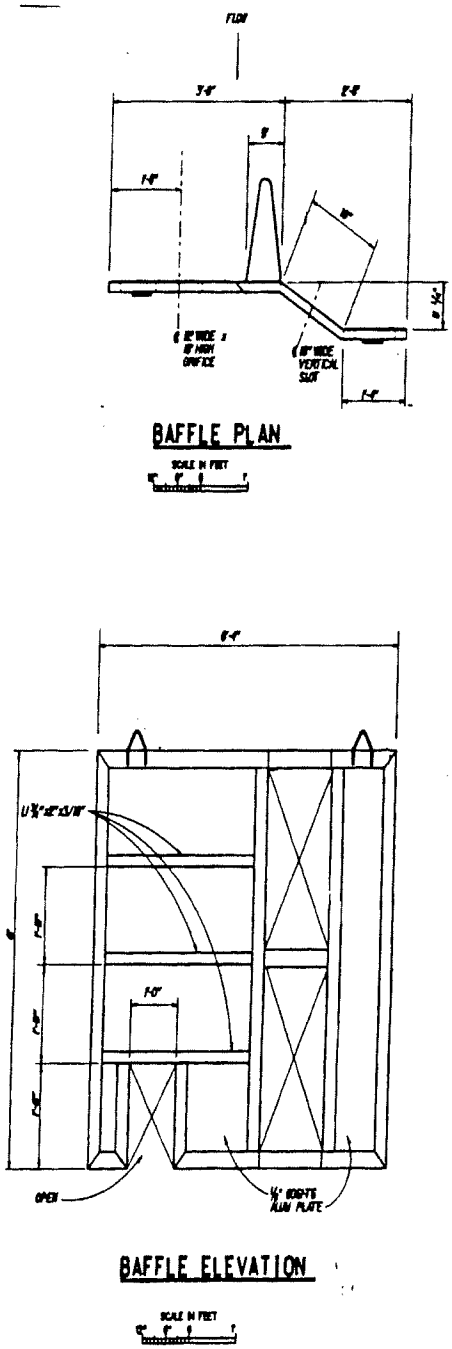


Figure 16 - Baffle design for Redlands Diversion Dam fishway.

Table 2. - Comparison of ladder gradient and baffle spacing

Gradient (slope)	Inclined Ladder Length (ft) (assume 35 ft el.)	Baffle Spacing, ft	
		0.28 ft drop	0.5 ft drop
1:10	350	2.8	5.0
1:12.5	437.5	3.5	6.25
1:15	525	4.2	7.5
1:20	700	5.6	10.0

Fishway capacity - FWS guidelines for sizing fishways assumes a value of 10 percent of the total run as the maximum rate of fish traffic during peak day. The peak hour fish traffic is then estimated as 15 percent of the peak day traffic. The peak fish passage objective at Marble Bluff Dam is 300,000 in 3 days or roughly 100,000 fish per day. Following FWS guidelines, the peak fish passage need is 15,000 fish/hour.

The pool volume needed between ladder baffles to accommodate peak fish passage is estimated as: fish/minute x minutes/pool x pool volume/fish + C (C = 15% is used as an allowance for non target species and unusable space in pools).

To meet desired capacity requirements for Marble Bluff Dam Fishway peak fish traffic requires:

Fish/minute = 250
Minutes/pool = 3 - 5 (Use 4 minutes as typical range for ladders.)
Pool Volume/fish = 1 ft^3 (May be less based on cui-ui crowding.)

Therefore, pool volume required = 250*4*1 = 1000 ft^3 +15% = 1150 ft^3.

Pool Size = width * length between baffles * pool depth
Assuming a desired ladder depth and width of 5 ft and 8 ft, the length between baffles is 28.7 ft. Assuming a drop between baffles of 0.4 ft the resulting ladder gradient is about 70:1.

Designing a fish ladder to meet both passage velocity and peak capacity objectives was considered to be size and ultimately cost prohibitive.

A second design approach was taken where the fishway capacity was not used as a design target. Passage velocity and structure costs were optimized with the resulting

fishway capacity then calculated. This process resulted in choosing a 1:15 gradient ladder with 5 ft pool lengths and a 5-ft-deep by 8-ft-wide flume section.

For a 5-ft baffle spacing, the peak capacity can be estimated as:
Peak fish/minute = (pool volume - 15%) / (minutes/pool * pool volume per fish)
Pool volume = 200 ft^3 - (.15*200), or 170 ft^3
Minutes/pool = 4

Therefore, the estimated peak fish passage capacity is 42 fish/minute [170 ft^3/(4 min. per pool*1 fish per ft^3)], or about 180,000 fish in 3 days.

The ladder design has pool lengths of 5 ft and drops of 0.33 ft per baffle. Flexibility should be provided in the design for installation of baffles at shorter intervals, if found necessary. Full or partial intermediate baffles could be installed to reduce peak passage velocities to about 3 ft/s.

Two concept options were also developed for a fish ladder option. As with the dual lock concept design, problems associated with construction near the dam identified during the concept study resulted in consideration of fish ladder options located both near the dam and approximately 200 ft downstream of the dam.

Near-Dam Fish Ladder Concept - The near-dam ladder design is shown in figures 17a and 17b. The development of this concept could allow for the existing mechanical hoist/trap system to be maintained as a backup system. The design incorporates a new fish ladder structure, a modified headworks providing for a new water supply pipe, a short section of fishway flume that intersects the existing fishway flume adjacent to the evaluation facility, and modification or replacement with a lock of the upstream most fishway ladder.

Fish enter the fish ladder adjacent to the existing river fish trap channel. Upon existing the ladder, fish enter the existing fishway flume where they can be diverted into the fish evaluation facility or allowed to move up channel directly to the river. Passage to the river requires an additional passage structure adjacent to the evaluation facility to provide about 4 ft. of elevation gain. As discussed for the dual-chamber lock concepts, passage could be achieved by modifying the existing fishway ladder located adjacent to the evaluation facility as shown in figure 17b, section A-A or modifying the existing mechanical fish trap to a low lift fish lock, figure 10.

Pros and cons of the near-dam location for a fish ladder concept - Positive aspects of this fish passage concept are:

1. Good capacity.
2. Requires minimal mechanical operation.

3. Some experience exists with the fishway ladders. Ladder design could be tested prior to final design by modifying the terminal ladder on the existing fishway.
4. Fish passage from the fishway downstream of the evaluation facility to the river can be achieved by modifying the existing ladder or converting the existing fish trap/lift to a low lift lock. An improved fish passage facility at the head of the fishway will benefit both river and fishway operation.

Negative aspects of concept:

1. Approach to ladder could become impassable if further degradation of the riverbed continues.
2. Close proximity to the existing structures requires extensive shoring and dewatering during construction.
3. Attraction conditions are poor. Spillway flow will inhibit or delay fish from finding the entrance to the ladder.
4. Without additional testing the ladder is an unproven concept for cui-ui.

Estimated construction costs are $2.6 million (Note: cost of replacing the upstream most fish ladder with a second lock are not included). Complete cost summary for the near-dam fish ladder concept are given in Appendix B, Near-Dam Fish Ladder Concept.

River Fish Ladder Concept

Many of the negative aspects identified for the near-dam ladder could be improved by moving the passage facility about 200 ft downstream from the toe of the dam in conjunction with adding a rock drop fish barrier, figures 18a and 18b. A downstream river location would allow for future degradation of the river channel below the dam, improved ease of construction, and improved fish attraction conditions.

In addition to the fish ladder the concept features a fish barrier in the river adjacent to the ladder, a section of new fishway flume, a new fishway bifurcation structure at the intersection between the new fishway flume and the existing, and modifications to the 24-inch-diameter fishway supply piping and fish trap attraction flow piping. The development of this concept precludes the use of the existing mechanical hoist as a backup system.

Improved attraction conditions - A riprap or roller-compacted concrete fish barrier will be placed in the river adjacent to the new fish passage facilities, as shown on figure 18a. The barrier would guide fish to the attraction channel leading to the fish ladder facility and prevent movement of fish to the base of the dam. The barrier would also stabilize the river grade at the toe of spillway, thus preventing future potential erosion

problems should the river continue to degrade. The extent of a barrier needed to prevent cutthroat trout from passing remains in question.

Excavation and dewatering - Excavation and dewatering are simplified by moving away from the immediate location of existing structures. It is likely that dewatering will be reduced significantly by moving the structure downriver from existing structures. The absence or presence of lake bed silts will need to be determined before dewatering needs can be estimated with certainty. Although shoring and dewatering costs are reduced for the down river ladder location, excavation quantities for the river site may be greater should shoring not be used during excavation. Discussions with the construction engineer for the original Marble Bluff Dam construction indicated the soils at the site may require 1-1/2:1, or flatter excavation slopes for stability during construction.

Modifications to existing structures - Modifications to the existing facilities for the river fish ladder option are shown on figure 12. Attraction flow for the ladder is supplied utilizing the three existing 24-in-diameter pipes, supplied by gates 2, 3, and 4, figure 12. These pipes will be manifolded together to supply the new 48-in-diameter attraction flow supply pipe.

Additional flow will be needed in the existing fishway channel down to the new bifurcation structure. This reach of the fishway channel will be enlarged to accommodate the increased flow. The additional flow will be supplied by teeing pipes 4 and 5 together as shown in figure 12. A new 36-in-diameter pipe would then carry flow to the existing fishway flow control structure. The remaining portion of pipe 5 will be abandoned.

Operation of the river ladder concept - A new fish ladder to the river would operate without changing the current operating mode of the fishway channel to the lake. Following is an outline of the operation of the integrated fish facilities:

1. Make sure all gates and valves are closed prior to startup.

2. Open Gates 1, 5, and 6 (figure 12) and establish flow into the existing fishway flume and fishway channel.

4. Open gate 11 (figure 18a) to establish flow in the new fish ladder.

5. Adjust attraction flow valves (number and location determined during final designs) to deliver the appropriate amount of attraction water.

Pros and cons of the down river location for a fish ladder concept - Positive aspects of this fish passage concept are:

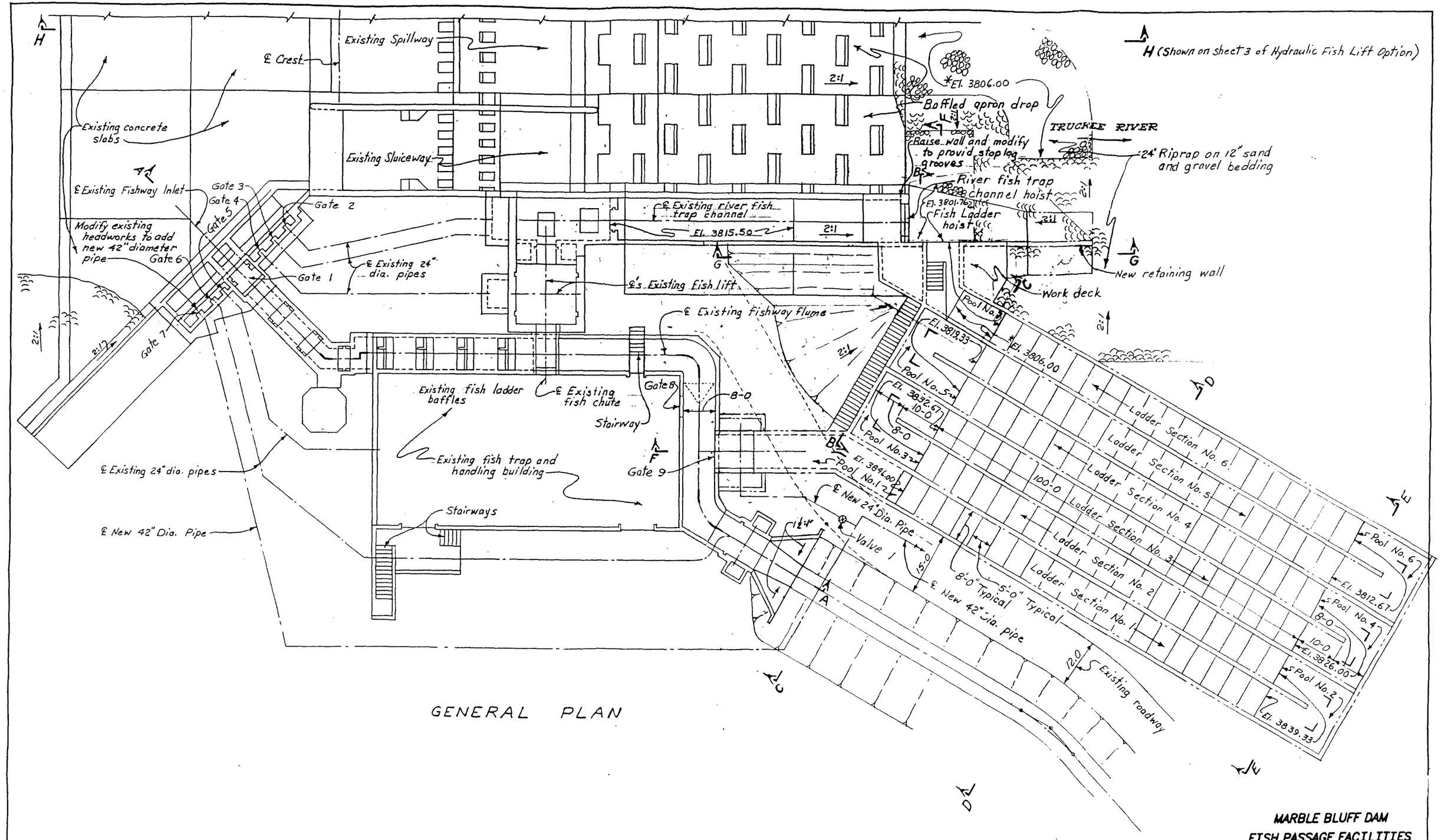
1. Good capacity.

2. Requires minimal mechanical operation after flow is established.
3. Some experience exists with the fishway ladders. Ladder design could be tested prior to final design by modifying the terminal ladder on the existing fishway.
4. Offers improved attraction conditions.
5. Fish passage from the fishway downstream of the evaluation facility to the river can be achieved by modifying the existing ladder or converting the existing fish trap/lift to a low lift lock. An improved fish passage facility at the head of the fishway will benefit both river and fishway operation.

Negative aspects of concept:

1. Existing river fish hoist/trap would be abandoned.
2. Without testing, the ladder is an unproven concept for cui-ui.
3. Fish barrier may be difficult to design for cutthroat trout.

Estimated construction costs for the river fish ladder concept are $ 2.4 million (Note: cost of replacing the upstream most fish ladder with a second lock are not included). Complete cost summary for the river fish ladder concept are given in Appendix B, River Fish Ladder Concept.



MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
NEAR-DAM FISH LADDER
UPSTREAM PASSAGE CONCEPT
SHEET 1 OF 2

FIGURE 17a

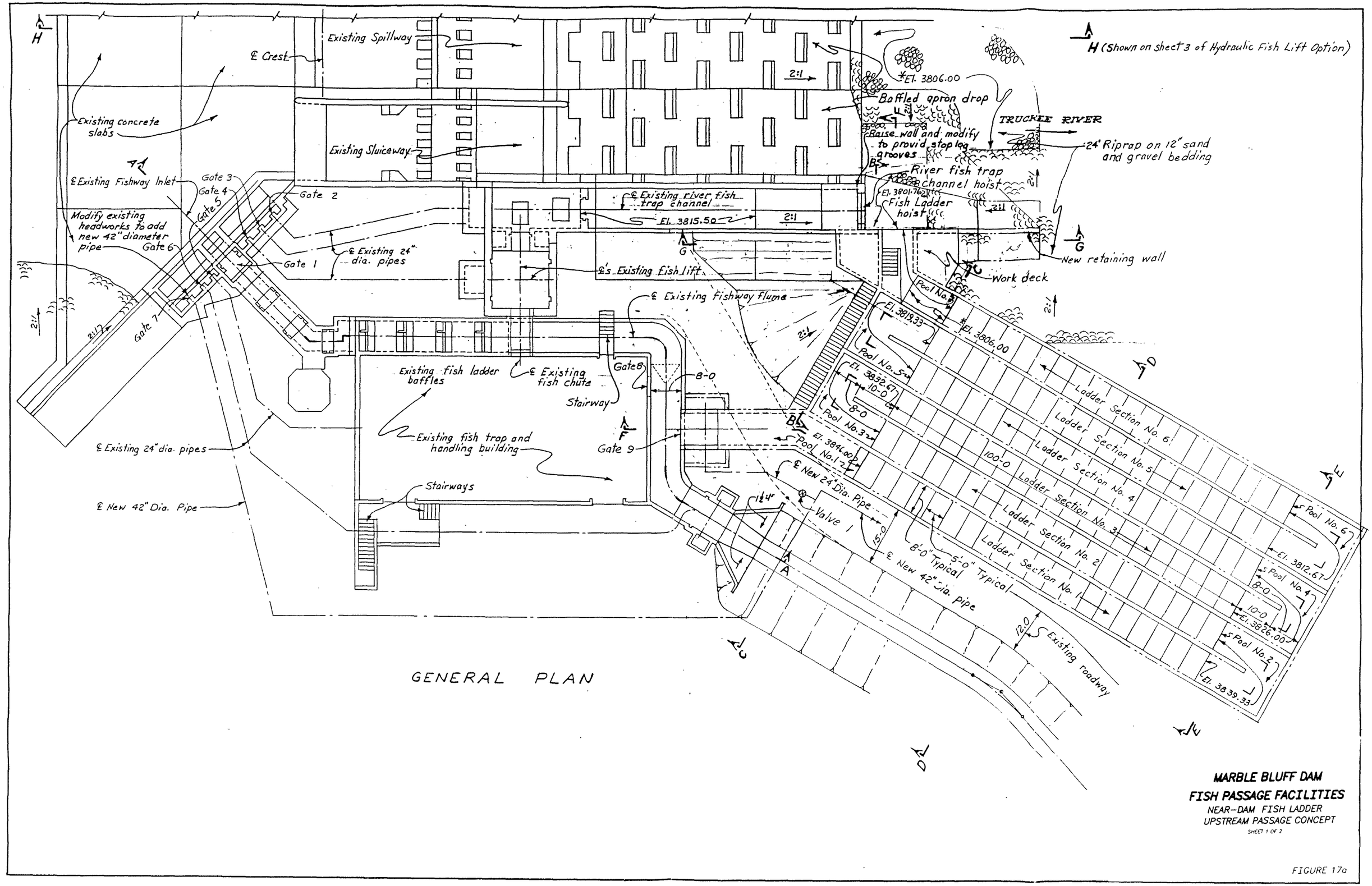
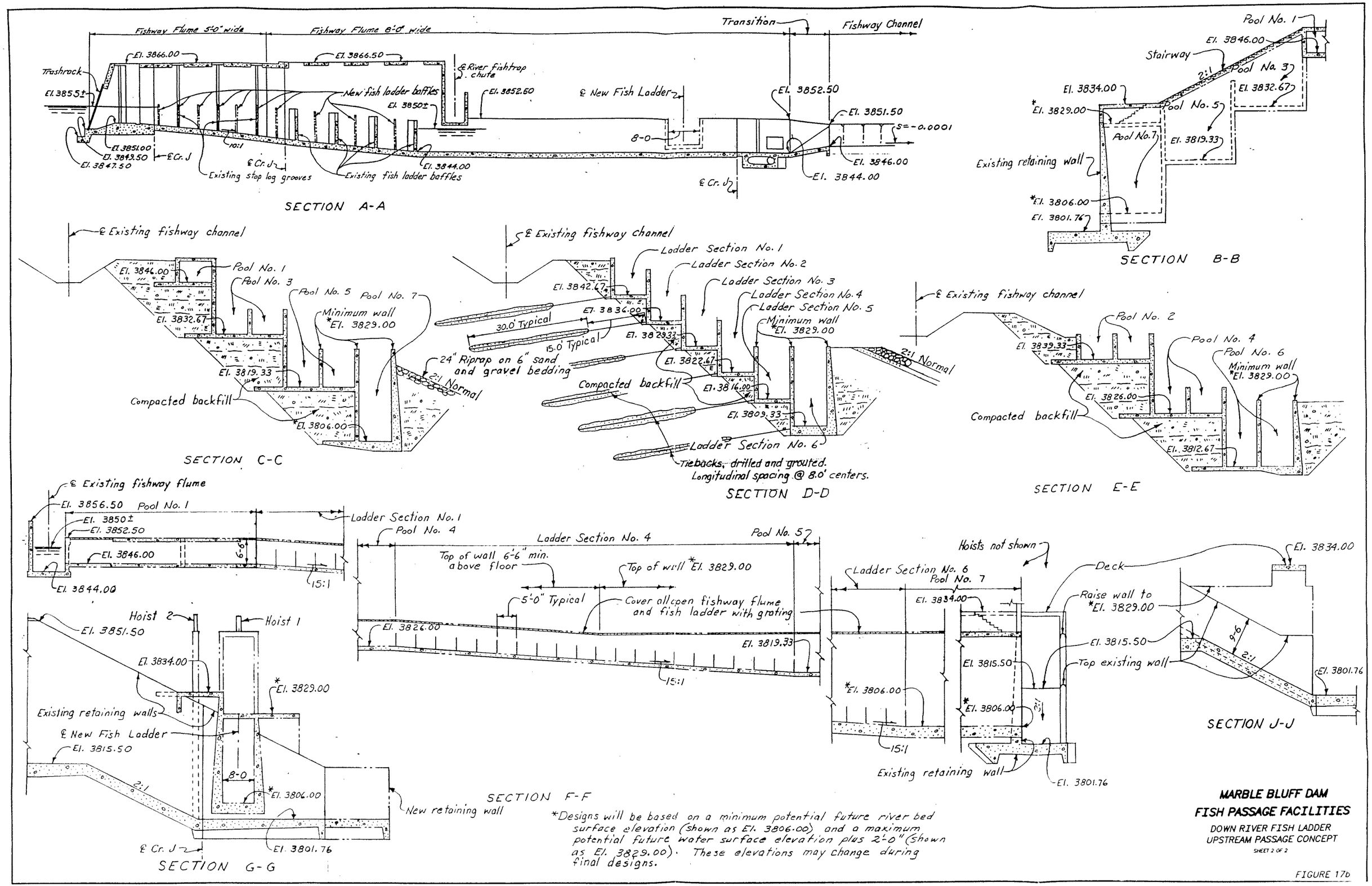

H (Shown on sheet 3 of Hydraulic Fish Lift Option)
Existing Spillway
℄ Crest
Existing concrete slabs
Existing Sluiceway
℄ Existing Fishway Inlet
Gate 3
Gate 4
Gate 5
Gate 2
Modify existing headworks to add new 42" diameter pipe
Gate 6
Gate 1
℄ Existing 24" dia. pipes
Gate 7
2:1
℄ Existing river fish trap channel
El. 3815.50
℄'s Existing fish lift
℄ Existing fishway flume
Existing fish ladder baffles
℄ Existing fish chute
Stairway
Gate 8
8-0
Existing fish trap and handling building
Gate 9
℄ Existing 24" dia. pipes
Stairways
℄ New 42" Dia. Pipe
*El. 3806.00
Baffled apron drop
Raise wall and modify to provid stop log grooves
TRUCKEE RIVER
24" Riprap on 12" sand and gravel bedding
River fish trap channel hoist
*El. 3801.76
Fish Ladder hoist
New retaining wall
Work deck
Pool No. 8
El. 3819.33
*El. 3806.00
Pool No. 5
El. 3832.67
10-0
8-0
Pool No. 3
El. 3846.00
Pool No. 1
℄ New 24" Dia. Pipe
Valve 1
15-0
8'-0" Typical
5'-0" Typical
℄ New 42" Dia. pipe
100-0
Ladder Section No. 6
Ladder Section No. 5
Ladder Section No. 4
Ladder Section No. 3
Ladder Section No. 2
Ladder Section No. 1
Pool No. 6
El. 3812.67
Pool No. 4
El. 3826.00
Pool No. 2
El. 3839.33
12.0
Existing roadway
GENERAL PLAN
MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
NEAR-DAM FISH LADDER
UPSTREAM PASSAGE CONCEPT
SHEET 1 OF 2

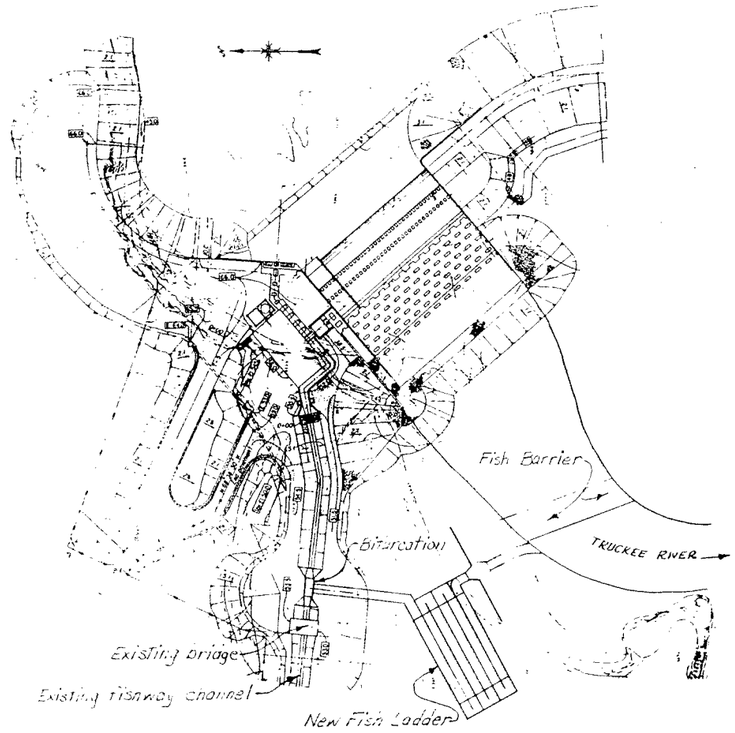
FIGURE 17a



*Designs will be based on a minimum potential future river bed surface elevation (shown as El. 3806.00) and a maximum potential future water surface elevation plus 2'-0" (shown as El. 3829.00). These elevations may change during final designs.

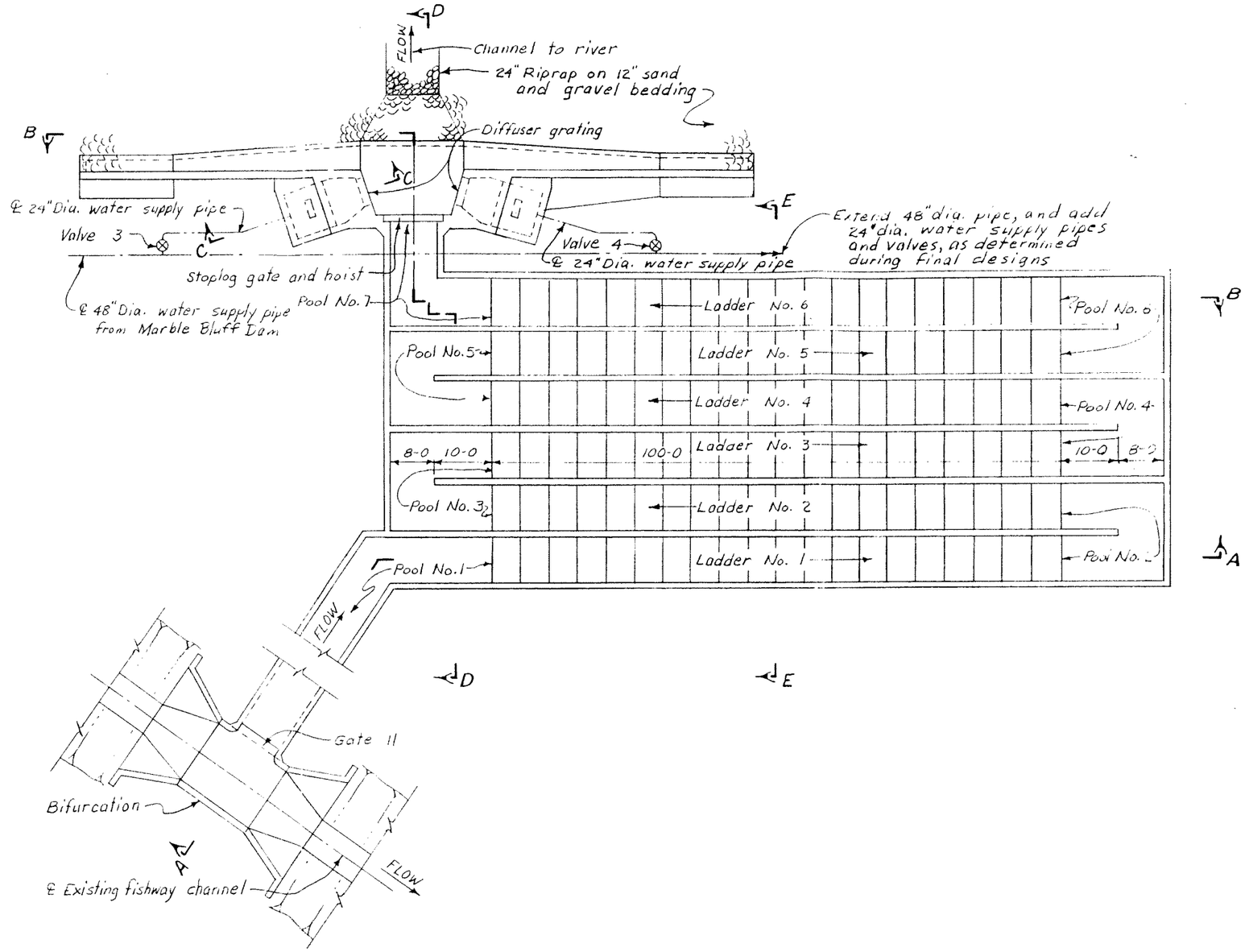
MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
DOWN RIVER FISH LADDER
UPSTREAM PASSAGE CONCEPT
SHEET 2 OF 2

FIGURE 17b

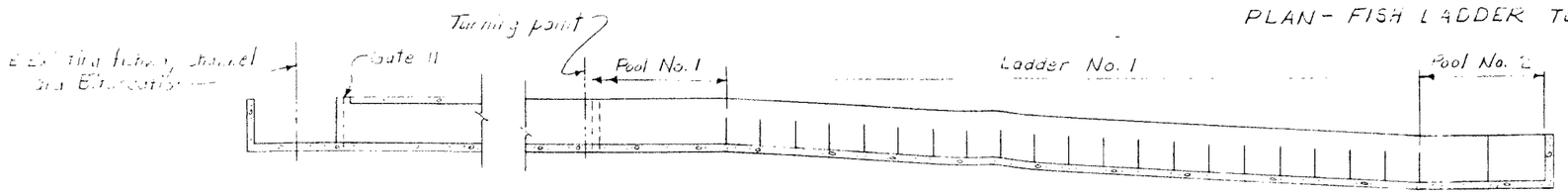


GENERAL PLAN

80 0 80 160 240
SCALE OF FEET



PLAN - FISH LADDER TO RIVER

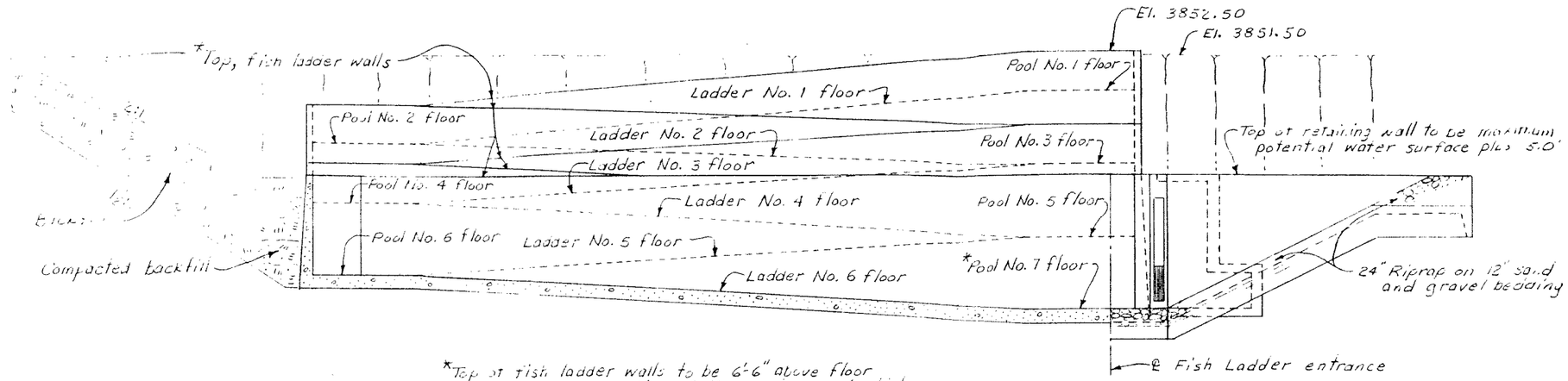


SECTION A-A

5 0 5 10 15 20 25 30
SCALE OF FEET

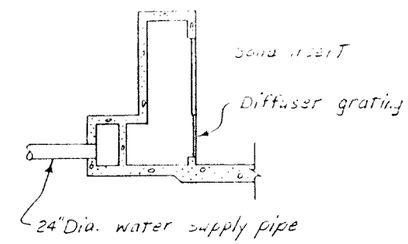
MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
DOWN RIVER FISH LADDER
UPSTREAM PASSAGE CONCEPT
SHEET 1 OF 2

FIGURE 18a

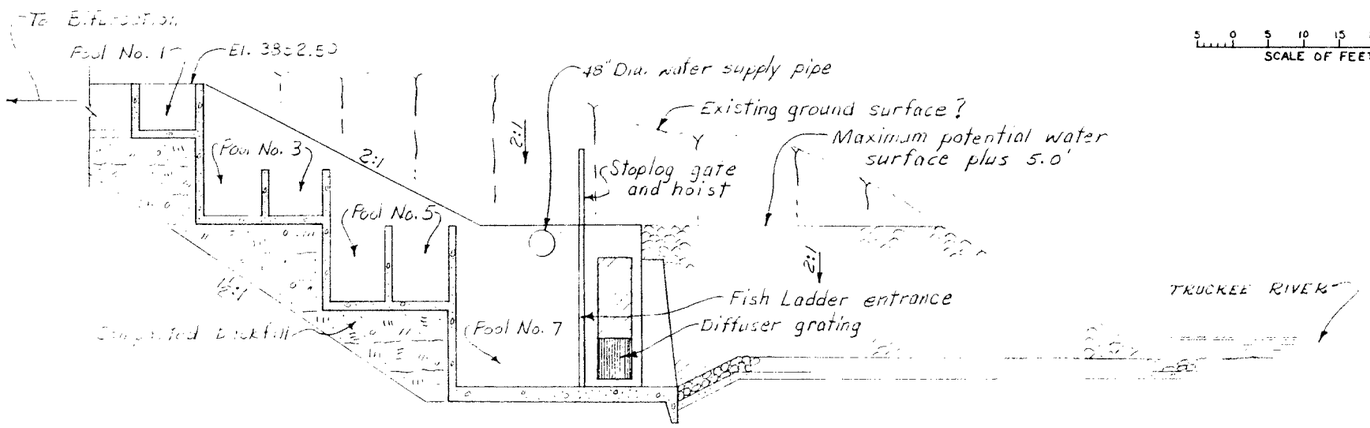


*Top of fish ladder walls to be 6'-6" above floor or a minimum elevation of the maximum potential water surface plus 5.0', which ever controls. Pool No. 7 floor elevation to be minimum potential adjacent river bed elevation.

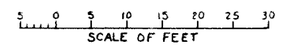
SECTION B-B

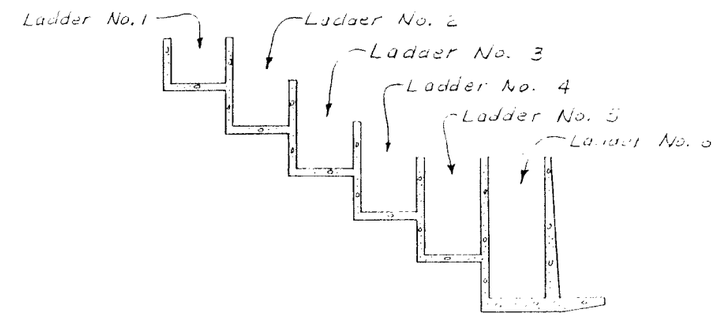


SECTION C-C



SECTION D-D





SECTION E-E

MARBLE BLUFF DAM

FISH PASSAGE FACILITIES

NEAR- DAM FISH LADDER
UPSTREAM PASSAGE CONCEPT

SHEET 2 OF 2

FIGURE 18b

Modifying the Existing River Hoist/Trap

As an alternative to constructing a new facility, a study was conducted to investigate improvements that could be made to the existing river fish hoist/trap system, figure 19. The results of this study are presented as a list of identified problems and recommended solutions.

Objective 1. - Improve fish crowding problems by preventing excessive numbers of fish from getting into the fish lift tank at one time (prevents fish from being out of the water during the lift).

Solutions -

A. Increase the capacity of the retained water in the existing fish lift tank.

1. Add steel plates and stiffeners to the existing tank to raise the height of the tank walls. Extend the steel plates over the existing perforated plate side walls to the desired height.

2. Provide higher capacity hoist and add steel bracing and stiffeners to the hoist support structure as required.

3. Furnish a hydraulic or air cylinder operated gate located within the opening to the entrance vee to the tank. The tank walls could then be raised to the same height as the top of the closed gate.

B. Reduce the volume available to the fish in the existing fish lift tank without changing the volume of water retained during the lift. Limit the number of fish that can crowd into the fish tank.

1. Position the fish entrance vee to its lowest position in the fish lift tank upstream wall. This also repositions the movable end panels, figure 20.

2. Provide an adjustable, perforated plate false ceiling. Position the false ceiling (inside the tank) at the same level as the top of the inside vee (at the 6-in-wide open end of vee). Solutions B1. and B2. together will limit the volume in the tank available to fish, to only what can be lifted without harming the fish.

3. Position the adjustable stoppers in the guide tracks so the bottom of the fish lift tank entrance vee is not lower than El. 3816.50 (top of upstream concrete). This will position the bottom of the tank approximately 3 ft 3 in below the concrete sill. A higher stop position will be required if the top of the fish lift tank would be below the river water surface, however, the tank bottom should not be

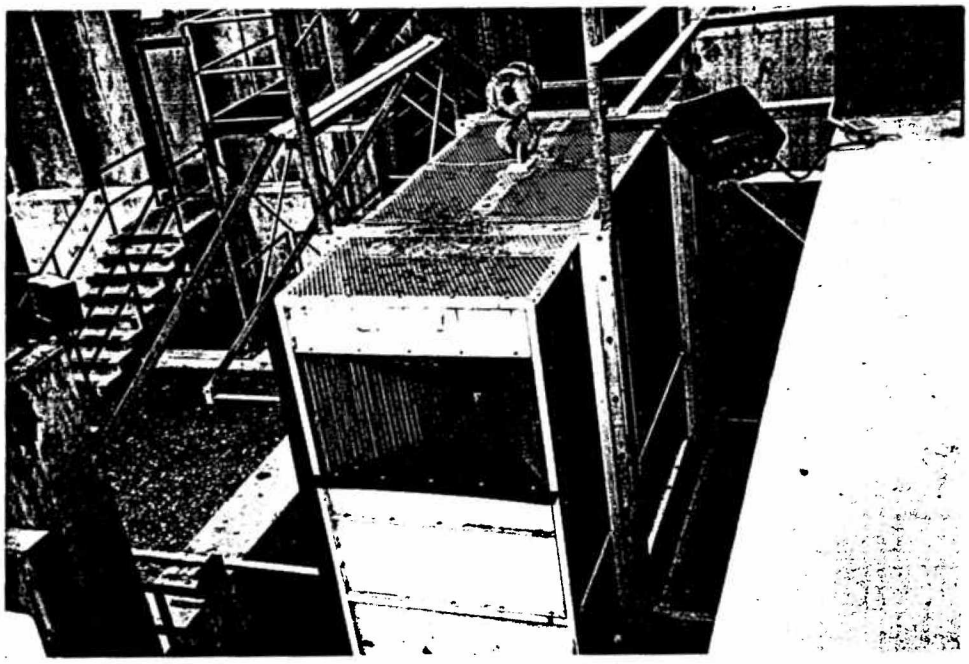


Figure 19 - Upstream view of the existing fish trap/lift in raised position.

raised above the concrete sill without additional modifications to the upstream entrance gate, (see Objective 4, Solution B).

In lieu of having to reposition the adjustable stoppers, set the hoist limit switch to only lower the tank to the correct elevation based on the existing (or predicted) river water surface. This lowered tank position would be set prior to operating the fish lift tank at the beginning of the run.

C. Provide a new, larger capacity fish lift tank and hoist system. Modify guide system as required.

D. Limit the number of fish that can crowd into the existing river fish trap channel at one time.

1. Add a motorized or hoist operated barrier (bar) gate near the entrance to the fish channel or at the existing stoplog slot in the river fish trap channel (may be

able to modify and use the existing river fish vee trap and fish vee hoist). Furnish an adjustable timer which can be set to open and close the barrier gate for preset (adjustable) time periods. The barrier gate would be designed to allow attraction water to flow through when the gate is down.

2. Furnish an adjustable timer which can be set to open and close the entrance gate (just upstream of the tank entrance) for a preset (adjustable) time period. Add appropriate interlocks to prevent misoperation of the systems (i.e., tank has to be in its lowered position before the entrance gate can be opened).

Objective 2. - Improve the fish lift tank exit gate and operating process. Use solution A or B.

Solutions -

A. Keep existing gate but replace the crank/release mechanism.

1. Replace old or worn seals and hinges. Add additional seals as required.

2. Add rollers along the bottom corner edge of the existing and previously modified troughs. The rollers would be positioned to close the gate door as the tank is lowered after dumping the fish. The door would close enough to allow the locking mechanism to lock the door against the seals.

3. Provide a mechanism to lock the gate against the seals (gate in the closed position). This locking mechanism should also include a quick release to allow the gate to drop, dumping the fish into the flumes.

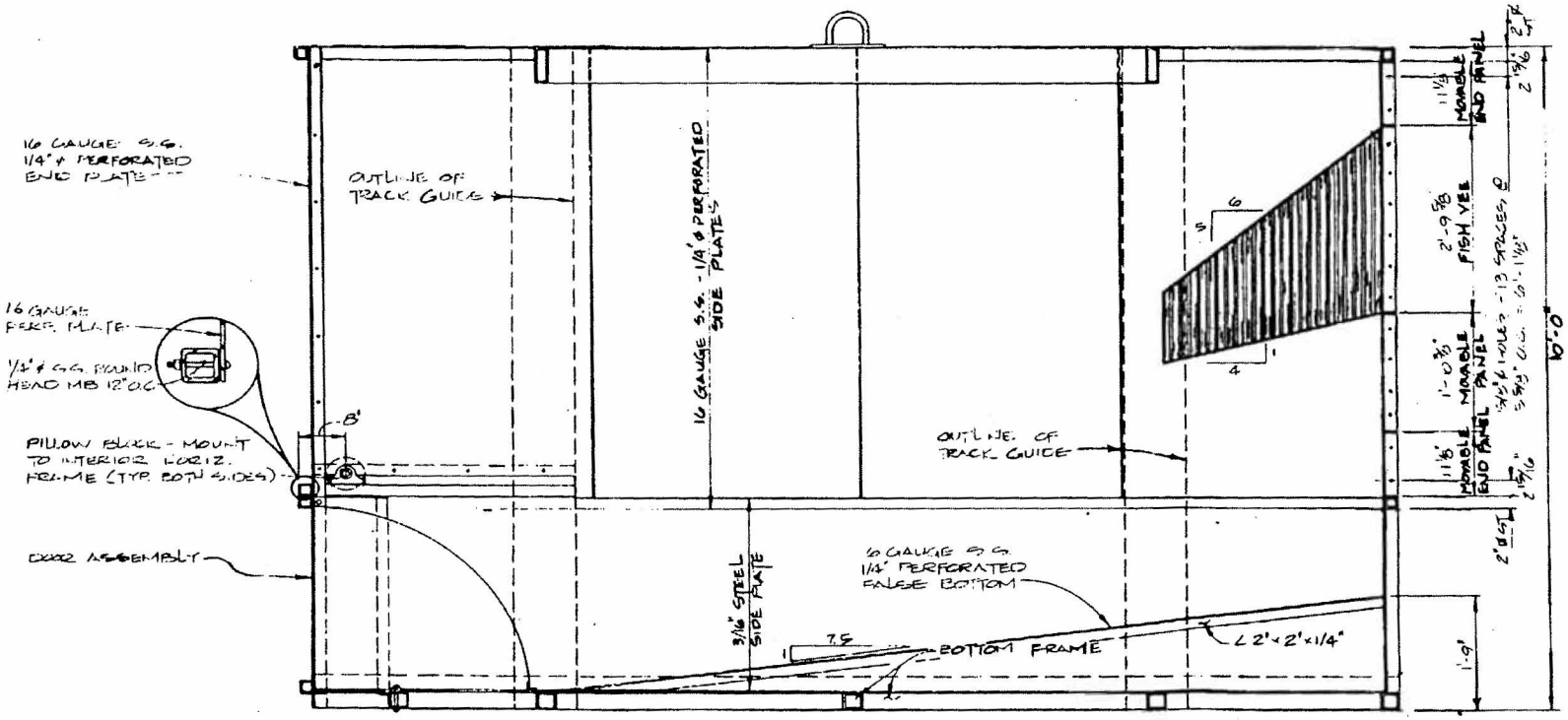


Figure 20 - Section through existing fish lift tank, U.S. FWS.

4. Add skin plate or stiffeners to the downstream side of the gate door. This will prevent the door from hanging up on the rollers as the tank is lowered.

B. Provide another means of operating (raising, lowering, and sealing) the gate (i.e., air or hydraulic cylinders, motorized or manual winch with free spooling capability, etc.). May also need to furnish a new gate.

C. Provide better access to the gate crank/release mechanism when the tank is raised to the higher flume (flume that dumps directly into the existing fishway).

Objective 3. - Decrease the time it takes to complete a lifting cycle.

Solutions -

A. If new higher capacity hoist is provided.

1. Specify hoist with fast lifting speed.

2. Add additional weight to the tank bottom to assist sinking the tank when lowering into the water. The amount of additional weight will be limited by the available capacity of the hoist and the total tank weight including the water weight, friction load, and additional safety factors.

B. If new or existing hoist.

1. Add additional flap valves in the bottom of the fish lift tank to allow the tank to quickly fill with water when lowering (tank presently has one small flap valve in its bottom). The valves would be located beneath the false floor in the bottom of the tank. The valves will be required to seal during lifting of the tank to retain the water in the tank. Also, provide a means to let the air trapped between the tank bottom frame members to escape when the tank is lowered into the water.

2. After all modifications to the tank are complete, locate the center of gravity of the tank using the weight distribution of the tank including the full capacity of retained water. Reposition the lifting lug of the tank and the hoist support beam at their proper lifting positions, if required. Another option would be to add additional weight to the tank bottom to correct the imbalance without requiring any repositioning. Add stops to the hoist support beam, so the hoist trolley can always be positioned at the correct location. These modifications should improve racking problems and also reduce the friction loading in the guides, thus, reduce the load that the hoist lifts.

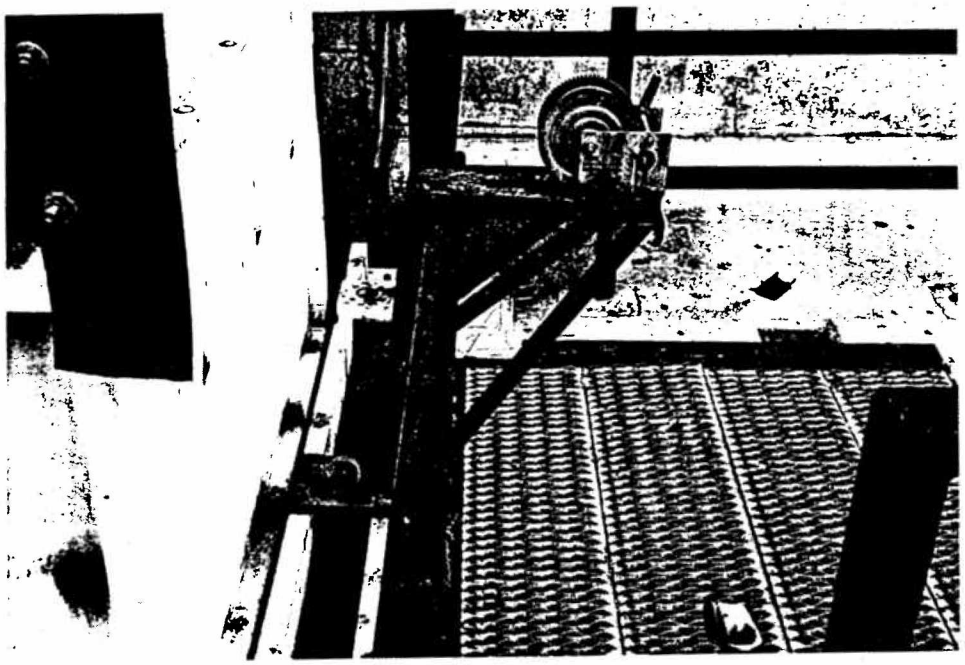


Figure 21 - View of the entrance gate lifting mechanism upstream of fish trap.

3. Improve the process for opening and closing the fish lift tank exist gate, see Objective 2. This will reduce the amount of time it takes between dumping the tank and when the tank can be lowered.

4. Provide limit switches and interlocks where required.

Objective 4. - Improve the entrance gate lifting mechanism located just upstream of the fish lift tank well, figure 21.

Solutions -

A. Provide an electric hoist or winch system with the necessary controls to raise and lower the entrance gate (presently use a manual crank to raise or lower the gate). Lift would be provided with pushbutton controls.

B. Provide stoplogs that can be positioned below the entrance gate. This will allow the bottom of the entrance gate opening to be positioned at the same

elevation as the bottom of the fish lift entrance vee, and allows adjustment as the downstream river water surface elevation changes. The entrance gate would need to be removed to allow insertion of the stoplogs, or additional guides would need to be provided. Will also require a means for retrieving the stoplogs.

Objective 5. - Improve the fish lift tank entrance.

Solutions -

A. Add guides at the tank entrance and a removable tank top to allow quick adjustments or changes to the tank entrance vee. Changes in the shape and location of the entrance vee may be required due to the varying number of migrating fish. (Presently bolt the entrance vee and removable end plates to the fish lift tank support frame.)

B. Provide an in place, adjustable tank entrance vee or several different removable entrance vee-shaped structures, which can be installed or removed to the tank depending on the number of migrating fish.

C. Provide a new entrance vee or modify the existing vee to position the inside top of the vee at the same elevation as the top of the existing side wall skin plates. The false ceiling would then be located at the top of the side wall skin plates. This restricts the fish holding area to the (water) volume that is retained during the lift and also makes an easier installation.

Objective 6. - Reduce number of steps requiring manual operation.

Solution -

A. Change from manual cranks or lifts to motorized hoists, cranks and/or lifts (could also be cylinder operated systems) and provide pushbutton controls for these systems.

B. Automate the system where possible, by utilizing timers, limit switches, interlocks, and controls.

C. Locate controls (pushbuttons) in one centralized location.

Objective 7. - Improve access (for people) into the existing river fish trap channel bottom.

Solution - Provide access ladders and platforms (meeting OSHA standards) to allow safe access to the bottom of the fish trap channel near the existing fish lift entrance.

Estimated material costs for improving the existing fish trap facility are $180,000. Labor for tasks that could be accomplished by site personnel was not included in the cost estimates. Complete cost summary for the identified improvements to the existing fish trap are given in Appendix C.

Downstream Passage

Current downstream passage at Marble Bluff Dam is largely over the baffled apron drop spillway. A statistical summary of river flows at Nixon, Nevada, for the years 1957 to 1971 indicates average river flows during the April and May spawning period have typically been between 500 and 1,200 ft^3/s. This range of flows corresponds to between 1.1 and 1.9 ft of head on the spillway. Assuming these flows or larger, screening or guiding fish toward the existing fishway or another low flow channel is difficult at best. Adult fish could likely be guided with some success, however young fry will typically be distributed evenly in the flow drifting downstream with the current.

There are three options for downstream passage. These options are: continue to pass fish over the existing spillway, guide adult fish back to the fishway, construct a new axillary spillway.

Downstream Passage Over the Baffled Apron Spillway - A baffled apron drop spillway is designed to dissipate high amounts of flow energy on the spillway face. Flow passing down the spillway strikes alternating rows of vertical baffles creating high turbulence and energy dissipation. Viewing the spillway in operation, one assumes fish injury or mortality would be extremely high. However, the highly turbulent condition of flow passing down the spillway may not be as detrimental to fish as it might appear. The objective of a baffle apron spillway is to maintain low flow velocities down the face of the spillway, and thus limit the erosion potential of the jet at the toe of the spillway. Baffled apron drop spillways are typically designed to provide near constant flow velocity after the flow passes three or four rows of baffles. The average flow velocity for a standard baffle apron drop is less than 5 ft/s for flows up to full baffle submergence, figure 22. Rhone and Peterka (USBR Engineering Monograph No. 25) measured maximum baffle impact velocities in laboratory tests from 15 to 20 ft/s for unit discharges of 10 to 40 ft^3/s per ft. These velocities are comparable to the maximum velocity attained by assuming a hydraulic head as the greatest vertical drop along an unobstructed path down the spillway. For Marble Bluff Dam, the vertical distance between every other row of baffles is 8.5 ft. A hydraulic head of 8.5 is equivalent to a velocity of 23 ft/s assuming no energy losses.

Studies on other fish species presented by Bell (2) give some guidance for assessing the severity of the spillway conditions for fish passage, figure 23. Bell's empirical data predict fish mortality will result for impact velocities of greater than about 15 ft/s. An impact velocity of 20 ft/s against a solid object would result in 10 percent

mortality. The probability of fish impacting a baffle while passing through the baffle apron spillway cannot be predicted. It is unlikely mortality or injury can be totally averted as a result of adults and fry passing over the spillway. However, additional biological studies could provide insight for defining the flows (high or low) that produce the lowest mortality.

Guide Adult Fish into the Fishway - Based on discussions with the advisory group for this study, it is assumed that the best downstream fish passage is the existing fishway channel to the lake. The fishway prevents fish from passing over the baffled apron drop and reduces the chance for bird predation or stranding in the river delta. However, guiding even adult fish to the fishway channel presents many problems.

One option is to guide fish to the fishway entrance at the headworks structure. This would require a large fish barrier to be constructed upstream of the dam spillway. The barrier would likely be a series of louvers similar to systems used to discourage fish from entering large canals, figure 24. Louvers would have to be installed each year prior to the run and removed following downstream migration. Obviously, handling trash debris and installation and removal would be major tasks. The sluiceway gate would be closed during this period of time, and all water that does not pass through the fishway would pass through the louvers and over the spillway.

A second option is to utilize the sluiceway as a deep water approach to the fishway. This type of concept could be effective if the adult fish tend to avoid the shallow high velocity flow found near the approach to the spillway crest. A barrier gate could be installed in the sluiceway in conjunction with a new bypass flume, from the sluiceway to the existing fishway, figure 25. In this option, about 200 ft^3/s flow would move into the sluiceway. Water in excess of the fishway bypass capacity (48 ft^3/s), would pass over the top of gate 9 (a weir gate), or through the 4-foot by 3-foot opening between the sluiceway and the spillway. A fish barrier fabricated with perforated plate would be inserted into the sluiceway prior to the run and removed after the run ends. The viability of this type option should also be proven through field experimentation with a temporary structure.

In addition to the above guidance options, acoustic noise deterrence should be considered as a possible method of guidance. Some fish species have been found to be very sensitive to certain frequencies of sound. Sound can be used as an attracter or more typically as a means of avoidance. Correct placement of sound speakers upstream of the spillway could help concentrate adult cui-ui toward the right bank. In this case, structural guidance such as a limited louver system might then be effective at moving fish into the fishway entrance.

Construct an Axillary Spillway - A new axillary spillway could be constructed to carry up to about 3,000 ft^3/s flow down a smooth surface spillway into a hydraulic jump type stilling basin. However, passing fish through the high shear zones of a hydraulic

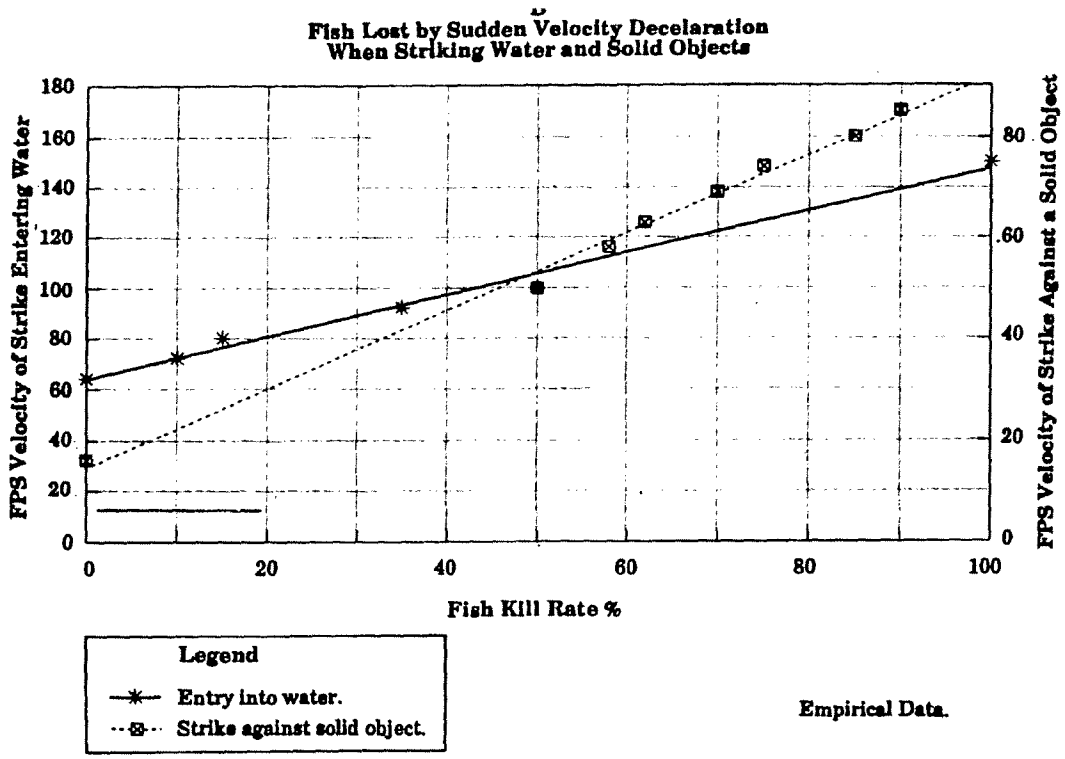


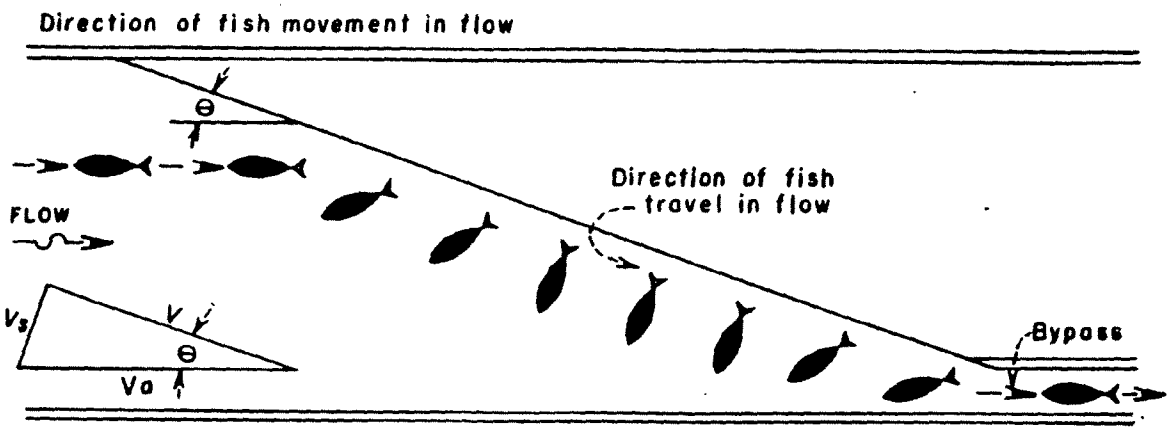
Figure 23 - Fish loss by sudden impact with objects or water, Bell 1991.

It is possible to achieve the desired passage goal of 300,000 fish in 3 days utilizing a dual-chamber fish lock concept. The dual-chamber fish lock concept provides a fish passage capacity that is about 5½ times greater than the single chamber lock placed in the existing fish trap well. However, cost and complexity of operation are both greater than desired. Although not studied, cost and complexity could be reduced by modifying the design to a single chamber lock located at the down river site. Peak fish passage capacity would be reduced to about 180,000 fish in three days assuming an attraction period of 20 minutes per cycle. Experience gained from passing cui-ui in the existing fish trap/lift support the viability of a lock concept.

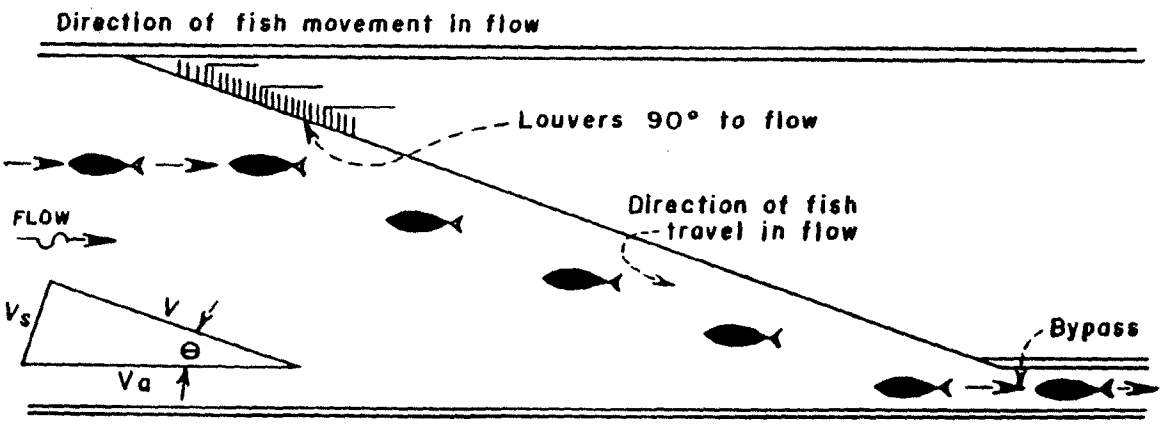
Fish ladders are generally simpler to operate than fish locks. Recent successes at achieving better cui-ui passage up the existing fishway ladders shows promise for improved ladder concepts. However, more work on the existing ladders is needed to prefect an efficient ladder design. At present, constructing a large fish ladder for cui-ui passage around Marble Bluff Dam carries a high level of uncertainty that cui-ui will move steadily through a ladder of the length required.

The costs of building a new, high-capacity fish passage facility will likely be in the range of $2 to $2.5 million. These costs could be reduced to around $1.5 million if the targeted fish passage capacity is downsized. Building a new facility will also require that several unanswered technical questions be addressed.

DIAGRAMS ILLUSTRATING REACTION OF FISH TO LOUVERS



(A) When approach velocity exceeds swimming speed of fish.



(B) When approach velocity is under or near the swimming speed of fish.

Figure 24 - Schematic showing louvers for guiding fish into a bypass, Tracy Fish Collection Facility.

Remaining Questions - The uncertainty of future riverbed degradation below the dam needs to be addressed prior to design. The Sedimentation and River Hydraulics Group at the Technical Service Center is presently conducting a study of the Truckee River Basin. As part of this study we should be able to estimate the potential future maximum and minimum riverbed elevations and corresponding water surfaces for various flow capacities. This information is needed to determine how deep the downstream entrance must be set, so a passage facility will remain functional for its intended life. This information could also have significant impact on estimated project cost.

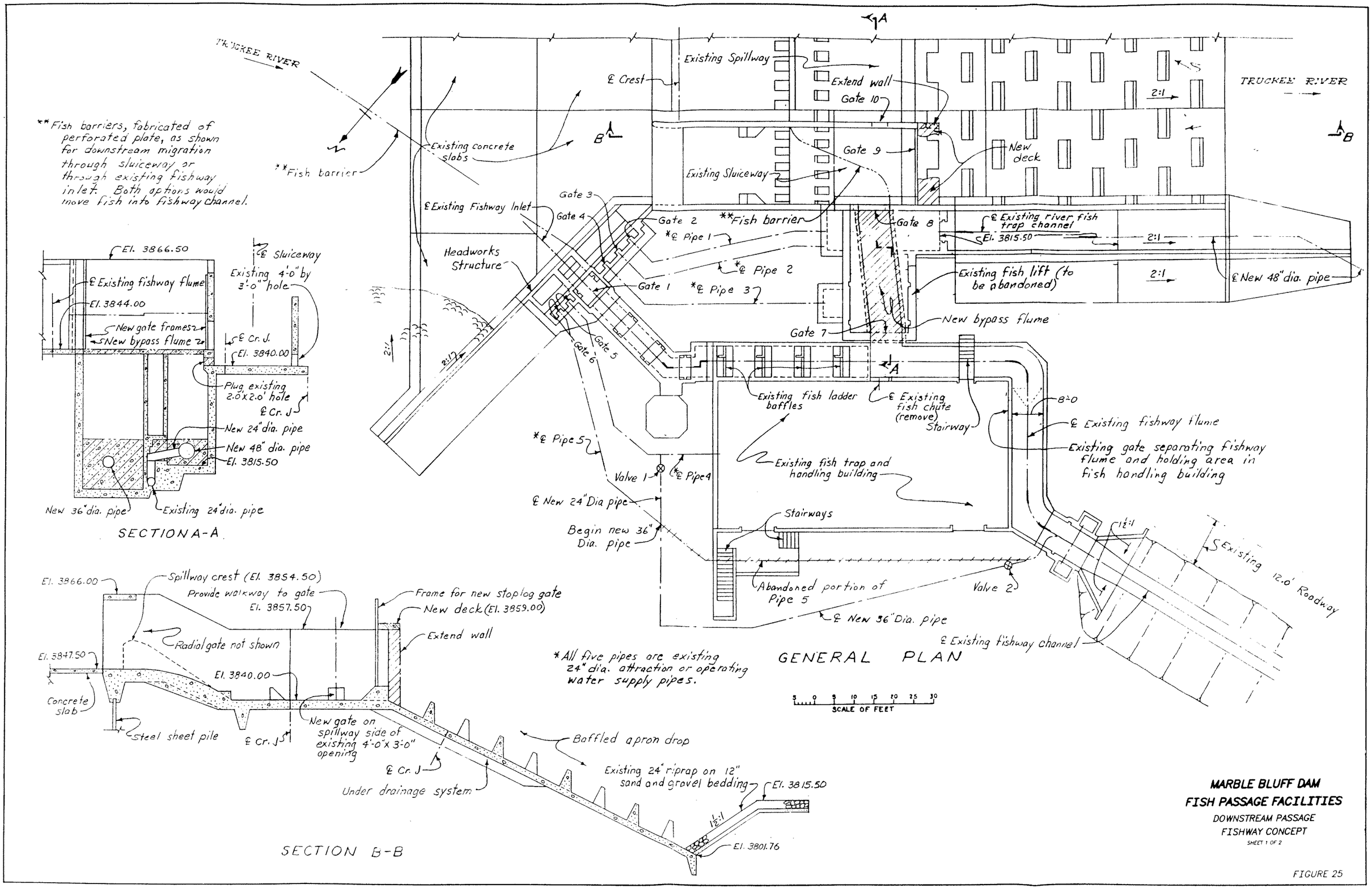
Secondly, there is no proven design for a ladder concept. Building a large passage facility which totally or in part requires cui-ui passage up a ladder without additional field experience on improved ladder designs carries significant risk. Clearly, ladder baffle design and velocity criteria for cui-ui need to be established through model and field testing if a ladder option is selected.

In conjunction with this study several baffle designs were model tested in Reclamation's Water Resources Research Laboratory. Model tests have included testing of the existing ladder design, the design modified with baffle weirs and orifices alternating side to side, and tests of a vertical slot and orifice baffle suggested by experts at the National Biological Survey Anadromous Fish Research Laboratory. These model studies show promise for improving ladder passage. However, field testing during a cui-ui run is needed to evaluate performance.

Current topography data for the site have also been requested. Reclamation's Mid-Pacific Regional Office should be finished preparing topography covering the river approximately 1/2 mile either side of the dam by mid-1995. This information will allow better positioning of facilities to take advantage of existing topography, thus minimizing excavation or backfill.

The problem of fish leaving the fishway and passing back over the spillway also needs to be better defined. Flow velocity profiles as a function of river flow upstream of the dam are needed to evaluate the potential for fish being swept downstream. When river topography data become available, a series of numerical simulations using a two-dimensional depth averaged program, such as FastTabs (Corp of Engineers software), should be used to determine the sweeping velocities along the right bank in the vicinity of the fishway inlet structure. If determined necessary, the use of small rock barbs or other forms of river bank treatment could also be examined numerically.

Estimated Time to Construct New Fish Passage Facilities - Normal construction effort (one shift per day) would require approximately 6 months. This could be shortened to 4+ months with double shift work. Diversion of the river would be required for at least 4 months of the normal construction period.



MARBLE BLUFF DAM
FISH PASSAGE FACILITIES
DOWNSTREAM PASSAGE
FISHWAY CONCEPT
SHEET 1 OF 2

FIGURE 25

ODF D-8170

ESTIMATE WORKSHEET

FEATURE: 07-Mar-95

Marble Bluff Dam Fish Passage
Feasibility Study
HYDRAULIC FISH LIFT OPTION

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

SUMMARY Marbleb

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal					1,700,775.50
		Unlisted Items (10 %+/-)					149,224.50
		Contract Cost					1,850,000.00
		Contingencies (20 %+/-)					350,000.00
		Field Cost					2,200,000.00

QUANTITIES		PRICES	
BY	CHECKED	BY Krafette Hirm D-8170	CHECKED
DATE PREPARED	APPROVED	DATE 3/7/95 07-Mar-95	PRICE LEVEL

ESTIMATE WORKSHEET

28-Feb-95

PROJECT: WASHOE PROJECT

FEATURE: Marble Bluff Dam Fish Passage Feasibility Study FISH LADDER OPTION

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUAN	UNIT	UNIT PRICE	AMOUNT
	1	NEMA size 1 combination motor starter for 480	D8430	9	EA	$1,750.00	$15,750.00
		VAC, 3 phase motors with reversible contactor,					
		motor circuit protector (MCP), and NEMA					
		4 enclosure					
	2	NEMA type 12 enclosure (72"H x 36"W x 18"D)	D8430	1	EA	4000	$4,000.00
		with misc. pushbuttons, lights, selector switches,					
		and relays					

QUANTITIES		PRICES	
BY M. Schuh	CHECKED	BY Charlotte Nunn	CHECKED Joe W. Lawrence Jr
DATE PREPARED Feb. 14, 1995	APPROVED	DATE 2/28/95	PRICE LEVEL

ODF D-8170

ESTIMATE WORKSHEET

FEATURE: 07-Mar-95

Marble Bluff Dam Fish Passage
Feasibility Study
HYDRAULIC FISH LIFT OPTION

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

SUMMARY Marbleb

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal					1,700,775.50
		Unlisted Items (10 %+/-)					149,224.50
		Contract Cost					1,850,000.00
		Contingencies (20 %+/-)					350,000.00
		Field Cost					2,200,000.00

QUANTITIES		PRICES	
BY	CHECKED	BY Jeanette Hirm D-8170	CHECKED
DATE PREPARED	APPROVED	DATE 3/7/95 07-Mar-95	PRICE LEVEL

ODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 28-Feb-95

Marble Bluff Dam Fish Passage
Feasibility Study

Fish Ladder Option Summary
Marble2

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal					1,976,360.50
		Unlisted Items (10 %+/-)					223,639.50
		Contract Cost					2,200,000.00
		Contingencies (20 %+/-)					400,000.00
		Field Cost					2,600,000.00

QUANTITIES		PRICES	
BY	CHECKED	BY Charlotte Brim D-8170	CHECKED Joe W. Lawrence Jr
DATE PREPARED	APPROVED	DATE 28-Feb-95	PRICE LEVEL

Down river location fish ladder concept

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 07-Mar-95

MARBLE BLUFF DAM FISH PASSAGE
Feasibility Study
FISH LADDER OPTION

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			D8140				
	1	mobilization and preparation			LS		$87,000.00
	2	construct cofferdam and dewatering system					$240,000.00
	3	excavation for structures		13,000	CY	$8.00	$104,000.00
	4	backfill about structures		6,000	CY	$3.00	$18,000.00
	5	compacting backfill about structures		6,000	CY	$5.00	$30,000.00
	6	concrete in structures		1,500	CY	$350.00	$525,000.00
	7	furnish/place reinforcing bars		225,000	LB	$0.60	$135,000.00
	8	furnish/handle cementitious materials		420	TON	$100.00	$42,000.00
	9	furnish/lay the following symbol precast					
		concrete pipe					
		48C50		400	LF	$95.00	$38,000.00
		36C50		110	LF	$70.00	$7,700.00
		24C50		70	LF	$26.00	$1,820.00
	10	fabricate/install support beams		18,500	LB	$2.00	$37,000.00
		(84 ea, W8X24, 8' long w/end plates)					
	11	furnish/place 12" sand and gravel bedding		750	CY	$20.00	$15,000.00
	12	furnish/place 24" riprap		1,500	CY	$30.00	$45,000.00

QUANTITIES		PRICES	
BY K.S.	APPROVED	BY [signature]	CHECKED R. Keith Copeland
DATE PREPARED March 6, 1995	DATE	DATE 3/7/95	PRICE LEVEL

ODE:D-8170

ESTIMATE WORKSHEET

07-Mar-95

PROJECT: WASHOE PROJE

FEATURE: Marble Bluff Dam Fish Passage Feasibility Study FISH LADDER OPTION

DIVISION: STAMPEDE DIV

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUAN	UNIT	UNIT PRICE	
	1	One 96" x 72" fabricated steel slide gate	D8420	3420	lbs	$4.50	$15,390.00
		with motor operator and guides					
	2	Five 24" butterfly valve with motor	D8420	7500	lbs	$4.50	$33,750.00
		operators (1500 #/valve)					
	3	Steel pipe	D8420				
		48" Dia. x 20' length		2560	lbs	$2.00	$5,120.00
		36" Dia. x 40' length		3840	lbs	$2.00	$7,680.00
		24" Dia. x 200' length		12800	lbs	$2.00	$25,600.00
	4	One steel stoplog/bulkhead/bar gate with	D8410	9500	lbs	$3.50	$33,250.00
		motor operator and guides					
	5	Two steel diffuser panels, 2' x 10'	D8410	1200	lbs	$1.50	$1,800.00
		600 #/panel					
	6	Ten steel diffuser panels or false floors	D8410	18000	lbs	$1.50	$27,000.00
		each 4' x 15' (1800 #/panel)					
	7	One hundred twenty six steel fish baffles	D8410	136080	lbs	$1.50	$204,120.00
		and guides in the new ladder (1080 #/baffle)					
	8	Ten steel fish ladder baffles and guides	D8410	20250	lbs	$1.50	$30,375.00
		in existing ladder (2025 #/baffle)					
	9	Steel safety grating over new fish ladder	D8120	44064	lbs	$2.00	$88,128.00
	10	Miscellaneous metalwork (handrails, ladders,	D8120	3000	lbs	$4.00	$12,000.00
		other safety grating, walkway)	D8410				

QUANTITIES		PRICES	
BY R. Christensen	CHECKED	BY Charlotte Nam	CHECKED
DATE PREPARED March 6, 1995	APPROVED	DATE 3/7/95	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

07-Mar-95

PROJECT: WASHOE PROJE

FEATURE: Marble Bluff Dam Fish Passage Feasibility Study FISH LADDER OPTION

DIVISION: STAMPEDE DIV

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUAN	UNIT	UNIT PRICE	
	1	NEMA size 1 combination motor starter for 480 VAC, 3 phase motors with reversible contactor, motor circuit protector (MCP), and NEMA 4 enclosure	D8430	7	EA	$1,750.00	$12,250.00
	2	NEMA type 12 enclosure (72"H x 36"W x 18"D) with misc. pushbuttons, lights, selector switches, and relays	D8430	1	EA	$4,000.00	$4,000.00

QUANTITIES		PRICES	
BY M. Schuh	CHECKED	BY Charlotte Mann	CHECKED
DATE PREPARED March 6, 1995	APPROVED	DATE 3/7/95	PRICE LEVEL

ODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 07-Mar-95

Marble Bluff Dam Fish Passage
Feasibility Study

FISH LADDER OPTION

SUMMARY marblea

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal					1,825,983.00
		Unlisted Items (10 %+/-)					174,017.00
		Contract Cost					2,000,000.00
		Contingencies (20 %+/-)					400,000.00
		Field Cost					2,400,000.00

QUANTITIES		PRICES	
BY	CHECKED	BY D-8170	CHECKED
DATE PREPARED	APPROVED	DATE 07-Mar-95	PRICE LEVEL

Appendix C

Cost Estimate Summary Sheets for improving the existing fish lift

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 28-Feb-95

MARBLE BLUFF DAM FISH PASSAGE
Feasibility Study
MODIFICATIONS TO EXISTING MECHANICAL FISH LIFT

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization and Preparatory Work		1	LS		$6,500.00
	1	Increase capacity of existing tank	D8410				
		a. Furnish and install steel plates, stiffener bars and tubes to the existing fish lift tank and the hoist support structure		6,000	lbs	$2.50	$15,000.00
		b. Furnish and install 20 ton, motorized trolley hoist ($45,000)*		7,000	lbs		$65,000.00
	2	Furnish adjustable, stainless steel, perforated plate false ceiling with bracing	D8410	300	lbs	$10.00	$3,000.00
	3	Furnish and install motor operated barrier gate and guides (steel)	D8410	9,500	lbs	$3.00	$28,500.00
	4	Improve existing fish lift tank exit gate	D8410				
		a. Furnish and install steel angles to the existing gate and a new locking mechanism		150	lbs	$2.50	$375.00
		b. Furnish and install polyurethane rollers to fish flumes ($250/roller)*		2	EA	$420.00	$840.00
	5	Furnish and install 1000 lb capacity electric winch/hoist and sheave for existing entrance gate ($1500)*	D8410	500	lbs		$3,250.00
	6	Furnish ten 1'-0" high stoplogs (barrier logs) to be used under the entrance gate as req'd steel (20 #/stoplog)	D8410	200	lbs	$2.00	$400.00
	7	Furnish and install steel guides for tank entrance vee and modify existing entrance vee and removable steel panels	D8410	150	lbs	$2.50	$375.00
		* Price does not include shipping or installation					

QUANTITIES		PRICES	
BY R. Christensen	APPROVED	BY [signature]	CHECKED [signature]
DATE PREPARED 2/22/95	DATE	DATE 2/28/95	PRICE LEVEL

ODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 28-Feb-95

MARBLE BLUFF DAM FISH PASSAGE
Feasibility Study
MODIFICATIONS TO EXISTING MECHANICAL FISH LIFT

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	8	Furnish and install an access ladder with one intermediate platform for the river fishway channel	D8410 D8120	650	lbs	$2.40	$1,560.00
	9	Furnish and install access stairway and platform for the raised tank exit flume	D8410 D8120	1,000	lbs	$2.40	$2,400.00
	10	NEMA size 1 combination motor starter for 480 VAC, 3 phase motors with reversible contactor, motor circuit protector (MCP), and NEMA 4 enclosure	D8430	3	EA	$1,750.00	$5,250.00
	11	Programmable controller with 30 I/O points, Allen-Bradley SLC 500 or equal	D8430	1	EA	$1,000.00	$1,000.00
	12	NEMA type 12 enclosure (72"H x 36"W x 18"D) with misc. pushbuttons, lights, selector switches, and relays	D8430	1	EA	$4,000.00	$4,000.00

QUANTITIES		PRICES	
BY R. Christensen & M. Schuh	APPROVED	BY Charlotte Norm	CHECKED Jim W. Lawrence Jr
DATE PREPARED 2/22/95	DATE	DATE 2/28/95	PRICE LEVEL

ODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 28-Feb-95

Marble Bluff Dam Fish Passage
Feasibility Study
MECHANICAL FISH LIFT

SUMMARY

Marble1

PROJECT: WASHOE PROJECT

DIVISION: STAMPEDE DIVISION

UNIT: NEVADA

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal					$137,450.00
		Unlisted Items (10 %+/-)					$12,550.00
		Contract Cost					$150,000.00
		Contingencies (20 %+/-)					$30,000.00
		Field Cost					$180,000.00

QUANTITIES		PRICES	
BY	CHECKED	BY Charlotte Norm D-8170	CHECKED Joe W. Lawrence Jr
DATE PREPARED	APPROVED	DATE 28-Feb-95	PRICE LEVEL