DESIGN SUMMARY

AND

OPERATING CRITERIA

ARAVAIPA CREEK FISH BARRIERS

CENTRAL ARIZONA PROJECT

WINKLEMAN, ARIZONA

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Aravaipa Creek Fish Barrier
Design Summary and Operating Criteria

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I. Introduction

A. Purpose of design summary and operating criteria - The design summary describes the engineering methods used in the design of the Aravaipa Creek Fish Barriers. The operating criteria provides basic maintenance requirements for operation and maintenance personnel.

B. Location and purpose of the barriers - In 1994 the U.S. Fish and Wildlife Service rendered a Biological Opinion on the transport and delivery of Central Arizona Project (CAP) water to the Gila River basin in Arizona and New Mexico. The Biological Opinion concluded that long-term CAP water deliveries are likely to introduce additional non-native fish to central Arizona via the CAP aqueduct system, jeopardizing the continued existence of four species of endangered native fish.

Aravaipa Creek contains one of the best preserved assemblage of native fish species in Arizona. Fish barriers were constructed under this project to prevent non-native fish from the San Pedro River from moving up into the critical habitat of native threatened and endangered species in Aravaipa Creek.

The project is located in Pinal County, about 6 miles upstream of the point where Aravaipa Creek joins the San Pedro River. The Aravaipa Creek Wilderness Area is approximately 10 miles upstream of the fish barrier site.

C. History - As a result of the U.S. Fish and Wildlife Service Biological Opinion, the Bureau of Reclamation initiated site investigations to locate two fish barriers on Aravaipa Creek. The reach of stream within the wilderness area was determined to be infeasible for the project since barriers would separate existing fish populations. Private land downstream of the wilderness area was then considered, but the landowners were not supportive of the project. The final option was a site on San Carlos Apache allotted land. The allottees were agreeable to the placement of fish barriers at the site, which was about 1,700 feet downstream of private land.

The fish barriers were engineered and designed in Reclamation's Phoenix Area Office. A Value Engineering Study for the project was performed in November 1998. At the request of the upstream property owners, an independent private consulting firm, Tetra Tech, Inc. of Phoenix, Arizona, reviewed the fish barrier designs and provided a report dated January 28, 2000. The pile design was reviewed by Reclamation's Technical Service Center, with comments transmitted February 29, 2000.

An 8a contractor, EPC Corporation of Glendale, Arizona was selected for the construction contract, and a negotiated price of $2,699,000 was settled on. The contract was awarded on August 11, 2000 and the job was officially declared substantially complete on April 19, 2001.

The bulk of the construction was performed by the subcontractor Royden Construction Co. of Phoenix, Arizona. The contractor and subcontractor performed well. The construction progress was interrupted by near record rains in October and November 2000 which sent high flows through the job site. The major contract modifications resulted primarily from bedrock being higher than expected near the right abutment, some poor draining silt that provided inadequate bearing strength, and Reclamation's decision to eliminate the belled ends on the piles.

II. Design Summary

A. Design criteria - The U.S. Fish and Wildlife Service required the following physical criteria for the fish barriers:

1. A minimum 4-foot high vertical drop.
2. A concrete apron downstream of the drop to prevent a deep scour hole from developing. A scour hole could allow fish to gather near the drop, increasing chances of human aided fish passage, or hydraulically assisted fish movement during high flows. The apron also creates shallow, high velocity flows that reduce the jumping abilities of fish, and acts as a velocity barrier to some extent.
3. Construct the barriers to prevent upstream fish movement up to the 100-year flood.
4. Construct two barriers for multiple protection and to create a management area between the barriers.

B. Design Flood - For this project, the instantaneous peak flow defines the design flood. A U.S. Geologic Survey stream gage is located within half a mile upstream of the barrier site. Because the barriers are required to prevent upstream fish movement up to the 100-year flood, the design flood needs to equal or exceed the 100-year flood.

The frequency flood calculation is complicated by controversy surrounding the highest flow on record, which occurred on October 1, 1983. The U.S. Geological Survey (USGS) calculated that flood to be 70,800 cfs. The University of Arizona (UA) believes the high flow to be only 27,000 cfs. As a result of the controversy, 100-year flood determinations by USGS, UA, Pinal County, and Reclamation range from a low of 28,200 cfs (USGS) to a high of 40,000 cfs (Reclamation). The next highest flow of 20,000 cfs occurred on August 2, 1919, which is actually outside the period of record. Extrapolating the USGS frequency flood curve out to 70,800 cfs yields a 1,200-year frequency flood.

Because of the discrepancy between USGS and UA, and the lack of other recorded floods approaching 70,000 cfs, it is difficult to justify designing the fish barriers to 70,800 cfs. Reclamation's 100-year flood is the highest of the contributing agencies, and exceeds UA's highest flow on record. For these reasons, 40,000 cfs was selected as the design flood. 40,000 cfs corresponds to the USGS

300-year flood and Pinal County's 200-year flood.

C. Bankfull Discharge - In order to limit the geomorphological effects of the fish barriers on the stream channel, it is important to ensure that sediment transport is maintained through the project area. Maintaining sediment transport will reduce sediment aggradation and therefore flooding effects, and keep the stream channel from migrating from side to side and destabilizing banks.

To promote sediment transport, notches were designed in the barriers to keep the stream in its original alignment. Notches were sized to carry bankfull discharge, which is accepted as the bank forming discharge within a stream. Bankfull discharge usually falls within the range of the 1.5-year and the 1.6-year floods. Using USGS, UA, Pinal County, Reclamation flood frequency curves, and Arizona Department of Transportation ungaged method, flood frequencies were averaged, yielding a 1.5-year flood of 1,540 cfs and a 1.6-year flood of 1,950 cfs. The discharge through the notches was calculated using the following equation for a free overfall:

$$Q = 9.35\ B\ D^{3/2}$$

where:
Q = flow
B = length of overfall, perpendicular to flow
D = Depth of flow

The notches at the upper and lower barriers were sized to discharge 1,610 cfs and 1,880 cfs, respectively, which fall within the necessary range.

D. Geologic Investigations - Geologic investigations were performed in June of 1999. Two auger holes were drilled near the centerline of each fish barrier in order to determine the depth to bedrock. Three test pits were excavated along the centerline of each fish barrier in order to determine material gradations of the alluvium in the stream channel for scour calculations. An additional test pit and three in-place densities were excavated downstream of the downstream fish barrier for more scour data.

E. General Design Configuration

The primary design challenge was to provide a stable structure on alluvium, anchoring only to the rock at the abutments. The structures needed to be engineered to be stable during large flood events by resisting scour, sliding, and overturning forces.

The fish barrier structures needed to be constructed of reinforced concrete to withstand damaging forces from water and sediment movement. A 4-foot vertical drop is the principle component to control fish movement. A concrete apron downstream of the drop is necessary to prevent a deep scour hole from developing and increasing the potential for fish passage. Cutoff walls at the upstream and downstream ends of the barriers prevent scour damage to the barriers. Concrete piles support the structures in case of unexpected scour depths and to provide sliding resistance. At the abutments, the concrete structure is keyed into rock about 6 feet and anchored to the rock with steel anchor bars.

In addition to the low notches, another step taken to minimize geomorphologic changes was to shape the barriers to follow the contours of the channel. Thus the top of the drop structure is approximately 4 feet higher than the original ground surface across the entire channel. This shape will assist the channel in achieving equilibrium by maintaining the original shape of the stream bank and terraces. The configuration ensures a full 4-foot vertical drop at the edge of the water for any discharge, until the flows reach the rock canyon walls where the water surface will rise up the near vertical rock slopes.

Riprap was placed downstream of the barriers within the high velocity portion of the stream channel to reduce downstream scour depths.

F. Scour Calculations

Scour of the stream channel alluvium is one of the critical design considerations for a structure of this type. Scour action can undercut the structure, resulting in settlement, cracking, or breaching. In order to determine the cutoff wall depths required at the upstream and downstream ends of the barriers, several types of scour must be evaluated: natural channel scour, bridge pier type scour, abutment scour, and downstream scour induced by the structure. The methods used to analyze scour were the Reclamation Technical Guideline "Computing Degradation and Local Scour" and the Corps of Engineers HEC-6 computer program.

40,000 cfs was used as the design flow for all calculations. Several scour equations were used for each type of scour, then an average was determined.

1. Natural channel scour - This type of scour occurs in a movable bed stream channel. The tractive forces of the water cause the channel materials to move in a downstream direction. The depth of channel materials movement is the scour depth. This type of scour primarily affects the upstream cutoff wall. The following equations were used:

Neill: $d_f = d_i (q_f/q_i)^m$

where:
d_f = scour depth below water level (ft)
d_i = bankfull depth (ft)
q_f = design flood per unit width (cfs/ft)
q_i = bankfull discharge per unit width (cfs/ft)
m = 0.67 sand to 0.85 coarse gravel

Lacey: $d_m = 0.47(Q/f)^{1/3}$

where:
d_m = mean flow depth (ft)

Q = flow (cfs)
$f = 1.76(D_m)^{½}$
D_m = mean grain size (mm)

Blench: $d_{fo} = q_f^{2/3}/F_{bo}^{1/3}$

where:
d_{fo} = depth water surface to zero bed sediment transport (ft)
q_f = Q/width (cfs/ft)
F_{bo} = zero bed factor (graph not included, figures range from 0.7 for D_m of 0.05 mm, to 3.1 for D_m of 8.6 mm)

The Neill, Lacey, and Blench equations yield values that must be adjusted by a multiplying factor, Z, that considers stream channel bends to obtain the final scour depth, d_s. For moderate bends, Z was taken as 0.6 for the Neill and Blench equations, and 0.5 for Lacey.

$$d_s = Z\ (d_f, d_m, d_{fo})$$

Neill (competent velocity method): $d_s = d_m(V_m/V_c - 1)$

where:
d_s = scour depth below streambed (ft)
d_m = mean depth of water (ft)
V_m = mean velocity of water (ft/sec)
V_c = competent velocity (graph not included, figures range from 4.0 for D_m of 0.5 mm to 5.9 for D_m of 8.6 mm)

The results of these natural channel scour equations yielded an average high velocity zone scour depth about 17 feet. At the abutments, the average scour depths were about 7.5 feet. These results were the principle reason for the upstream cutoff walls being 16 feet below the channel in the high velocity zone and 8 feet deep at the abutments. The HEC-RAS Corps of Engineer's program indicated about 7 feet of scour would occur.

2. Bridge pier type scour - This type of scour also affects the upstream cutoff wall. Bridge pier type scour occurs when the streamflow encounters an obstruction in the channel. A circulatory flow pattern develops on the upstream side of the obstruction, resulting in scour. The following equations were used:

Jain: $d_s = 1.84b(d/b)^{0.3}(F_c)^{0.25}$

where:
d_s = scour depth below streambed (ft)
b = pier diameter, 10 ft assumed (ft)
d = depth of flow (ft)
$F_c = V_c/(gd)^{½}$
V_c = competent velocity (ft/sec)

g = acceleration due to gravity, 32.2 ft/sec^2

Lacey and Blench regime equations from above were also used and a Z factor applied to convert to bridge pier type scour. For Lacey equation, use Z = 1.5; for Blench, use Z = 0.75.

The results of the bridge pier type scour equations yielded a high velocity zone scour depth of about 19 feet.

3. Downstream scour induced by the structure - Immediately downstream of the fish barriers, the riverbed is subject to erosion caused by the structure. As streamflows discharge off the end of the apron, a scour hole will develop downstream of the structure. Unless accounted for properly, the apron will be undercut. This scour is the primary reason for the downstream cutoff wall. The following equations were used:

Schoklitch: $d_s = [(KH^{0.2}q^{0.57})/(D_{90}^{0.32})] - d_m$

where:
d_s = scour depth below streambed (ft)
K = 3.15 inch-pounds
H = Vertical difference between upstream and downstream of structure (ft)
q = discharge per unit width (cfs/ft)
D_{90} = Particle size for which 90% is finer than (mm)
d_m = downstream mean water depth (ft)

Veronese: $d_s = KH_T^{0.225}q^{0.54} - d_m$

where:
d_s = scour depth below streambed (ft)
K = 1.32 inch-pounds
H_T = head from upstream reservoir to tailwater level (ft)
q = discharge per unit width (cfs/ft)
d_m = downstream mean water depth (ft)

Zimmerman and Maniak: $d_s = K(q^{0.82}/D_{85}^{0.23})(d_m/q^{2/3})^{0.93} - d_m$

where:
d_s = scour depth below streambed (ft)
K = 1.95 inch-pounds
q = discharge per unit width (cfs/ft)
D_{85} = Particle size for which 85% is finer than (mm)
d_m = downstream mean water depth (ft)

Calculations for scour caused by the structures resulted in widely varying scour depths, from 12 to 14 feet at the abutments, to 20 to 50 feet in the high velocity zones. These figures indicated that scour protection in addition to the cutoff walls should be considered. Riprap was introduced to the design to control the downstream erosion potential. Piles would contribute by keeping the structure stable if the undercutting occurred.

Scour conclusions - The depths to construct the cutoff walls needed to be balanced with construction costs and other scour prevention methods, such as riprap and piles. Deeper cutoff walls require more dewatering effort, excavation, concrete, and result in construction operations being exposed a longer time to flooding.

Natural channel scour calculations indicate upstream cutoff wall depths of 16 feet in high flow zones and 8 feet at abutments are adequate. Bridge pier scour figures, especially Blench, justify deeper keys. Cutoff walls over 20 feet deep are undesirable from a cost and construction standpoint. Considering that Jain and Lacey figures indicate scour depths of 15 to 16 feet, and that piles were added to the design, cutoff walls of 16 feet in high velocity zones and 8 feet at the abutments were selected.

Scour potential at the end of the structure indicate that a downstream cutoff wall depth of 20 to 40 feet is necessary. Since a cutoff wall of such depths is very difficult to construct, it was decided to use riprap to control the scour. The riprap was designed to stay in place during the 40,000 cfs design flood. A riprap depth of 12 feet was specified. By arresting scour with the riprap, the downstream cutoff wall depth could match the depth of the upstream wall, thereby simplifying construction.

G. Sliding and Overturning Stability Analyses

Structural sliding and overturning conditions were analyzed. Horizontal, vertical, and moment forces were summarized. Utilizing piles, there is a factor of safety of 2.1 against sliding. The desired safety factor is 2, so the criteria was met.

Overturning analyses yielded a factor of safety of 4.2.

G. Pile Design

Reinforced concrete piles were incorporated into the design to support the fish barriers in case of undercutting from flows and to resist sliding. 10 piles were installed, one below each concrete fish barrier section, with the exception of the four abutment end sections. The original pile design incorporated bells at the ends of the piles and had four 3-foot diameter piles and six 4-foot diameter piles. The piles were dimensioned to support the weight of the fish barrier in case of undercutting. This design was modified during the construction contract when the drilling subcontractor said it was infeasible to construct bells in the alluvium. Although this question was raised during the design process peer review and not considered to be a problem, the bells were dropped from the specifications. The elimination of bells reduced the end bearing capacity of the piles and required that the piles rely nearly entirely on friction to support the loads. The piles were lengthened as necessary to achieve the required friction resistance, and the four 3-foot diameter piles were increased to 4-foot diameter.

Two formulas were used to determine the bearing capacity of the piles:

$B = A_pF_{v0}N_q + E()L)(a_s)(KF_{v0}tanN)$
end + friction

where:

B = bearing capacity (lb)
A_p = end area of pile (ft^2)
F_{v0} = initial effective vertical stress (lb/ft^2)
N_q = bearing capacity factor, use 30 for N = 30/
)L = length of pile (ft)
a_s = outside area of pile contact (ft^2/ft)
K = factor, use 2
N = friction angle, pile to alluvium, use 30/

and $B = [A_p(1/2DDN_(+ cN_c + Dz(N_q - 1)] + (BDzf_o)$
end + friction

where:

B = bearing capacity (lb)
A_p = end area of pile (ft^2)
D = soil density, use 120 lb/ft^3
D = pile diameter (ft)
$N_($ = Terzaghi bearing capacity factor (19.7)(0.7) = 13.8
c = cohesion, 0 for sand, gravel, and silt ($lbft/ft^2$)
N_c = Terzaghi bearing capacity factor (37.2)(1.2) = 44.6
z = depth of pile, use mid-depth for friction average (ft)
N_q = Terzaghi bearing capacity factor, use 22.5
f_o = skin friction coefficient = c + k(Dz- :)tanN
k = coefficient of lateral earth pressure at failure, use 3
: = pore water pressure = (62.4 lb/ft^3)z

The lowest bearing capacity values were obtained using the first equation, so this equation was used for the remaining calculations to be conservative. The pile lengths were designed to achieve a factor of safety of at least 2, meaning that each pile can support twice the weight of the associated concrete fish barrier section. However, only the length of piling which is below the scour depth is considered to have effective friction support during large flooding events. Therefore, scour was accounted for by subtracting the full scour depths from the pile length. The factor of safety for scoured piles was kept above 1.3. The required pile depths ranged from 55 feet to 60 feet. However, 4 piles reached bedrock and were socketed in at depths of 26, 28, 29, and 43 feet.

The axial compressive strength of the piles was checked to confirm adequacy of the pile materials. The nominal ultimate capacity, P was computed using:

$$P = 0.85f_c'(A_g - A_{st}) + f_y A_{st}$$

where:
f_c' = compressive strength of concrete (psi)
A_g = area of concrete (in^2)
A_{st} = area of steel reinforcement (in^2)
f_y = steel yield strength (psi)

4-foot diameter piles with 12 #8 bars and #3 spiral reinforcement have ample axial compressive strength to support the design loads, with a factor of safety of 2.6.

The bending strength of the piles with respect to sliding forces on the barrier were evaluated. The figures showed the piles met the bending criteria for a factor of safety of 2.

I. Concrete Reinforcement - Reinforcement was designed in accordance with "Building Code for Structural Concrete". The rebar was sized such that the nominal flexural strength of the structural members could withstand the forces created by flooding.

Reinforcing bars were used for abrasion protection in the fish barrier aprons. In the low notch, high velocity area where cobbles and boulders can be expected to fall over the 4-foot drop, the concrete making up the apron will suffer impact damages. Reinforcement was placed on a 6-inch spacing to arrest the anticipated pitting of the concrete at a 2-inch depth before the damage becomes a structural concern.

J. Contraction Joints - Because of the length of the fish barriers, contraction joints were required for thermal expansion. Since reinforcing steel does not extend through contraction joints, concrete sections have the potential to move relative to one another at the joint. To prevent movement, keys were added to lock the concrete sections together. The keys were designed to withstand one-half the weight of adjacent section, with at least a factor of safety of 2. Therefore, in theory, the keys would fully support an undercut section of concrete. The shear strength of the concrete was assumed to be equal to tensile strength, 1/10 of the concrete compressive strength, or about 400 psi for 4,000 psi, 28-day strength concrete.

K. Riprap Sizing

Riprap was necessary to prevent scour at the downstream end of the structures from undercutting the downstream cutoff walls. By installing riprap, the depth of the cutoff walls could be reduced.

Riprap was sized using the "Bank and Shore Protection in California Highway Practice" guidelines. This method accounts for velocity, specific gravity of rock, rock placement methods, and slope. A uniform gradation curve was required for better interlocking results. A specific gravity of 2.64 or greater was specified. The required dimensions for the riprap ranged from about 4.5-foot diameter to 1.5-foot diameter rock. A bedding layer was placed to reduce the potential for fines to migrate from beneath the fish barrier structures into the voids within the riprap.

L. Bearing Capacity of Soil Below Cutoff Walls

Prior to backfilling, several cutoff wall sections would be freestanding during construction. Although the walls would be guyed with cables and anchors to prevent tipping, the bearing strength of the native materials was investigated to ensure settlement did not occur prior to backfilling and connection to adjacent sections.

The ultimate bearing capacity, $(\,)\,q_s)_u$, was calculated using:

$$(\,)\,q_s)_u = Q_{ult}/B = ((B/2)N_{(} + (dN_q$$

where:
Q_{ult} = ultimate load (lb/ft)
B = length of wall (ft)
(= Unit weight of soil, 120 lb/ft^3
$N_{(}$ = bearing capacity factor
d = embedment depth (0 ft in this case)
N_q = bearing capacity factor

Using Terzaghi's bearing capacity factor of $N_{(} = 20$, the ultimate bearing capacity, 3,600 lb/ft^2, is high enough to achieve a safety factor of 1.75, which is adequate for this temporary situation.

M. Diversion Pipelines - As part of the Bureau of Indian Affairs requirements allowing Reclamation to construct the fish barriers on San Carlos Apache allotted land, Reclamation was asked to provide a means to divert water at the fish barriers. In the early 1900's allottees living near the site diverted Aravaipa Creek flows for sustenance crops. Remnants of one of the diversion canals are still visible about ½ mile downstream of the fish barriers. The diversion system was requested in the event allottees chose to divert flows for irrigation in the future.

The fish barriers provide a solid diversion structure. However, sediment would be a constant operational issue, as it is at most surface flow diversions. The intakes for any type of system would need to be at the low notches where the flows are. Sediment will fill to the top of the notches, necessitating minor dredging in the immediate vicinity of the intakes if irrigation is pursued.

Two concrete box intakes were constructed on the upstream side of the lower barrier. Steel plates were welded over the opening for public safety. Without the plates, water would flow into an intake box, then into a 1-foot diameter polyvinyl chloride (PVC) pipe embedded in the fish barrier concrete. The diversion pipes exit as steel pipe at the downstream side of the barrier apron on each side of the stream, and are capped with a welded plate. A pipeline would need to be attached at this point to convey the water for downstream use.

The embedded pipe within the structure is sloped at 0.02 or steeper to self-clean. The capacity of the two pipelines is about 14 cfs total, provided the stream is impounded, forcing the streamflow into the inlets before discharging over the drop.

III. Operating Criteria

The purpose of this Operating Criteria is to provide operation and maintenance personnel with maintenance requirements associated with the fish barriers. There are no gates or valves to operate on the system. The operation of the facility consists primarily of periodic checks, particularly following large runoff events to assess damage.

Aravaipa Creek is a perennial flowing stream, with 7 to 15 cfs the usual base flow. The watershed is uncontrolled, so precipitation can create high flows that often rise rapidly. When working in the stream channel, appropriate attention should be paid to the weather.

A. Maintenance Requirements - The following maintenance procedures are intended to prevent flood related problems from developing into conditions that threaten the structural integrity of the fish barriers. Also of concern is increased upstream flood inundation caused by flood debris at the barriers.

1. Inspection of Structures

a. At least once a year the barriers should be inspected for movement, damage to the apron from cobbles or boulders falling over the drop structure, damage to the crest, evidence of scour at upstream and downstream ends, log jams, abutment erosion, and vandalism.

Damage to the concrete apron just downstream of the drop should be watched closely. Rocks are expected to create some impact damage. Additional rebar was placed in the critical areas to halt the concrete pitting at two inches in depth. However, if this measure does not adequately arrest the damage, further steps may need to be taken. Armor plating, as done at Tule Creek Fish Barrier north of Lake Pleasant, or periodic replacement of the damaged concrete, may be needed.

b. Within 5 days following flooding events greater than 5,000 cfs the barriers should be inspected for movement, damage to the apron from cobbles or boulders falling over the drop structure, damage to the crest, evidence of scour at upstream and downstream ends, log jams, and abutment erosion.

Although not expected, log jams at the barriers need to be removed immediately. Log jams can raise the upstream water surface, creating a potential flooding liability. Vegetative materials from log jams can be spread downstream of the affected barrier in an aesthetic manner, on flood terraces above the stream.

c. The site should be checked immediately if San Carlos Apache allottees or upstream private land owners report a problem.

d. 404 permit - If repairs to the structures necessitate fill or dredged material to divert flows around the work, a U.S. Corps of Engineers 404 permit or Nationwide permit will be required. The individual permit obtained to construct the barriers will be in effect until August 15, 2002. After that date, applicable work will need to comply with the 404 requirements in effect at that time.

2. Vegetation Control - To prevent trees from taking hold at the barrier low flow notch and contributing to log jams by catching floating debris, the following maintenance is recommended.

Remove trees greater than 8 feet in height for a distance of 50 feet upstream of the barriers; from Station 1+55 to Station 3+74 for the downstream barrier; and Station 5+57 to the right abutment for the upstream barrier. These stations correspond approximately with the existing treelines along the canyon walls. Bushes, willows, and other vegetation do not need to be removed.

3. Access - Three gates permit vehicles and equipment to access the site. The roads through the gates provide access upstream and downstream of the fish barriers. There is no permanent access road to the area between the barriers, so equipment would require temporary ramps, for example, to access this area.

The fish barrier aprons can withstand loading from heavy equipment.

Aravaipa Road is maintained by Pinal County Public Works Department.

4. Fence - At the request of local landowners, a 5-foot tall, three rail pipe fence was installed along Aravaipa Road to keep vehicles from accessing the streambed in the vicinity of the barriers. This fence must be maintained, so periodic checks are recommended.

The fence has 3 access gates, which are equipped with locks. Housings over the locks prevent cutting or shooting of the locks. Agencies possessing keys to access the gates are:

a. Central Arizona Project - Responsible for maintaining the fish barriers.

b. Bureau of Indian Affairs Agency Office, San Carlos - Responsible for San Carlos Apache tribal member access, including allottees and tribal police.

c. San Carlos Irrigation Project, Bureau of Indian Affairs - Owns and operates power lines within the fenced area.

d. Bureau of Reclamation - Long term monitoring of fish movement and stream channel geomorphology.

Check on the fence at least once a year, or if notified by the public of a problem.

B. Stream Channel Monitoring - The Bureau of Reclamation will monitor the stream geomorphology for 5 years, beginning April 2001 and ending in 2006. The monitoring includes a yearly survey of the stream thalweg, structural survey of the fish barriers, channel cross-sections, aerial photos, and vegetation analysis. Reclamation will also monitor fish populations at the site for an undetermined number of years.