Fish Passage at Road Crossings Assessment
Boise National Forest
FY 2003

By

TJ Clifford, Forest Hydrologist
Michael S. Kellett, Fishery Biologist

EXECUTIVE SUMMARY

Inventory

The Fish Passage at Road Crossings Project for FY 2003 on the Boise National Forest evaluated 372 road/stream crossings and completed full culvert inventory assessments on 142 of those crossings on fish-bearing streams (Table 1). The Boise National Forest completed a partial assessment on any crossing that did not require a full inventory to be used as precursor information for future reference. The total number of road crossings on fish-bearing streams across the Forest is estimated to be about 1,430 (Table 2). Of the evaluated culvert crossings, about 90% do not meet the criteria to pass fish (red) and are a barrier for at least one life stage (Table 1). Most of the "red" crossings were associated with circular or squashed pipe-arch culverts (Table 3). Most of the "red" crossings were a barrier at least due to the outlet drop (Table 9), but upon further evaluation may be a barrier for other reasons as well. Only one of the evaluated culverts met the passage criteria and was not a barrier (green) to fish for both juvenile and adult life stages. This crossing was an open-bottom arch. The remaining 9% of the evaluated culverts were found to be undeterminable (gray) and candidates for further evaluation (e.g.; Fish Xing software). This report summarizes the prioritization of sites, the methods and assumptions used throughout, the evaluation criteria, the results, and a proposal for rehabilitation or reconstruction. For a more detailed description of the results by Hydrologic Unit Code, refer to the appendices. All of the assessments, whether full or partial, are summarized by watershed in the included appendices.

Table 1: Summary of Aquatic Organism Passage Barriers

Lifestage	Red	Grey	Green	Total
Adult	124	17	1	142
Juvenile	131	10	1	142
Total	255	27	2	284

Red = is a barrier to fish. Grey = is unknown and in need of further assessment to determine passability. Green = is passable to these lifestages of fish. As seen in the table, of the 142 crossings inventoried, a large majority (90%) were found to be barriers to all lifestages of fish.

Table 2: Summary of Regional Priority Crossings Inventoried and those Estimated to be Remaining

Priority	# Crossing Sites Done	# Crossing Sites Remaining
1st (Chinook, Steelhead)	81	0
2nd (Bull Trout)	184	159
3rd (Cutthroat)	46	0
4th (Other Species)	0	1271
Total	311	1430

This table summarizes the priorities identified within Region 4 and the accomplishment compared to the remaining sites in each priority category. As illustrated the 1st and 3rd priroities are completed for the Boise National Forest. These sites were all within the SFSR making it possible to accomplish 3rd priority sites concurrently with the 1st priority sites. The 2nd priority sites are scattered across the Forest. The most efficient method was to move systematically from the anadromous drainages South across the Forest allowing for effective use of government quarters and travel distances.

Table 3: Crossing Type Designations by Lifestage and Passability

Crossing Type	Adult Red	Juvenile Red	Adult Grey	Juvenile Grey	Adult Green	Juvenile Green	Total
Circular	92	97	10	5	0	0	204
Pipe-Arch	27	29	6	5	1	1	69
Open-Bottom Arch	2	2	0	0	0	0	4
Box	3	3	0	0	0	0	6
Bridge	1	1	0	0	0	0	2
Total	125	132	16	10	1	1	285

This table represents a summary of the types of crossings, mainly culverts, that were encountered during the full crossing assessment. As illustrated the majority of crossings inventoried (72%) were circular culverts. One reason for this bias is that most of the bridges were identified prior to field inventory and were only observed for passability and not identified as a priority for inventory.

Inventory Results

The majority of culverts (90%) in the nine 5th field watersheds surveyed rated out in the red category (Table 1, Appendix A). Most of these pipes are circular or squashed pipe-arches, which occur

in headwater tributaries (Table 3). The majority of the barriers or "red" culverts was found in the South Fork Salmon River (SFSR) subbasin and the South Fork Payette River subbasin and corresponds to those drainages with completed inventory (Appendix A).

Recommendations

We have taken these results and focused our energy on those crossing considered red. Priority was assigned mainly by calculating the miles of habitat available upstream from the crossing. The Boise and Sawtooth National Forests also asked the following questions to verify that these crossings were located in areas considered to be high quality for restoration.

- Is the project in a high priority subwatershed as determined by the Watershed Aquatic Recovery Strategy (WARS)?
- How many listed fish or other aquatic species would benefit from upgrading the barrier?
- Does critical habitat occur above the culvert?
- How many miles would be made accessible if passage was restored?
- Will correction of this barrier make the stream more accessible to introduced species?

The order within Table 4 is not necessarily firm, but as illustrated is listed in order of the culverts with the most upstream critical habitat to culverts with the least upstream critical habitat. Also, note that the miles of perennial stream above each culverts varies greatly. This habitat is not necessarily labeled as critical habitat but would still be in the same Aquatic Conservation Strategy watershed. The cost of replacement is of course based on an average cost for replacing similar-sized culverts with concrete arches. The average is based on a limited number of replacements on the Boise National Forest. The planning cost added to the construction and supply cost gives us our total with the construction and supplies costing about $40 - $50,000 alone. Roaring River is an extremely large culvert crossing with a large volume of fill material above. Both the cost and benefit for this culvert will be tremendous. The Boise National Forest will replace Rammage Meadows and Wilson Creek this year. Many of the remaining culverts on this list are in the SFSR basin, which is an anadromous priority. This inventory made it easier to utilize some of the more recent research currently underway at the Rocky Mountain Research Station to evaluate culvert combinations for their importance in terms of patch size for the various priority fish species. We plan to accomplish this with the data that we have collected as we complete some of the identified "highest" priorities per criteria/assumptions developed from applicable research and the San Dimas Aquatic Organism Passage Inventory Protocol.

Further recommendations include continuing the inventory across the Forest for another field season at least, as funding allows, to fill gaps in lower regional priority areas or fish species. As illustrated in Table 2, the Boise National Forest has about 159 crossings remaining for Bull Trout and over 1,000 crossings remaining for all species. After reviewing the data collected we feel it important to collect crossing information for all species, regardless of priority because it may provide better connections within and between patches.

Table 4: Top Priority Culverts on the Boise National Forest for Replacement
Forest-wide Priority determined by San Dimas Aquatic Organism Passage Inventory Protocol

Culvert or Creek Names	Regional Fish Species Inventory Priority	Miles of Upstream Critical Habitat	Miles of Upstream Perennial Stream	Cost of Replacement	Aquatic Conservation Strategy Priority	Watershed & Aquatic Recovery Strategy
Roaring River	2nd	18.0	35.0	$500,000	Yes	Moderate - Passive
Rammage Meadows	2nd	7.0	8.2	$60,000	Yes	High - Active
Wilson Cr.	2nd	6.1	7.3	$60,000	Yes	High - Active
Fir Cr.	1st & 2nd	6.0	12.2	$60,000	No	High - Active
Fool Hen Cr.	2nd	5.3	5.1	$60,000	Yes	High - Active
Bear Cr.	2nd	5.0	9.4	$60,000	No	High - Active
SixBit Cr.	2nd	4.5	11.9	$60,000	No	High - Active
Mores Cr.	2nd	4.2	11.5	$60,000	No	Moderate - Active
Renwyck Cr.	2nd	3.8	7.3	$60,000	Yes	Moderate - Active
North Fork Dollar Cr.	1st	3.8	11.5	$60,000	No	High - Active

Criteria for ranking culverts is weighted mainly on the miles of habitat that will be accessible after replacement, because all sites are within critical habitat. However, our criteria included the inventory priority for species, the aquatic conservation strategy, the watershed and aquatic recovery strategy, the benefit to listed species, and the accessibility to introduced species. Rather than providing an order to the top 10 replacement culverts we plan to complete as funding, planning, and workforce allow.

Inventory Procedure Discussion

Initial Prioritization of Sites

Upon learning that the Boise National Forest would be funded for culvert assessment in FY 03, the Resource Staff assembled information to determine how big of an inventory task lay ahead. The Forest Team first focused on those subbasins that contained the key species emphasized by the Regional Office (Table 5). These included salmon, steelhead, bull trout, and cutthroat trout as a priority in the same order. We then determined how many stream crossings occurred in fish-bearing streams within these selected subbasins by using GIS stream and road coverages. Because the Forest does not yet have a linear fish distribution layer, perennial streams were intersected with roads to estimate the number potential survey sites. The INFRA database was queried to identify road-stream intersections that were bridges. District personnel reviewed maps displaying this information to help verify which crossings were bridges, fords, or culverts. This gave us a starting point of where to focus the surveys. Further field verification confirmed the presence of bridges, fords, and culverts.

Table 5. Threatened, endangered, sensitive, Idaho state special concern fish species present on the B.N.F.

Fish Species	Status	Subbasin							
		S.F. Salmon	S.F. Boise	Payette (Squaw Creek)	N.F. Payette	M.F. Payette	S.F. Payette	N.F. M.F. Boise	Boise Mores
Snake River Spring/Summer Chinook	Threatened	X	--	--	--	--	--	--	--
Snake River Steelhead	Threatened	X	--	--	--	--	--	--	--
Bull Trout	Threatened	X	X	X	X	X	X	X	X
Westslope Cutthroat Trout	Special Concern	X	--	--	--	--	--	--	--

Field Crews and Inventory Collaboration

The Boise National Forest and the Sawtooth National Forests entered into a challenge cost-share agreement to accomplish the FY2003 target of completing culvert inventories (Agreement #03-CS-11040214-061 and #03-CS-11041430-022). These agreements established a working partnership with the Southwest Idaho High Country and West Central Highlands Resource conservation and Development Councils (RC&Ds). The partnership provided necessary equipment to the Forest Service to accomplish the inventories within budget while providing the RC&Ds information on privately owned barrier culverts to provide future partnerships for culvert replacements. The two Region 4 Forests also (i.e. Boise and Sawtooth) entered into a partnership for funding the crews and vehicles. The field crews consisted of internship students provided to the FS under an agreement with the Student Conservation Association (Agreement #03-PA-11040214-053). This allowed us to pay for a total of ten individuals to accomplish the task in six months within an $80,000 budget. Field crews consisted of two persons per crew with one vehicle for a total of five crews or about 2.5 crews per Forest. The two Forests hired one inidividual under a Personnel Services Contract to provide logistics, training, and organization for the field crews

Table 6: Crew Production Information (Totals)

Forest	Total Sites Inventoried	Total Miles Driven	Total Gas $ Spent
Boise N.F.	311	8644	1085.77
Sawtooth N.F.	475	12514	1535.49

Total Sites Inventoried does not include Inaccessible or Bogus Crossing sites. Mileage driven for the sites accomplished varies slightly between the two Forests. The Boise National Forest averaged about 28 miles per site and the Sawtooth averaged about 26 miles per site.

(Agreement #03-IA-11040214-051). Because of the partnerships established with the RC&Ds, one of the most important tasks involved communication about private owners that were "en route" (along streams) to Federal land and that were willing to cooperate in allowing inventory on their lands. The funding worked well for the two Forests, however, the budget was still very tight due to high overhead, material, and equipment costs to initially start such a cooperative project. It is highly recommended to expand this type of partnership for a much more cost-effective outcome for such a specific task and goal.

Crew production was tracked throughout the season for two reasons. The first was to continue to reorganize the crews based on most productive pairs and ensure there was an even match of expertise across both Forests. The second reason was to establish an accurate estimate of the costs and time required to complete extensive inventories like this San Dimas Aquatic Organism Passage Inventory Protocol. Tracking the production as illustrated by the tables gives us a much more accurate method for requesting budget for completing the remaining crossing sites on these Forests or other Forests using the same protocol.

The crews were given the responsibility for determining what sites warranted a full inventory and the local professional fisheries biologist or hydrologist verified this decision. The Boise and Sawtooth also tasked the crews with locating on a paper USGS 7.5 minute quad topographic map or during an initial drive by, those sites that were inaccessible or mapped inaccurately (i.e. locations where the road was mapped on the wrong side of the stream). The third set of sites was labeled as partial assessments because the crew was not responsible for a full assessment. The partial assessment provided the Forest with information on stream crossings that were not considered to be perennial and/or fish bearing. This information will be used as an aid in future analysis documents to determine the connectivity between the road and stream systems.

Table 7: Crew Production Information (Averages)

Forest	Average Time Spent Per Site	Average Driving Time Per Site	Average Distance Traveled Between Sites	Cost of Gas Per Site
Boise N.F.	0.8 hrs	0.6 hrs	14.1 miles	$3.63
Sawtooth N.F.	0.7 hrs	0.5 hrs	15.6 miles	$3.23

This table represents an average production rate on a per-site basis enabling accurate budgeting for future culvert inventory projects. The field crews on the Boise and Sawtooth National Forests were required to enter into log books information regarding travel and site time for each site. This information was then entered into a spreadsheet and caluculated as a whole. This summary did not account for Inaccessible or Bogus crossing points.

Additional Methods & Assumptions

Evaluation Criteria

The USFS Region 1 fish passage evaluation criteria screening process was used to classify existing crossings as either meeting, needing further hydraulic analysis, or failing to meet fish passage criteria for selected **resident** fish species. Region 1 constructed two flow charts (Figures 1 and 2), similar to ones developed by the California Department of Fish and Game (2001), for juvenile and adult cutthroat and bull trout. These flowcharts attempt to define whether passage is provided through existing structures at the time of survey.

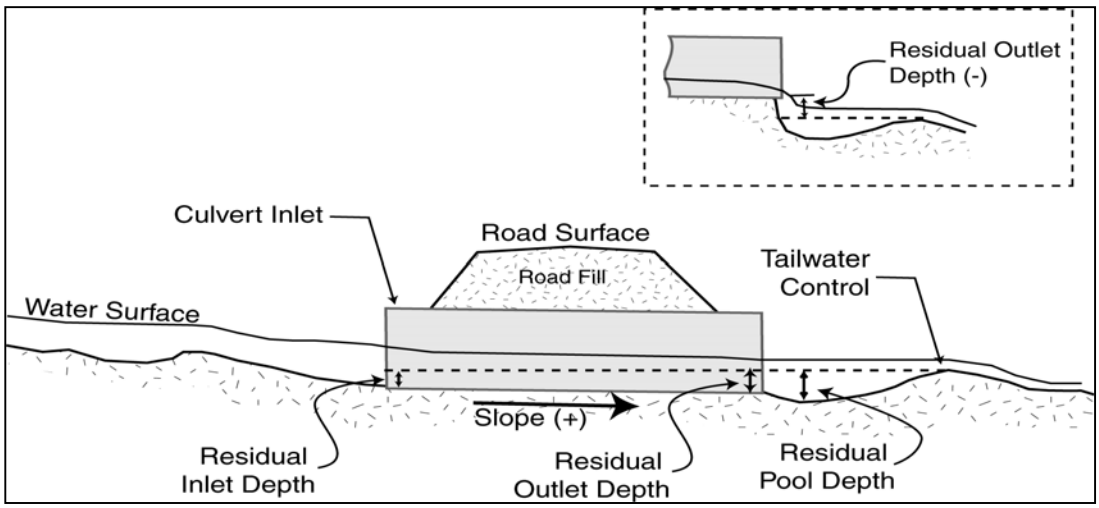
The regional passage evaluation criteria flowcharts first determine whether the crossing meets natural channel simulation criteria. It is important to remember that these evaluation criteria are not as rigorous as stream simulation DESIGN criteria. Criteria for evaluating for natural channel simulation include:

- Streambed substrate is continuous in character and profile throughout the entire length of structure (Representative bed material must be arranged in a stable configuration that provides for flow diversity, energy dissipation, and continuity of bedload transport throughout the structure).
- Crossing is set at or below stream grade – no outlet perch (No perch is assumed if streambed substrate is continuous throughout the structure).
- Structure width is equal to or greater than the average bankfull width of the channel out of the influence of the crossing – no constriction of the active channel exists.
- No steep drops occur immediately upstream of structure – channel slope between the crossing inlet and the first upstream holding habitat is similar to overall channel gradient (This must be verified for all crossings initially considered passable from the screen).

If the site inventory data verifies the above natural channel simulation criteria, the crossing is considered adequate for passage of all salmonids, including the weakest swimming lifestage. If not, one proceeds through the flowcharts to further evaluate each culvert until a passage status is determined. These criteria can be viewed in three stages:

1. getting into the culvert,
2. getting through the culvert,
3. and getting out of the culvert.

Figure 3.



Residual Pool Depth = (Elev $_{\text{Tailwater Control}}$ – Elev $_{\text{Pool Bottom}}$)
Outlet Drop = (Elev $_{\text{Tailwater Control}}$ – Elev $_{\text{Outlet Invert}}$)
Residual Inlet Depth = (Elev $_{\text{Tailwater Control}}$ – Elev $_{\text{Culvert Inlet}}$)
Culvert Slope Percent = (Elev $_{\text{(Inlet Invert – Outlet Invert)}}$ / Dist $_{\text{(Inlet Invert – Outlet Invert)}}$ X 100)
Inlet Gradient = (Elev $_{\text{(Inlet Gradient Control Point – Inlet Invert)}}$ / Dist $_{\text{(Inlet Gradient control Point – Inlet Invert)}}$ X 100

Measurements used in evaluation criteria (from Taylor and Love, 2001).

Getting into the Culvert

Outlet Drop

Culvert outlets that are perched above the water surface are common obstacles to fish passage. Perch height is flow-dependent. Therefore, the stream discharge at the time of the field assessment does not provide for a comprehensive measurement of perch height. The Region 1 protocol uses a conservative

assessment of perch height by comparing the outlet invert elevation to the tailwater control elevation (Figure 3). This is a flow-independent measurement. Ideally, the perch height should be evaluated at various discharges up to the high-flow design discharge. However, this would be too time consuming for this comprehensive assessment of all culverts in the region.

The Boise National Forest developed the following screening criteria to evaluate culvert outlets. This criteria is based on literature review and consultation with fisheries biologists, which is also documented in this section.

	Green (juvenile)	**Green (adult)**	**Gray (juvenile)**	**Gray (adult)**	**Red (juvenile)**	**Red (Adult)**
Culvert Outlet	Not perched	Perch ≤ 0.5’	Perch < 0.34’ plus Outlet pool depth at least 1.25 times perch height	Perch 0-0.8’ plus Outlet pool depth at least 1.25 times perch height	Perch > 0.34’ or Outlet pool depth < 1.25 times perch height	Perch > 0.8’ or Outlet pool depth < 1.25 times perch height
			Note: Hydraulic analysis required to determine passability.			

Through biological monitoring, fish have been observed jumping considerable vertical and horizontal distances to clear obstacles. However, few studies have actually documented the jumping ability of fish, especially for young and small fish. Lab studies have determined that ideal jumping conditions for fish occur when the ratio of the jump height to the depth of the pool below the jump is 1:1.25 (Robison et al 1999). NMFS SW Region (2001) states that culvert perch needs to be evaluated for both high design flow and low design flow and should not exceed 1 foot for adult fish and 6 inches for juveniles with a jump pool of at least 2 feet. Burton (1998) states in his protocol for assessing fish passage at culverts in the Boise River Basin that the standard maximum jumpable height for adult trout is 0.984 foot (11.8 inches) and 1.968 foot (23.6 inches) for adult salmon. The Idaho Dept of Lands (1998) guidelines for new stream crossing installation permits a maximum drop of 1 foot from the culvert outlet when a holding pool is provided. The USFS R6 and R10 fish passage assessment screening criteria indicate that culverts with an outlet perch height of less than four inches may accommodate upstream movement of juvenile Coho salmon, but the crossing is only considered passable (GREEN) when the structure is not perched.

Getting through the Culvert

Culvert Slope

Water velocity within a culvert is determined primarily by culvert length, width, gradient and roughness. If the culvert gradient is too steep, or the culvert width is narrower than the streambed width, the water velocity will be increased within the culvert. Even very slight changes in the slope of the culvert (0.5% to 1.0%, for example) or substrate roughness within the structure may significantly change the culvert velocity.

The Boise National Forest developed the following screening criteria to evaluate culvert outlets. This criteria is based on literature review and consultation with fisheries biologists, which is also documented in this section.

	Green (juvenile)	**Green (adult)**	**Gray (juvenile)**	**Gray (adult)**	**Red (juvenile)**	**Red (Adult)**
Embedded Culvert	Maximum Gradient ≤1% (unless inlet depth > 0.34') plus Culvert width/ Bankfull width ratio ≥ 0.7 plus No outlet drop	Maximum Gradient ≤2% (unless inlet depth > 0.34') plus Culvert width/ Bankfull width ratio ≥ 0.7 plus Perch ≤ 0.5'	Maximum Gradient ≤1% plus Perch < 0.34' plus Insufficient Backwatering	Maximum Gradient ≤2% plus Perch 0.5-0.8' plus Insufficient Backwatering	Gradient >1%	Gradient >2%
Culvert not embedded	Maximum Gradient ≤0.5% (unless inlet depth > 0.34') plus Culvert width/ Bankfull width ratio ≥ 0.7 plus No outlet drop	Maximum Gradient ≤1% (unless inlet depth > 0.5') plus Culvert width/ Bankfull width ratio ≥ 0.7 plus Perch ≤ 0.5'	Same as above	Same as above	Same as above	Same as above
Note: In cases where the residual inlet depth meets the minimum depth criteria, backwatering exists, and there is no outlet perch (or up to 0.5 foot perch for adults), then culvert gradient is automatically allowed to be higher to some degree.			Note: Hydraulic analysis required to determine passability.			

According to Idaho Dept. of Lands (1998), bare culverts greater than 50 ft long will cause fish-passage problems for adult spring-migrating trout (6-12 inches) if installed at over a 0.5% gradient and for juvenile and weak swimming fish if over 0%, unless properly backwatered. If adequately backwatered, the culvert could be up to 4% gradient for adults and 3% for juveniles and still allow upstream passage. The Idaho guidelines state that culverts without streambed substrate that are less than 50 ft long can be installed up to 1% gradient for adult passage and 0.5% for juvenile passage. NMFS SW Region (2001) new installation guidelines require the slope of a non-embedded culvert to be less than 0.5% for salmon and steelhead. In the USFS Region 6 and 10 passage assessment matrices for juvenile Coho salmon, culvert grade for bare culverts must be less than 0.5% to be considered passable (GREEN). Bare culvert crossings with gradients between 0.5% and 1% would be considered GRAY for juvenile passage and would require hydraulic analysis to determine passability. Pipe arches with less than 100% substrate coverage can have a gradient of up to 2% (GRAY) before being considered non-passable (RED). If the culvert contained 100% substrate coverage of adequate depth (20% of culvert rise), then culvert gradient could be up to 2% in circular culverts with 2x6 corrugations and still be passable (GREEN) and go as high as 4% in that same situation before being considered non-passable (RED). The California Dept of Fish and Game (2001) assessment flowchart determines that culverts with slopes greater than 2% and not adequately backwatered and/or with a perch are considered non-passable (RED) for adult and juvenile anadromous salmonids. Culverts at

with less than 2% gradient and not adequately backwatered and/or with a perch are considered GRAY, thus requiring hydraulic analysis.

Residual Inlet Depth

Residual inlet depth is the depth of water at the inlet of the structure under no flow (or very low flow) conditions. When the outlet tailwater control elevation is higher than that of the inlet invert, the residual inlet depth will be a positive number and the structure will be backwatered at all flows (Figure 3). This positive depth, i.e. backwatering, is generally conducive to passage of most species and lifestages since it tends to reduce velocities within the structure. It is important to note that spring-fed streams may never experience very low flows and therefore maintain ample water depth throughout the structure even without a positive residual inlet depth. The main reasons for setting a minimum residual inlet depth are to ensure that depth is adequate to allow passage at low flow conditions, and to acknowledge that backwatering may facilitate passage through culverts that are otherwise too steep.

The minimum depth necessary for successful passage depends on fish size, as larger fish require more water for passage. Based on a literature review of research findings and stream crossing design guidelines, the minimum water depths that allow most adult and juvenile trout to pass through a culvert range from 0.25 foot (3 inches) to 1 foot (12 inches). For adult steelhead and salmon the minimum water depth required for passage varies from 0.59 foot to 1 foot. Belford and Gould (1989) found that 0.26 foot (3.12 inches) was sufficient depth to pass adult trout through the six Montana highway culverts evaluated in their study. The Idaho Department of Lands fish passage manual (1998) sets minimum depth criteria of 0.25 foot (3 inches) during migration. California Department of Fish and Game (1998) has a minimum of 1 foot for adult Chinook and steelhead and 0.5 ft for juvenile salmon and all trout. The Washington Department of Fish and Wildlife (2000) has a design standard minimum depth criterion of 0.8 foot for adult trout and 1 foot for adult Chinook and steelhead. Thompson (1972) found that for successful upstream migration of adult salmon and trout through non-embedded culverts, a minimum of water depth of 0.59 foot (7.1 inches) for steelhead and 0.79 foot (9.5 inches) for Chinook is required. The NMFS SW Region (2001) requires a minimum water depth of 1 foot (12 inches) for adult steelhead and salmon and 0.5 foot (6 inches) for juvenile salmon when designing non-embedded culverts. Burton (1998) suggests having a minimum water depth of 0.49 foot (5.9 inches) for adult trout and 0.984 foot (11.8 inches) for adult salmon for the Boise River basin. Virginia's trout can maneuver a minimum depth of flow of 0.29 foot (3.5 inches) (Warren and Pardew 1998).

Getting out of the Culvert

Average Bankfull Width to Inlet Width Ratio

Constriction is addressed at two levels within the flowchart. The first discriminator is found within the natural channel simulation criteria – the culvert width must be equal to or greater than the average bankfull width and have substrate retained throughout the structure. If the crossing meets these criteria, it is not constricting the channel and considered GREEN. Secondly, in all other structures (embedded or non-embedded), the culvert width must be at least equal to 70% (ratio of 0.7) of the bankfull channel width as well as meeting requirements for outlet drop and slope to be categorized as GREEN. If the culvert width is less than 50% (ratio of 0.5) of the average bankfull channel width, it is considered RED for all lifestages. In most cases, if a culvert overly constricts the channel, the tailwater control becomes scoured and incised by the higher velocity, backwatering is significantly reduced or eliminated and a perch may or may not form. In other words, if the structure overly constricts the channel, most likely there is an outlet perch as well. Constriction thresholds are based on initial culvert inventory data review and hydraulic analysis for a number of sites in R1.

Note that for all natural channel simulation crossings and other structures categorized as GREEN, it will still be necessary to review the inlet gradient and identify sites that have a steep drop in the channel profile directly in front of the culvert inlet providing evidence that the crossing does indeed constrict the channel (Evidenced by hourglass shapes that suggest velocities within the structure are higher than that of the stream channel). This steep slope can be a migration barrier to both adult and juvenile fish, because it creates supercritical flow just inside the inlet. Therefore, if the inlet gradient is excessive compared to channel gradient upstream of the crossing, the site will be designated as GRAY until hydraulic analysis can be completed for the site.

Evaluation Categories

The following categories will be used to classify crossings for juvenile and adult cutthroat and Bull trout for Region 1:

CHANNEL SIMULATION: Conditions assumed to be passable for all species/lifestages.

GREEN: Conditions assumed adequate for passage of the analysis species lifestage.

GREY: Conditions may not be adequate for the analysis species lifestage presumed present. Additional analysis is required to determine the extent of barrier. It is here where we would denote possible flow barriers using hydraulic analysis.

RED: Conditions do not meet passage criteria at all desired flows for the analysis species lifestage. Assumed to be a barrier for that lifestage.

It is important to note that fish may be able to pass through a number of the culverts identified in the RED and GREY categories during portions of the year, i.e. the culvert may actually be only a partial (flow) barrier. However, passage may only be possible during a very discrete period. The primary concern is that passage may not be possible for a particular lifestage during the more extreme flow periods and most important migration times of the year such as during spring runoff and low base flows.

The passage evaluation criteria flowcharts do not cover all possible scenarios, thus the inventory data need to be thoroughly reviewed for any unique passage problems that may exist at crossings initially categorized as CHANNEL SIMULATION or GREEN. For example, a crossing may meet all flowchart criteria for passage but may still have an inlet drop, significant debris or sediment blockage, or a break within the structure itself. Further manual data review will catch and redefine these crossings appropriately.

The literature indicates that Chinook salmon and steelhead tend to demonstrate swimming and jumping abilities that are superior to other salmonids. However, anadromous fish-bearing streams on the Boise N.F. also support populations of bull trout and/or westslope cutthrout trout. Therefore, the Boise N.F. did not develop separate screening criteria for anadromous fish.

Juvenile salmonid fish passage evaluation criteria at flows less than bankfull flows for Region 1

(NOT INTENDED TO BE USED FOR DESIGNING NEW STRUCTURES)

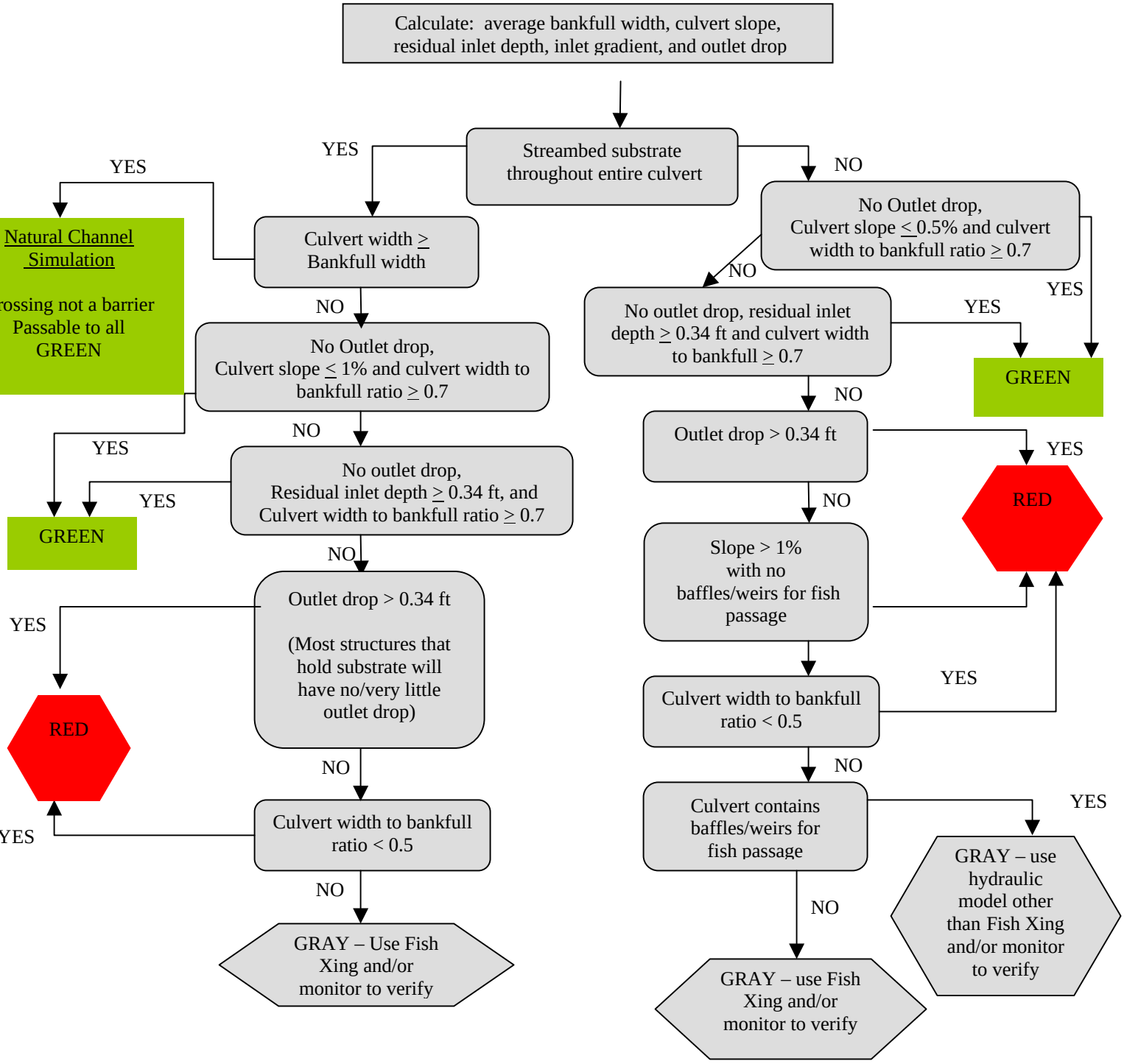


Figure 1. Fish passage evaluation criteria for Region 1 juvenile salmonids.

Adult salmonid fish passage evaluation criteria for Region 1

(NOT INTENDED TO BE USED IN DESIGNING NEW STRUCTURES)

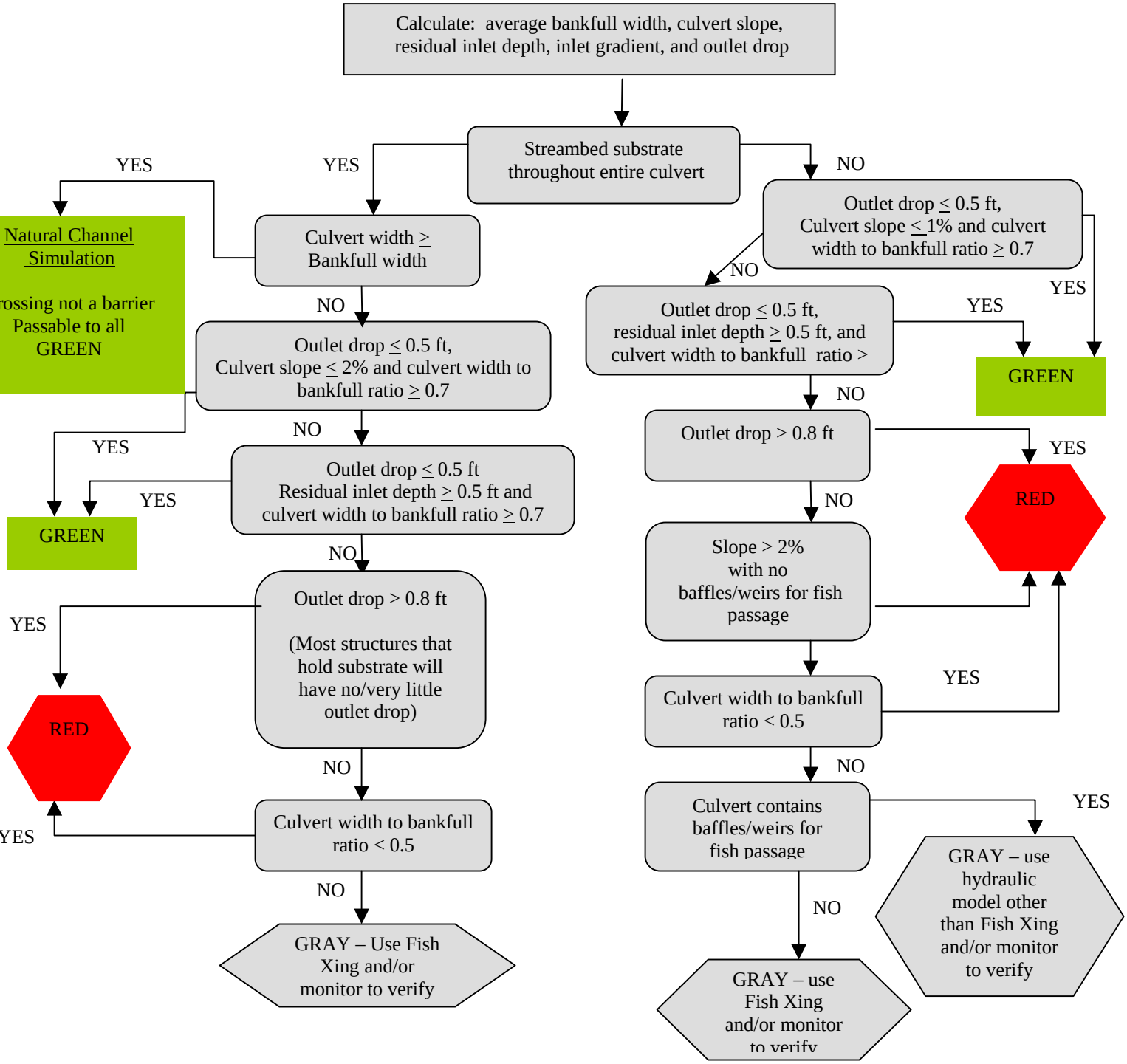


Figure 2. Fish passage evaluation criteria for Region 1 adult salmonids.

Assumptions for Determining Miles of Blocked Habitat

Each culvert's location was used to determine how many miles were blocked or accessible. If the culvert was a barrier, the distance up to the next culvert, a natural barrier, or end of fishes' distribution was considered blocked to fish below the culvert. Unfortunately, the Boise N.F. does not have natural barrier or fish distribution GIS layers to quickly determine of how far upstream a barrier culvert influences. Instead, fish surveys, extent of proposed and designated critical habitat, and topographic features from ortho-quads, were used to approximate miles blocked. These distances were then summarized by resident/anadromous juvenile, anadromous adult, and resident adult to repre sent total miles of stream blocked by lifestage. Miles accessible within those subwatersheds surveyed were also totaled.

It was assumed that if fish occurred above a barrier culvert that it was either a resident fish whose distribution has been fragmented by the culvert or an adult anadromous fish that at certain flow conditions could migrate through it.

In situations where a fish's distribution occurred up to or just downstream of a culvert, it was assumed that the culvert was a complete barrier to both juveniles and adults lifestages. It was also assumed that the species downstream had the potential to colonize habitat above the culvert to where a natural fish barrier occurred.

Table 8: Total Crossing Inventory Summary

Assessment Type	Count
Full Crossing Assessments	142
Partial Crossing Assessments	169
Inaccessible/ Bogus Sites	61
Total	372

Full Crossing = those crossings that were inventoried using entire protocol. Partial Crossing = those crossings that were inventoried just to make note of characteristics, but not considered a barrier. Inaccessible/ Bogus Sites = those crossings that did not actually exist in the field or were not accessible due to the road being overgrown or closed permanently.

RESULTS

The majority of culverts (90%) in the nine 5th field watersheds surveyed rated out in the red category (Table 1, Appendix A). Most of these pipes are circular or squashed pipe-arches, which occur in headwater tributaries (Table 3). The majority of the inventories were completed in the following drainages as seen in Appendix A:

1. South Fork Salmon River
2. South Fork Payette River
3. Payette River
4. North and Middle Fork Boise River
5. North Fork Payette River

Table 9: Summary of Barrier Triggers

"Red" Crossing Assessment	Outlet Drop	Culvert Slope	Inlet/ Channel Ratio	Total
Adult	70	42	13	125
Juvenile	99	27	5	131
Total	169	69	18	256

This table illustrates a summary of the crossings found to be a barrier (Red) and the trigger or first reason for the current barrier. As the assessment completed calculations and followed the flowchart for determining passability the outlet drop, culvert slope, and inlet/channel ratio were the reasons for the barrier to exist. As illustrated 66% are determined to be barriers due to the outlet drop or before the fish ever actually enters the culvert.

The majority of the barriers or "red" culverts were found in the South Fork Salmon River subbasin and the South Fork Payette River subbasin (Appendix A). Each culverts was evaluated by calculating the parameters necessary to move through the flowcharts (Figures 1 & 2). Table 9 summarizes the first trigger for determining the crossing to be a barrier as defined through the flowchart. Outlet is the first trigger as you move through the flowchart and also was the number 1 reason for the crossing to be a barrier on the Boise National Forest. Basically, outlet drop defined the first barrier that a fish swimming upstream would encounter at that particular crossing even though there may be other reasons that the fish cannot move past the crossing if they were to swim past the outlet drop. Outlet drop defined the barrier in 60% of the crossings surveyed for adults, followed by 30% for culvert slope and 10% for inlet/channel ratio. For juveniles, outlet drop defined the barrier in 80% of the crossings surveyed while culvert slope made up about 20% and inlet/channel ratio made up an insignificant remaining portion.

Table 10: Summary of Partial Assessments and the Crossing Types Encountered

Crossing Type	Crossing Count
Bridge	75
Ford	17
Intermittent	20
Non-Fish Bearing	27
Private	1
Culvert Pulled	8
Inaccessible/ Road Closed	22
Bogus/ No Xing	39
Other	12
Total	221

This table represents a summary of the types of crossings, mainly bridges, that were encountered during partial crossing assessments. These assessments, while important data was collected demand a large amount of time and effort to locate and find that it is not to be considered for fish passage issues.

The majority of surveyed culverts have impacted bull trout. Due to their limited distribution on the Boise N.F., Chinook salmon, steelhead, and Westslope cutthroat trout have been affected a relatively small fraction of the total culverts. However, the culverts that were surveyed represent mostly Chinook salmon, steelhead, and Westslope cutthroat habitat only and a small fraction of other habitat. The majority of culverts (90%) in the nine 5th field watersheds surveyed rated out in the red category (Table 1, Appendix A). Most of these pipes are circular or squashed pipe-arches, which occur in headwater tributaries (Table 3). The majority of the barriers or "red" culverts was found in the South Fork Salmon River (SFSR) subbasin and the South Fork Payette River (SFPR) subbasin and corresponds to those drainages with completed inventory (Appendix A).

PROPOSAL FOR REHABILATION/RECONSTRUCTION:

Recommendations

We have taken these results and focused our energy on those crossing considered red. Priority was assigned mainly by calculating the miles of habitat available upstream from the crossing. The Boise and Sawtooth National Forests also asked the following questions to verify that these crossings were located in areas considered to be high quality for restoration.

- Is the project in a high priority subwatershed as determined by the Watershed Aquatic Recovery Strategy (WARS)?
- How many listed fish or other aquatic species would benefit from upgrading the barrier?
- Does critical habitat occur above the culvert?
- How many miles would be made accessible if passage was restored?
- Will correction of this barrier make the stream more accessible to introduced species?

The order within Table 4 is not necessarily firm, but as illustrated is listed in order of the culverts with the most upstream critical habitat to culverts with the least upstream critical habitat. Also, note that the miles of perennial stream above each culverts varies greatly. This habitat is not necessarily labeled as critical habitat but would still be in the same Aquatic Conservation Strategy watershed. The cost of replacement is of course based on an average cost for replacing similar-sized culverts with concrete arches. The average is based on a limited number of replacements on the Boise National Forest. The planning cost added to the construction and supply cost gives us our total with the construction and supplies costing about $40 - $50,000 alone. Roaring River is an extremely large culvert crossing with a large volume of fill material above. Both the cost and benefit for this culvert will be tremendous. The Boise National Forest will replace Rammage Meadows and Wilson Creek this year (2004). Many of the remaining culverts on this list are in the SFSR basin, which is an anadromous priority. This inventory made it easier to utilize some of the more recent research currently underway at the Rocky Mountain Research Station to evaluate culvert combinations for their importance in terms of patch size for the various priority fish species. We plan to accomplish this with the data that we have collected as we complete some of the identified “highest” priorities per criteria/assumptions developed from applicable research and the San Dimas Aquatic Organism Passage Inventory Protocol.

Further recommendations include continuing the inventory across the Forest for another field season at least, as funding allows, to fill gaps in lower regional priority areas or fish species. As illustrated in Table 2, the Boise National Forest has about 159 crossings remaining for Bull Trout and over 1,000 crossings remaining for all species. After reviewing the data collected we feel it important to collect crossing information for all species, regardless of priority because it may provide better connections within and between patches.

Table 4: Top Priority Culverts on the Boise National Forest for Replacement
Forest-wide Priority determined by San Dimas Aquatic Organism Passage Inventory Protocol

Culvert or Creek Names	Regional Fish Species Inventory Priority	Miles of Upstream Critical Habitat	Miles of Upstream Perennial Stream	Cost of Replacement	Aquatic Conservation Strategy Priority	Watershed & Aquatic Recovery Strategy
Roaring River	2nd	18.0	35.0	$500,000	Yes	Moderate - Passive
Rammage Meadows	2nd	7.0	8.2	$60,000	Yes	High - Active
Wilson Cr.	2nd	6.1	7.3	$60,000	Yes	High - Active
Fir Cr.	1st & 2nd	6.0	12.2	$60,000	No	High - Active
Fool Hen Cr.	2nd	5.3	5.1	$60,000	Yes	High - Active
Bear Cr.	2nd	5.0	9.4	$60,000	No	High - Active
SixBit Cr.	2nd	4.5	11.9	$60,000	No	High - Active
Mores Cr.	2nd	4.2	11.5	$60,000	No	Moderate - Active
Renwyck Cr.	2nd	3.8	7.3	$60,000	Yes	Moderate - Active
North Fork Dollar Cr.	1st	3.8	11.5	$60,000	No	High - Active

Criteria for ranking culverts is weighted mainly on the miles of habitat that will be accessible after replacement, because all sites are within critical habitat. However, our criteria included the inventory priority for species, the aquatic conservation strategy, the watershed and aquatic recovery strategy, the benefit to listed species, and the accessibility to introduced species. Rather than providing an order to the top 10 replacement culverts we plan to complete as funding, planning, and workforce allow.

VII. BIBLIOGRAPHY

Powers, P.D., and J.F. Orsborn. 1985. Analysis of barriers to upstream fish migration: an investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls. U.S. Department of Energy, Bonneville Power Administration, Project 82-14 Final Report, Portland Oregon.

Reiser, D.W., and R.T. Peacock. 1985. A technique for assessing upstream passage problems at small-scale hydropower developments. Pages 423-432 in F.W. Olson, R.G. while, and R.H. Hamre, editors. Symposium on small hydropower and fisheries. American Fisheries Society, Bethesda, Maryland.

Stuart, T.A. 1962. The leaping behavior of salmon and trout at falls and obstructions. Department of Agriculture and Fisheries for Scotland, Freshwater and Salmon Fisheries Research Report 28, Edinburgh.

Appendix A – Inventory Data by Hydrologic Unit

Summary of Culvert Inventory and Assessment Type by Subbasin and Watershed

HUC5CODE	HUC5NAME	HUC4NAME	# Full Assessments	# Partial Assessments	Grand Total
1705011101					
	Lower NF Boise River		4	0	**4**
		North and Middle Fork Boise	4	0	
1705011102					
	Crooked River		2	7	**9**
		North and Middle Fork Boise	2	7	
1705011103					
	Bear-Trail		2	4	**6**
		North and Middle Fork Boise	2	4	
1705011104					
	Upper NF Boise River		0	2	**2**
		North and Middle Fork Boise	0	2	
1705011106					
	Roaring-Granite		3	3	**6**
		North and Middle Fork Boise	3	3	
1705011108					
	Upper MF Boise River		0	3	**3**
		North and Middle Fork Boise	0	3	
1705011201					
	Arrowrock Reservior		1	0	**1**
		Boise-Mores	1	0	
1705011203					
	Lower Grimes Creek		3	4	**7**
		Boise-Mores	3	4	
1705011206					
	Middle Mores		0	2	**2**
		Boise-Mores	0	2	
1705011207					
	Upper Mores Creek		7	5	**12**
		Boise-Mores	7	5	
1705011305					
	Feather-Grouse		9	3	**12**
		South Fork Boise River	9	3	

Appendix A – Inventory Data by Hydrologic Unit

1705012004				
	Whitehawk	7	6	**13**
	South Fork Payette	7	6	
1705012005				
	Upper Deadwood	4	6	**10**
	South Fork Payette	4	6	
1705012006				
	Lowman	9	8	**17**
	South Fork Payette	9	8	
1705012007				
	Clear Creek	13	11	**24**
	South Fork Payette	13	11	
1705012008				
	Wapiti	2	12	**14**
	South Fork Payette	2	12	
1705012010				
	Canyon Creek	1	4	**5**
	South Fork Payette	1	4	
1705012103				
	Boiling Springs	0	11	**11**
	Middle Fork Payette	0	11	
1705012104				
	Upper MF Payette	4	3	**7**
	Middle Fork Payette	4	3	
1705012212				
	Second Fork	6	12	**18**
	Payette	6	12	
1705012213				
	Upper Squaw	6	7	**13**
	Payette	6	7	
1705012303				
	Beaver-Big	3	14	**17**
	North Fork Payette	3	14	
1705012310				
	Gold Fork River	8	4	**12**
	North Fork Payette	8	4	
1706020506				
	Elkhorn-Soldier	1	2	**3**

Appendix A – Inventory Data by Hydrologic Unit

	Upper Middle Fork Salmon	1	2	
1706020508				
	Bear Valley	4	2	**6**
	Upper Middle Fork Salmon	4	2	
1706020509				
	Elk Creek	4	4	**8**
	Upper Middle Fork Salmon	4	4	
1706020803				
	Lower EFSFSR	1	0	**1**
	South Fork Salmon	1	0	
1706020804				
	Upper EFSFSR	1	4	**5**
	South Fork Salmon	1	4	
1706020805				
	Lower Johnson	2	5	**7**
	South Fork Salmon	2	5	
1706020806				
	Middle Johnson	6	21	**27**
	South Fork Salmon	6	21	
1706020807				
	Upper Johnson Creek	4	29	**33**
	South Fork Salmon	4	29	
1706020810				
	Warm Lake	8	22	**30**
	South Fork Salmon	8	22	
1706020811				
	Upper SF Salmon	17	10	**27**
	South Fork Salmon	17	10	
Grand Total		**142**	**230**	**372**

Appendix A – Inventory Data by Hydrologic Unit

Summary of Lifestage Passage Assessment Barrier Color Coding by 5th Field HUC

HUC5CODE	HUC5NAME	HUC4NAME	# Adult Red	# Adult Gray	# Adult Green	# Juvenile Red	# Juvenile Gray	# Juvenile Green	Grand Total
1705011101	Lower NF Boise River	North and Middle Fork Boise	3	1	0	3	1	0	8
1705011102	Crooked River	North and Middle Fork Boise	1	1	0	1	1	0	4
1705011103	Bear-Trail	North and Middle Fork Boise	2	0	0	2	0	0	4
1705011106	Roaring-Granite	North and Middle Fork Boise	2	1	0	2	1	0	6
1705011201	Arrowrock Reservior	Boise-Mores	1	0	0	1	0	0	2
1705011203	Lower Grimes Creek	Boise-Mores	1	2	0	1	2	0	6
1705011207	Upper Mores Creek	Boise-Mores	6	0	1	6	0	1	14
1705011305	Feather-Grouse	South Fork Boise River	7	2	0	9	0	0	18
1705012004	Whitehawk	South Fork Payette	5	2	0	7	0	0	14
1705012005	Upper Deadwood	South Fork Payette	4	0	0	4	0	0	8
1705012006	Lowman								

Appendix A – Inventory Data by Hydrologic Unit

		South Fork Payette	9	0	0	9	0	0	**18**
1705012007									
	Clear Creek								
		South Fork Payette	12	1	0	13	0	0	**26**
1705012008									
	Wapiti								
		South Fork Payette	2	0	0	2	0	0	**4**
1705012010									
	Canyon Creek								
		South Fork Payette	1	0	0	1	0	0	**2**
1705012104									
	Upper MF Payette								
		Middle Fork Payette	4	0	0	4	0	0	**8**
1705012212									
	Second Fork								
		Payette	6	0	0	6	0	0	**12**
1705012213									
	Upper Squaw								
		Payette	6	0	0	6	0	0	**12**
1705012303									
	Beaver-Big								
		North Fork Payette	2	1	0	3	0	0	**6**
1705012310									
	Gold Fork River								
		North Fork Payette	8	0	0	8	0	0	**16**
1706020506									
	Elkhorn-Soldier								
		Upper Middle Fork Salmon	1	0	0	1	0	0	**2**
1706020508									
	Bear Valley								
		Upper Middle Fork Salmon	4	0	0	4	0	0	**8**
1706020509									
	Elk Creek								
		Upper Middle Fork Salmon	3	1	0	4	0	0	**8**
1706020803									
	Lower EFSFSR								
		South Fork Salmon	1	0	0	1	0	0	**2**
1706020804									

Appendix A – Inventory Data by Hydrologic Unit

Upper EFSFSR							
South Fork Salmon	1	0	0	1	0	0	**2**
1706020805							
Lower Johnson							
South Fork Salmon	2	0	0	2	0	0	**4**
1706020806							
Middle Johnson							
South Fork Salmon	6	0	0	6	0	0	**12**
1706020807							
Upper Johnson Creek							
South Fork Salmon	4	0	0	4	0	0	**8**
1706020810							
Warm Lake							
South Fork Salmon	5	3	0	5	3	0	**16**
1706020811							
Upper SF Salmon							
South Fork Salmon	15	2	0	15	2	0	**34**
Grand Total	**124**	**17**	**1**	**131**	**10**	**1**	**284**