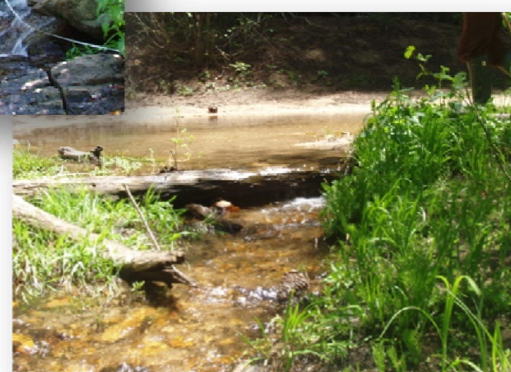
Aquatic Organism Passage (AOP) Assessment



U.S. Forest Service

Lake Tahoe Basin Management Unit

FY 2010

By Richard Vacirca, LTBMU Forest Aquatic Biologist

Contributors: Kendal Bell–Enders and Rosealea Bond, LTBMU Aquatic Field Crew;

& Craig Oehrli, LTBMU Hydrologist

Executive Summary

Stream crossings by roads can pose serious threats to fishery ecosystems. The cumulative effect of culverts, fords, and other structures throughout a stream channel can significantly change the streams geomorphology and impair fish passage by blocking valuable spawning and rearing habitat.

In the summer of 2010 the LTMBU evaluated 112 road/stream crossings. Of these, 61 had full assessments completed and 51 were partial assessments due to factors such as no flow, no structure, the crossing was a bridge, or the crossing was on a decommissioned road. Of the full assessments, 53 were on Forest Service system roads and 8 assessments were on CA and NV highways (Table1).

Table 1: Total crossings inventory summary

Assessment Type	FS	HWY	Total
Full Crossing Assessments	53	8	61
Partial Crossing Assessments	49	2	51
Inaccessible Sites	0	0	0
Total	102	10	112

FS = Crossings on Forest Service System roads
HWY = Crossing is on CA/NV Highway or county road.

Approximately 82% (50 of 61) of the full assessment on all road crossings do not meet the criteria for fish passage (RED), and are barriers for at least one life stage of salmonid or sculpin. Only 11% of the fully assessed crossings met the passage criteria (GREEN) to fish for both juvenile and adult salmonid life stages. The remaining 7% of fully assessed crossings were undetermined (GREY) for salmonid or sculpin and are candidates for further evaluation (Table 2).

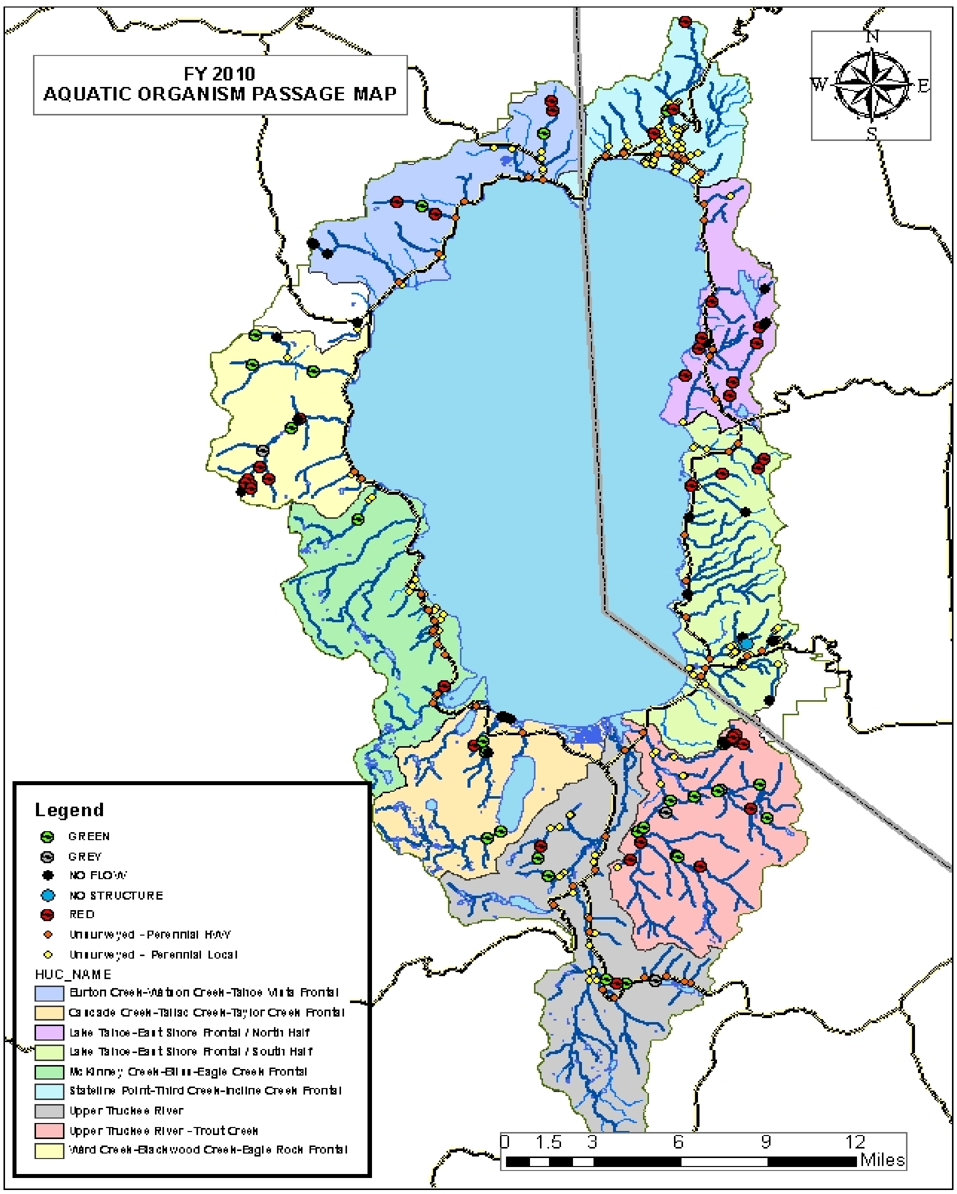
Table 2: Summary of Aquatic Organism Passage results on fully Assessed crossings on all roads

Lifestage	RED	GREEN	GREY	Totals
Adult Salmonid	49	7	5	61
Juvenile Salmonid	50	6	5	61
Sculpin	7	2	1	10

Twenty six sites of the 112 road/stream crossings were selected for Paiute sculpin analysis. Ten sites had full assessments completed and the remaining sixteen sites were partial assessments. Of the full assessments, 70% (7 of 10) of road crossings did not meet the criteria for sculpin passage (RED) while 20% of road crossings met the passage criteria (GREEN). One crossing (10%) was undetermined (GREY) (Table 2).

This report summarizes the prioritization of sites (Appendix A), the AOP methods and assumptions, the salmonid and sculpin evaluation criteria applied (Appendix B), the results, and the strategy for replacement for red crossings.

The LTBMU has created a map showing the locations of crossings surveyed coded by their determination (Figure 1).



Introduction

The Lake Tahoe Basin Management Unit (LTBMU) was funded to conduct an aquatic organism passage (AOP) assessment for FY 2010. The AOP assessment was funded by Budget Line Item CMLG Legacy Road and Trails ($49,000). There are a total of 63 tributaries that feed directly into Lake Tahoe (Lake Tahoe Watershed Assessment 2000). Most of these tributaries have multiple road intersections on them that have caused water quality and habitat degradation to some extent.

The purpose of this assessment was to document the extent of road – stream crossings across the Tahoe basin (primarily on Forest Service system roads) and assess which crossings were barriers to local fish species, specifically native fishes including threatened Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*), endemic Paiute Sculpin ***(****Cottus beldingi),* Speckled dace (*Rhinichthys osculus*), Lahontan Redside shiner (*Richardsonius egregius*), Lahontan Tui Chub (*Gila bicolor pectinifer*), and Tahoe Sucker (*Catostomus tahoensis*). The secondary goal of this assessment was to evaluate threats to water quality from poorly designed crossings. Finally, the assessment was used to prioritize culverts for replacement within the LTBMU Basin.

This project will help contribute to meeting strategies outlined in the Short-term Recovery Action Plan for Lahontan Cutthroat Trout created by the Tahoe Basin Recovery Implementation Team (TBRIT). Other interested stakeholders in native fish restoration include: CalTrout, Trout Unlimited, US Fish and Wildlife Service, California Department of Fish and Game, Nevada Department of Wildlife, the Washoe Tribe, and road maintenance agencies in the Lake Tahoe basin.

Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*)

LCT from the Upper Truckee River in 2009

The Lahontan cutthroat trout (LCT) is one of 14 recognized subspecies of cutthroat trout (in the western United States) endemic to the Lahontan Basin of northern Nevada, eastern California, and southern Oregon. Stream-dwelling LCT generally have a life span of less than 5 years, while those living in lakes may live 5 to 9 years (Sumner 1940, Coleman & Johnson 1988). LCT are the only native salmonid in the Lake Tahoe basin and before the introduction of non native fishes they were the top predator.

LCT was listed by the U.S. Fish and Wildlife Service (USFWS) as an endangered species in 1970 (Federal Register Vol. 35, p. 13520). The listing was reclassified to the less restrictive threatened status in 1975 to facilitate recovery and management efforts and authorize regulated angling (Federal Register Vol. 40, p. 29864).

The severe decline in range and numbers of LCT is attributed to a number of factors including hybridization and competition with introduced trout species; alteration of stream channels and morphology; loss of spawning habitat due to pollution, channelization, and sediment loads; and migration blockage due to dams [including culverts]. (Gerstung 1986 & 1988, Coffin 1988, USFWS 1995, Murphy and Knopp 2000).

Locally, the Tahoe Basin Recovery Implementation Team (TBRIT) has established short-term recovery actions for Lake Tahoe's LCT. These include:

- Expanding upon the existing LCT population in the Upper Truckee River,
- Active management of introduced lake trout in Fallen Leaf Lake which continued implementation of site –specific LCT stocking strategy,
- Conducting assessments of LCT recovery potential in additional tributaries in the basin and initiating fisheries and aquatic ecosystem studies in Lake Tahoe.

Native Non-Game Fishes

Paiute sculpin caught by the LTBMU Aquatics Crew 2009

Native non-game fishes such as the Paiute sculpin do not have strong swimming capabilities and are deterred by high water velocity (especially in the middle of the water column). This report uses sculpin passability as a criterion where small non-game native species occur at a specific site; namely Lahontan tui chub, speckled dace, Lahontan redside shiner and Tahoe Sucker. Sculpin are especially important in this analysis because they are the least likely to pass manmade crossings and can be used analogously with Cyprinids (minnows). Recent LTBMU sampling data indicates that native non-game fishes have potentially gone through localized reduction in their distribution and numbers. Presumably these effects are from anthropogenic impacts to aquatic habitat (i.e. roads, past livestock grazing, and other channel modification) and large-scale introductions of salmonids and more recently warm – water fishes (i.e. Largemouth bass).

The Paiute sculpin is the only sculpin found in the Lake Tahoe Basin. This species typically congregate in cold, shallow rocky riffles and are associated with trout presence. Sculpin reach sexual maturity in their 2^{nd} or 3^{rd} year and spawning occurs primarily in May and June. Sculpin prefer clear water and are considered an indicator of healthy functioning stream systems (Moyle 2002).

Non-native trout caught in a census survey by the LTBMU Aquatics Crew 2009

Non Native Introductions in the Lake Tahoe Basin

Lake Tahoe has experienced a wide range of non native introductions that comprise a large portion of the current fish assemblage. Non native lake trout, rainbow trout, brown trout, brook trout, and Kokanee salmon have been stocked throughout the basin. Moreover, warm water fishes such as largemouth bass, bluegill, black crappie, brown bullhead catfish, and goldfish have been illegally introduced into Lake Tahoe (i.e. Tahoe Keys and Taylor Marsh) (Kamerath et al

2008). Limited investigation into interactions between the warm - water fish and native species has occurred in the Tahoe Keys. Management of current nonnative fisheries is necessary for cutthroat trout establishment and self-sustainment (TBRIT 2011).

Watershed Restoration in the Lake Tahoe Basin

Since 2005, the LTBMU has engaged in large-scale stream restoration projects. This effort started in 2005 with the Cook House Meadow restoration project on Big Meadow Creek. Implementation and planning efforts continue in Blackwood, Cold, Upper Truckee, Angora, and Meeks creeks. The primary objectives of these projects are to decrease sediment yield from streams undergoing vertical and/or horizontal instability, reconnect flood plains, and restore aquatic habitat.

In order to meet these objectives (also termed desired conditions) the LTBMU looks at restoration in three categories:

1. abandon the channel in its current location and reconstruct a new one,
2. restore the channel in its current location,
3. allow the stream to recover on its own by removing the causal factor(s) of degradation.

In all cases across LTBMU, anthropogenic impacts such as gravel mining, grazing, logging, etc. have been removed from the system making the three restoration categories possible. Future restoration projects are anticipated to focus more on restoring specific elements of aquatic habitat and less on larger-scale water quality issues.

The AOP program will be brought into the LTBMU’s 10-year aquatic program plan for restoring stream processes and habitat function. In doing so, concepts of natural channel design (discussed later in the report) and species life history needs are taken into account in addition to obtaining a functional road system. The Forest fisheries biologist recognizes that future restoration efforts will be incomplete without the removal of road crossing barriers for migratory fishes.

Lake Clarity

The Lake Tahoe Basin has nine regional watersheds, 63 individual streams and numerous contributing tributaries which empty into the lake. Lake Tahoe is a designated "Outstanding National Resource Water" under federal anti-degradation regulations (Murphy and Knopp 2000). The Lake Tahoe Watershed Assessment in 2000 found that a number of independent studies recognized stream bank erosion as an overwhelming source of suspended sediments in Lake Tahoe’s tributaries. The assessment found that impervious land surface coverage such as roads in addition to historical land use have negatively affected stream morphology and bed load transportation.

Undersized, poorly sited, or poorly aligned culverts can produce accelerated water velocities; causing localized bed and bank scour of the upstream and/or downstream channel. This erosion can create high total suspended sediment (TSS) concentrations and debris problems throughout the stream channel.

Total suspended sediments have been a forceful factor in driving the basin's efforts to improve lake clarity; much of the LTBMU's restoration objectives have been to stabilize tributaries and reduce the amount of erosion within Tahoe. Since the 1960's continuous measurements of clarity in Lake Tahoe have shown a decline at approximately 0.3 meters (1.2 feet) per year. Also, algal production has increased approximately 5% per year since the 60's (Goldman 1988).

Lake clarity is most commonly measured by Secchi depth. Secchi depth is the point at which an eight inch white disc is no longer visible from the surface as it is lowered into the water (Lake Tahoe Watershed Assessment 2000). Secchi depth measurements have been linked to the amount of suspended solids in the water column (Jassaby et all. 1999).

Bank erosion from an improperly aligned pipe-arch on North Fork Blackwood Creek 1

Inventory

Methods

The "National Inventory and Assessment Procedure for Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings," commonly referred to as the "San Dimas Protocol" was used for this assessment.

Evaluation Criteria

The USFS Region 1 and 2 fish passage evaluation criteria for salmonids (Appendix B) was used to classify existing crossings as either meeting, failing to meet fish passage criteria for selected fish species, or needing further hydraulic analysis. The criteria flowcharts attempt to define whether passage is provided through existing structures at the time of survey.

The Region 2 sculpin criterion was applied only to streams that contain bottom dwelling species endemic to Lake Tahoe (twenty six total crossings). The Region 2 criterion was based on Region 8 criteria where benthic native non-game fishes composed the majority of local fish assemblages. Sculpin has the lesser swimming ability out of all the native non-game fishes.

These Region 1 and 2 fish 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. These criteria assume that if a given stream is in a natural condition, then aquatic organisms are able to pass through the crossing. 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).

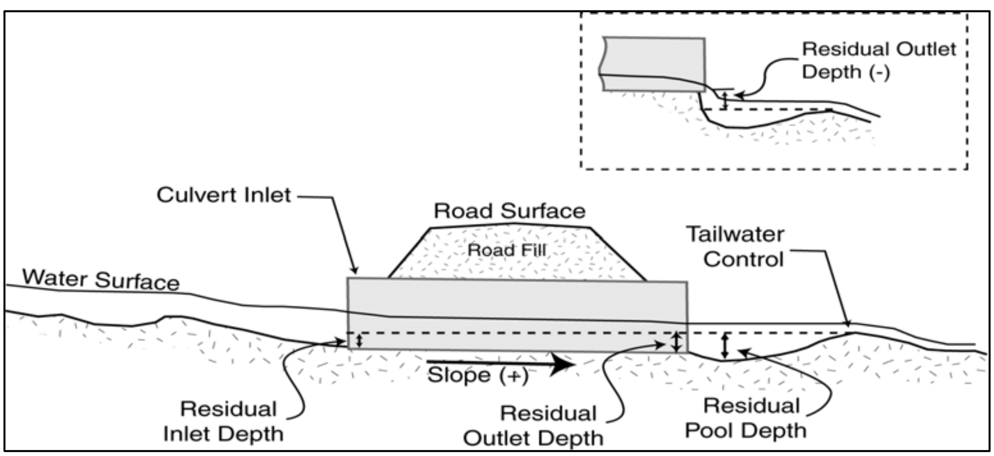
If the site inventory data verifies the above natural channel simulation criteria, the crossing is considered adequate for passage of all fishes, including the weakest swimming lifestages. If not, one proceeds through the flowcharts to further evaluate each culvert until a passage status is determined.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

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

Getting into the Culvert

Outlet Drop

Perching of a culvert above the water surface of the exit pool is a common obstacle to fish passage. The water level present in the culvert at the time of the survey is not a true measurement of perch height because it is flow dependent. Region 1 and 2 used a conservative assessment of perch by comparing the outlet invert elevation to the tailwater control elevation (Figure 2).



$$\text{Residual Pool Depth} = (\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Pool Bottom}})$$

$$\text{Outlet Drop} = (\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Outlet Invert}})$$

$$\text{Residual Inlet Depth} = (\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Culvert Inlet}})$$

Figure 2: Measurements used in evaluation criteria (Taylor & Love 2001)

This measurement is flow independent. Ideally, the perch height should be evaluated at various discharges up to the high flow design discharge. However, an extensive flow evaluation would be too time consuming for this comprehensive assessment of all culverts in the region.

Through biological monitoring, fish have been observed jumping considerable vertical and horizontal distances to clear obstacles. However, few studies of the ability of fish to jump have actually been conducted, especially for young and small fish. Lab studies have determined that ideal jumping conditions of 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). The California Department of Fish and Game (2002) states that outlet drop needs to be evaluated for both high design flows and low design flows and shall not exceed 1 foot for adult fish and 0.5 feet for juveniles with a jump pool of at least 2 feet. Native non-game fish require no hydraulic drop unless data is presented which will establish the leaping behavior of the targeted fish species. Coffman (2005) found a 2-foot barrier height to limit the movement of salmonids, using a conservative approach. There was less than a 1% chance that minnows could pass barriers greater than 1.2 feet.

Based on this literature review and consulting other local fisheries datasets, a maximum perch height of 4 inches is recommended for juvenile salmonid, 10 inches for adult salmonid and 3 inches for sculpin. Even so, for a crossing to be considered passable (GREEN), there must be no perch for juvenile salmonid and sculpin and less than or equal to 6 inches perch for adult salmonid only when backwatered at least 6 inches. All crossings with a perch up to and including 0.34 ft for juvenile salmonid and between 6 and 10 inches for adult salmonid will be considered GREY and hydraulic analysis must be conducted to make a passage determination. Additionally, if the outlet perch is less than 3 inches and has a culvert slope greater than 2% the crossing will be considered impassable for all lifestages of salmonid(RED).

Getting through the Culvert

Culvert Slope

Velocity within the culvert is determined primarily by culvert length, width, gradient, and roughness elements within the culvert. If a culvert is installed at too steep a gradient, 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.

California Fish and Game states that if the culvert length is between 60 and 100 feet the maximum water velocity is 4 fps for adult resident salmonid and if the culvert length is between 100 and 200 feet the maximum water velocity is 3 fps for adult resident salmonid. The maximum water velocity is 1 fps for juvenile salmonid for all culvert lengths. For weak-swimming fish such as sculpin, high flows can seldom be tolerated in the culvert barrel (Behlke, C.E., Kane, D.L., McLean R.F., Travis M.D). Bare culvert crossings with gradients between 0.5% and 1% would be considered GREY for juvenile passage and would require hydraulic analysis to determine passability. Culverts with less than 2% gradient and not adequately backwatered and/or with a perch are considered GREY, thus requiring hydraulic analysis.

Based on this literature review, a maximum culvert gradient of 1% is recommended for juvenile salmonid and 2% for adult salmonid when backwatering does not meet minimum residual depth criteria and/or an outlet perch exists before being categorized as non-passable (RED). To be considered GREEN for juvenile salmonid passage, an embedded culvert may have a slope of up to 1% (unless residual inlet depth 4 inches or greater), but must have no outlet drop and a culvert width to bankfull width ratio of at least 0.7.

If not embedded, the culvert slope must be no more than 0.5% (unless residual inlet depth is 4 inches or greater) and have no outlet perch and have a culvert width to bankfull width ratio of at least 0.7 to be considered GREEN for juvenile salmonid passage. For an embedded culvert to be considered GREEN for adult cutthroat, the slope may be 2% or less (unless residual inlet depth is 4 inches or greater) and have an outlet drop of no more than 6 inches and a culvert width to bankfull width ratio of at least 0.7. If the culvert is not embedded, the culvert slope must be no more than 1% (unless residual inlet depth is 6 inches or greater), have an outlet drop of no more than 6 inches and a culvert width to bankfull width ratio of at least 0.7.

In the cases where the residual inlet depth meets the minimum depth criteria and backwatering exists and there is no outlet perch (or up to 0.5 foot perch for adult cutthroat), then culvert gradient is automatically allowed to be higher to some degree. Any culverts that have no or insufficient backwatering and/or any perch for juvenile salmonid (between 6 inches and 10 inches perch for adult cutthroat) with gradients less than 1% for juvenile salmonid and 2% for adult salmonid will be considered GREY and will require hydraulic analysis to determine passability.

The sculpin criteria states that the culvert slope cannot be greater than 2% or it will be considered impassable (RED). If the culvert is not embedded and the culvert slope is less than 2%, then the integer of percent culvert slope multiplied by the culvert length (ft) is less than or equal to 16 then the culvert is considered passable (GREEN). If the integer of percent culvert slope multiplied by the culvert length is greater than 16 but less than 98 then the culvert is considered indeterminate (GREY) and biological sampling is necessary to make a final determination. If the integer of percent culvert slope multiplied by the culvert length is greater than or equal to 98 then the culvert is considered impassable (RED).

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 1). This positive depth (i.e. backwatering) is generally conducive to passage of most species and lifestages since it lowers velocities within the structure. It is important to note that spring-fed streams may never experience very low flows and have ample water depth throughout the structure but may not maintain a positive residual inlet depth. The main reasons for setting a minimum residual inlet depth are to acknowledge that passage may be possible in culverts with slightly higher gradients than would otherwise allow passage.

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 3 inches to 12 inches. California Department of Fish and Game (1998) has a minimum of 6 inches for juvenile trout.

Based on these findings, a minimum residual depth of 4 inches is recommended for passage of juvenile salmonid and 6 inches for passage of adult cutthroat. The sculpin criteria requires that the culvert to be backwatered (P6>P4) however no specific residual depth has been identified. When the culvert gradient is low enough (< 0.5 % for juvenile and 1% for adults salmonid) and meets outlet drop criteria (no drop for juvenile salmonid and < 6 inches for adult cutthroat), it is still considered GREEN even without meeting a minimum residual inlet depth criterion.

Getting out of the Culvert

Average Bankfull Width to Inlet Width Ratio

Constriction of the channel in the culvert is addressed in two manners within the flowchart. The first manner is addressed 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 is 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 of cutthroat. In most cases, if a culvert overly constricts the channel, the tailwater control becomes scoured and incised by the higher velocity. As a result, backwatering is significantly reduced or eliminated and a perch may form. In other words, if the structure overly constricts the channel, there is likely an outlet perch. Constriction thresholds are based on initial culvert inventory data review and hydraulic analysis for a number of sites in R1.

Be aware that at all natural channel simulation and GREEN categorized crossings, 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 salmonid 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 GREY until hydraulic analysis can be completed for the site.

Evaluation Categories

The following categories will be used to classify crossings for juvenile and adult salmonids and sculpin for Region 1 and 2:

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 of species lifestages that are presumed present. Additional analysis is required to determine the extent of the barrier. It is here where we would denote possible flow barriers using hydraulic analysis (i.e. Fish Xing Software).

RED: Conditions do not meet passage criteria at all desired flows for the analysis of each species lifestage. Crossing is 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 or seasonal (flow) barrier. However, in flow-dependent barriers, passage may only be possible for a short window of time. We are primarily concerned 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 will 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 a significant debris or sediment blockage either within or at the inlet, drop inlet, or a break within the structure itself. Further manual data review will catch and redefine these crossings appropriately.

Fish Xing Software

The LTBMU plans on assessing crossings that were undetermined (GREY) using Fish Xing Software. This software package integrates culvert configuration and fish passability by modeling organism capabilities against culvert hydraulics across a range of expected stream discharges (San Dimas Fish Xing Manual). The LTBMU plans to run the simulations on undeterminable sites in the near future.

Partial Surveys

The AOP crew conducted partial assessments to collect basic descriptive data and note general site conditions on any crossings that did not warrant a full inventory. These sites included all bridges, removed structures, and intermittent streams that were not flowing during the assessment period. The determination to conduct a partial versus full assessment was made in the field, upon initial site assessment.

Assumptions for Determining Miles of Blocked Habitat

Each culvert's location was used to determine how many miles of accessible habitat were accessible upstream. Unfortunately, LTBMU does not have a natural barrier GIS layer to determine available habitat. Instead, fish surveys, extent of proposed and designated critical habitat, and topographic features from digital elevation models (DEM), were used to approximate miles blocked. Also, if the crossing was a barrier, the distance between this crossing and the crossing downstream was the assumed available habitat for the lower crossing.

It was assumed that if fish occurred above a barrier crossing that it was either a resident fish whose distribution has been fragmented by the crossing or an adult fluvial salmonid 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 all lifestages of the fish. It was also assumed that the species downstream had the potential to re-colonize habitat above the culvert to where a natural fish barrier occurred.

Results

Red Crossings

Approximately 82% (50 of 61 crossings) of fully assessed crossings on all roads did not meet the criteria for fish passage (RED) and are barriers for at least one life stage of salmonid or sculpin (Table 2). The main crossing types which were deemed impassable were circular culverts and pipe arches for all life stages of salmonid and sculpin (Table3). Of the ten crossings fully assessed for sculpin 70% (7 of 10) did not meet the criteria for fish passage (RED) (Table2).

Table 3: Summary of Aquatic Organism Passage Barriers by Type on All Crossings for Cutthroat Trout

Crossing Type	RED	RED	GREY	GREY	GREEN	GREEN
	Adult Salmonid	Juvenile Salmonid	Adult Salmonid	Juvenile Salmonid	Adult Salmonid	Juvenile Salmonid
Box	4	4	0	0	0	0
Bridge	0	0	0	0	14*	14*
Circular	30	30	1	1	0	0
Ford	2	2	1	2	4	3
Open-Bottom Arch	2	2	1	1	3	3
Pipe-Arch	11	11	2	2	0	0
No Structure	0	0	0	0	8*	8*
Total	49	49	5	6	29	28

* = Partial Assessment

Red Triggers

The three main triggers for fish impassability were outlet drop, culvert slope, and culvert width to bankfull ratio. Twenty eight crossings (56%) were triggered impassable from outlet drop for adult cutthroat, 29 crossings (58%) were triggered red from outlet drop for juvenile cutthroat, and 6 crossings (86%, 6 of 7) were triggered barriers for sculpin. Culvert slope was the trigger for 17 crossings (34%) for adult cutthroat, 18 crossings (36%) for juvenile cutthroat, and 1 crossing (14%) for sculpin. The culvert width to bankfull ratio was the trigger for 5(10%) and 3 (6%) crossings for adult and juvenile salmonid respectively (Table 4).

Table 4: Summary of triggers on all roads surveyed

"RED" Crossing Assessments	Outlet Drop	Culvert Slope	Culvert/ Bankfull Ratio	Totals
Adult Cutthroat	28	17	5	50
Juvenile Cutthroat	29	18	3	50
Sculpin	6	1	0	7

Green Crossings

Ten percent (6 of 61) of crossings fully assessed on Forest Service roads did not pose a barrier to fish passage (GREEN) (Table 2). No California and Nevada highway crossings, with full assessments, met the fish passage criteria. The main crossing types with full assessments, which fell into green, were fords and open-bottom arches for all life stages of salmonid and sculpin (Table 3). Both structure types allow for continuous bottom substrate which is essential for fish passage (CITE). It is important to note that the majority of crossings which meet the criteria for fish passage (GREEN) were partially assessed bridges (Table 3).

In addition to crossings that were designated passable, the only watershed with no barriers was the upper Fallen Leaf Lake watershed. No barriers were found on the entire length of Glen Alpine Creek which is the primary inlet to Fall Leaf Lake. The two crossings found on the creek were bridges (receiving only partial assessments). Glen Alpine creek enters the lake primarily as cascades and consequently serves as fluvial spawning habitat for migratory fishes. There is an estimated 0.31 miles (0.5 km) of stream habitat is available before a 49 ft (15m) cascade which blocks fishes upstream migration (TBRIT 2011).

Grey Crossings

Grey crossings were found when site conditions were not adequate for the analysis of species and their lifestages. Eight percent (5 of 61) of crossings fully assessed on Forest Service roads were undetermined (GREY) for salmonid or sculpin (Table 2). No California and Nevada highway crossings were rated grey. The main crossing types rated grey were pipe-arches, open-bottom arches, fords, and circular culverts (Table 2).

An example of a crossing where conditions were not adequate to make a determination is Trout_Trib_5. Trout_Trib_5 has continuous organic substrate throughout culvert. However, the culvert width to bankfull ratio is less than 0.7 and greater than 0.5 and the culvert has no residual inlet depth. This crossing was rated grey for all lifestages of salmonid and


Outlet of Trout Tributary 5

sculpin (Appendix B). The LTBMU plans to run Fish Xing software simulations on this crossing.

Watersheds of Interest

Blackwood Creek

The extensive history of human disturbance in the Blackwood watershed has resulted in significant increases in erosion and sediment yield. Since the 1970's the LTBMU has implemented watershed restoration measures including the cessation of grazing, road decommissioning, gully stabilization and in-stream restoration (TBRIT 2011).

Outlet of Middle Fork Blackwood Tributary 3

The AOP crew surveyed twelve crossings in the Blackwood watershed; one highway crossing and 11 Forest Service crossings. Ten crossings were full assessments and two crossing were partial assessments. Of the ten crossings surveyed there was nine (90%) crossings did not meet the criteria for fish passage (RED) and are barriers for both life stages of salmonid (Appendix C). Also, one crossing (10%) was found undeterminable (GREY) for both life stages of salmonid (Appendix C). The two partial crossings consisted of one bridge (GREEN) and one crossing with no flow at the time of assessment (Appendix C).

Although the majority of full survey assessments were deemed barriers to fish passage there are a number of natural barriers that would restrict migration of salmonids in the Middle Fork Blackwood Creek and tributaries. These crossings include: M_Fork_Blackwood_1, M_Fork_Blackwood_2, M_Fork_Blackwood_2-1, M_Fork_Blackwood_Trib2, and M_Fork_Blackwood_Trib3. The observed natural barriers were boulder and woody debris cascades ranging from 2' to 6' in height.

Meeks Creek

The AOP crew surveyed one highway crossing on Meeks Creek. Meeks Creek's aquatic habitat above Highway 89 is considered in good condition while the aquatic habitat below highway 89 is in a highly degraded as a result of marina construction and continued maintenance dredging. Historically, Meeks Creek was used by LCT as a major spawning tributary. Today, Meeks Creek supports a range of native non-game fishes and nonnative salmonid species (TBRIT 2011).

Outlet of Meeks Creek 1

The crossing at Meeks creek did not meet the criteria for fish passage (RED) and is a barrier for both life stages of salmonid due to a large outlet drop (Appendix C).

Incline and Third Creeks

Incline Creek is located in the northern portion of the Lake Tahoe basin and runs through the city of Incline Village, NV. It is estimated that the Incline watershed is impacted 40% by urbanization. The creeks have also suffered by channelization. The Incline Village General Improvement District (IVGID) and the Nevada Department of Wildlife have identified four local road crossings for restoration. IVGID have also planned to incorporate a weir to segregate LCT and non-native salmonid species.

Inlet of Third Creek 8

Three stream restoration/water quality improvement projects were implemented on Incline Creek in 1986, 1999, and 2009 (TBRIT 2011)

The AOP crew surveyed four Forest Service crossings in the Incline watershed. Three crossings had full assessments and one crossing was a partial assessment. All three crossings with full assessments (100%) did not meet the criteria for fish passage (RED) and are barriers for both life stages of salmonid (Appendix C). The partial assessment crossing was a bridge and did not pose a barrier to fish passage (GREEN) (Appendix C).

Upper Truckee River

The Upper Truckee River and its tributaries, which make up the Upper Truckee River watershed, comprise the largest contribution to the waters of Lake Tahoe. Additionally, Trout Creek watershed is a major sub-watershed of the Upper Truckee River.

Outlet of Saxon Creek 2.

The Upper Truckee River has been disturbed by off-road vehicle use, residential, commercial, and industrial development, and highway construction and maintenance. The watershed includes two golf courses, and recreational and commercial facilities with expansive turf areas which have greatly affected the stream channel as it flows to Lake Tahoe. Historically, the watershed was affected by nineteenth century logging and livestock grazing. Today, overnight camping in Desolation Wilderness is limited but the water quality impacts of human waste disposal in the backcountry are still of concern. Furthermore, highway 50 crosses the Upper Truckee River at three locations; the prime disturbance concern being concentrated road salt discharge (TBRIT 2011).

The AOP crew surveyed a total of twenty three crossings in the Upper Truckee Watershed. There were five crossings in the Upper Truckee watershed (HUC 160501010101) and eighteen crossings in the Trout Creek sub-watershed (HUC 160501010102). All of the crossings were full assessments. The AOP crew found that two crossings (40%, 2 of 5) were red, two crossings (40%, 2 of 5) were green (both fords) and one crossing (20%) was grey (Appendix C).

In the Trout Creek sub-watershed had fifteen full assessments and three partial assessments. Twelve crossings (80%, 12 of 15) did not meet the criteria for fish passage (RED) and are barriers for both life stages of salmonid. Also, three crossings (20%) were grey for at least one lifestage of salmonid. The three partial assessments were bridges and did not pose barriers to fish passage (GREEN) (Table 3).

The sculpin criterion was only applied to two crossings in the Trout Creek sub-watershed. The AOP crew found that one crossing (50%, 1 of 2) did not meet the criteria for sculpin passage and the other crossing (50%) was found undeterminable (GREY) (Table 2).

Heavenly Valley Creek

Heavenly Valley Creek is a tributary of Trout Creek in the northern portion of the Upper Truckee Watershed. The headwater of Heavenly Valley Creek is within the permit boundaries of Heavenly Ski Resort (California side). The Heavenly Ski Resort has a special use permit issued by the LTBMU. The creek's headwater has been greatly damaged by sedimentation related to historic ski resort development. The creek has had significant hydro-modification; including a reservoir for snowmaking, diversion of the creek into an uncommonly large culvert for a ski run, and major road fill erosion from mountain springs which would typically flow into creek. (California Regional Water Quality Control Board).

Outlet of Heavenly Valley Trib. 2

The AOP crew surveyed ten crossings in the permit boundaries of Heavenly Ski Resort. Of the ten crossings, seven full assessments and three partial assessments were completed. All seven (100%) full assessments did not meet the criteria for fish passage (RED). Two partial assessments were on decommissioned roads with no structures (GREEN) and one assessment had no determination because the culvert was capturing spring flow under a utility road with no visible inlet (Table 5).

Although all full survey assessments were deemed barriers to fish passage there are a number of natural barriers that would restrict migration of salmonid in Heavenly Valley Creek. Natural barriers observed where boulder and woody debris cascades ranged from 1.5' to 5.1' in height. Appendix C is a catalog of eight natural barriers observed downstream of the Heavenly Valley Creek and Heavenly Valley tributary junction. It is currently unknown how far fish can migrate upstream from the junction of

Heavenly Valley creek and Trout creek. Also, the AOP crew did not observe any fish in the creek during assessment and LTBMU does not have a contemporary fish distribution for this creek.

Taylor Marsh and Tallac Creek

Taylor Creek is the only outlet to Fallen Leaf Lake. The outlet is located at the north end of the lake and flows 1.62 miles (2.6 km) before entering Lake Tahoe. The streamflow patterns in Taylor Creek are regulated by releases from Fallen Leaf Lake Dam, which was constructed in 1934. Strict operating guidelines for managing lake levels were established in a MOU between the Forest Service and Fallen Leaf Lake Protection Association, 1972 (MOU) and Amendments (1987). Overall, Taylor Creek appears to be functioning well with an abundance of high quality step-pool aquatic habitat. (TBRIT 2011).

A new bridge installed as part of the restoration efforts on Tallac Creek.

Post Grey /Partial Crossing Surveys

Partial surveys were 45% (51 crossings) of the total sites surveyed; forty nine crossings were on forest service roads and two were on California and Nevada highway crossings (Table). Fourteen (27%) of the partial survey crossings were bridges. Twenty one (42%) of the partial survey crossings were intermittent streams with no flow during the assessment period. Sixteen (31%) of the partial survey crossings had no structure/crossing. No structure crossings are typically on decommissioned roads where the culvert structure has been removed (Table 5).

Table 5: Summary of Partial Assessment Culvert Type

Culvert Type	FY 2010 FS Crossing Count	FY 2010 Highway Crossing Count	Total
Bridge	12	2	14
Intermittent Stream	21	0	21
No Structure/Crossing	16	0	16
Total	49	2	51

California / Nevada Highway and County Crossings

In addition to surveys done on Forest Service system roads the AOP crew surveyed an additional nine crossings on California and Nevada Highways and one on El Dorado County roads. Due to urbanization there are a high number of road crossings that intersect major streams and occur in the lower basin areas where fish species diversity is higher and adfluvial fish from the main lake try to migrate to spawning tributaries as was historically the case for LCT. Preference was given to the west shore tributaries and where the evaluation of LCT recovery potential is expected to occur and currently fish, such as lake-run rainbow trout attempt to migrate from Lake Tahoe to spawn.

Of the ten crossings surveyed, eight full surveys were completed and two partial surveys were completed. All eight (100%) full crossing assessments were barriers for both life stages of salmonid. Conversely, the two partial assessments on California and Nevada Highways were bridges and did not pose a barrier to fish passage (GREEN). It is important to note that the sculpin criterion was not applied to highway crossings since the highway crossings were prioritized for LCT migration (Table 6).

Table 6: Summary of Aquatic Organism Passage Barriers on California / Nevada and local county roads with complete surveys

Life Stage	RED (Barrier)	GREY (Partial Barrier)	GREEN (Passable)	Total
Adult Resident	8	0	0	8
Juvenile Resident	8	0	0	8
Piute Sculpin	0	0	0	0

Recommendations

The LTBMU has taken these results and focused its energy on those crossing considered RED (Appendix D). Priority was assigned mainly by calculating the miles of habitat available upstream from the crossing. The LTBMU Fishery Biologists also asked the following questions to verify that these crossings were located in areas considered to be priorities for restoration:

- Is the crossing in a sub-watershed which is currently being considered for LCT recovery by the TBRIT?
- Would native non-game fish or other aquatic species benefit from upgrading the barrier?
- How many miles would be made accessible if passage was restored?
- Is there adjacent stream restoration planning and /or current implementation efforts?
- Is the crossing structure actively contributing sediment to Lake Tahoe?

Appendix A displays the top twenty five crossings which the LTBMU plants to replace. The order within Appendix A is not necessarily firm, but is listed in order according to the answers to the above questions. Some perennial stream miles may not necessarily provide suitable fisheries habitat, but may provide habitat for other aquatic-dependent species (i.e. amphibians and invertebrates).

Strategy for Replacement

The LTBMU's current strategy is to put in place a multi-year indefinite deliverable / indefinite quantity that will have part of the scope of conducting further site surveys and structure and stream channel 100% designs. The implementation of each priority culvert may occur as part of the indefinite deliverable / indefinite quantity or may occur under a separate contract which includes specifications for heavy equipment, time, materials, etc. Cost for replacement will vary based on structure size and the amount of in-stream work necessary to achieve stream simulation.

Stream Simulation

Stream simulation is a channel restoration practice that utilizes natural channel design methodology. The goal is to achieve contiguous geomorphic, hydrologic, and aquatic habitat conditions throughout a stream not influences by manmade road crossing structures. By achieving these conditions it is assumed that fishes and other aquatic organisms will be able to migrate without encountering an unnatural abrupt change in conditions causing passage barriers.

Strategy for Lahontan Cutthroat Trout

Streams are currently being evaluated by the TBRIT as potential LCT recovery streams. The TBRIT is evaluating watershed size, amount of aquatic habitat, historic records demonstrating fish production, connectivity to Lake Tahoe, and a stream's ability to support lacustrine life histories. The current thought by the TBRIT is to achieve an LCT population where fish are imprinted to a stream and migrate to Lake Tahoe with a portion of individuals taking residence will form in a specific drainage. The degree to which man-made passage barriers exist is a factor when attempting to achieve habitat connectivity for LCT.

Strategy for Heavenly Valley Creek

Heavenly Valley Ski Resort is operating under a special use permit from LTBMU. The Aquatic Biologist will work with the LTBMU recreation and engineering departments on a yearly basis to upgrade crossings on Heavenly Valley Creek pertinent conditions of their operating plan.

Strategy for California / Nevada Highway Crossings

Taking into account our priorities we recommend partnerships in replacing state highway crossings. The LTBMU Aquatic Biologist will work with external partners (CalTrout, Trout Unlimited, TBRIT, etc.) to both raise awareness of degraded conditions and encourage CalTrans and Nevada Department of Transportation to actively restore highway crossings that were determined to be barriers to fish passage.

Other Factors for priority reasoning

Other issues that factor into culvert replacement were other important non-game native fishes where those strongholds are occurring; adjacent projects that occurred in the last ten years in the same watershed (i.e. Saxon and Blackwood creeks); and removal of pipes that are causing water quality degradation and impacting lake clarity. Lastly, prioritization of culverts is flexible to change due to resource priority changes.

Future Crossings to be Surveyed

There are at total of 80 perennial, state and U.S. highways crossings in the Lake Tahoe Basin, 30 of which are within or bordering Forest Service land. Nine highway crossings were surveyed in 2010, with 71 sites remaining (89%). Furthermore, there are a total of 153 perennial, local road crossings, 48 of which are within or bordering Forest Service land. Only one local crossing was surveyed in 2010, with 152 sites remaining (99%) (Table 7). The Nevada Department of Wildlife has surveyed crossings on perennial streams on non-Forest Service administrated roads, however such assessments on California crossings in Lake Tahoe has not been done by other agencies. The LTBMU will work to continue to conduct AOP passage assessments, in addition to working with external partners to determine and restore priority sites.

Table 7: Summary of Crossings Surveyed and Crossings Remaining

Summary of Crossings Inventoried and those Estimated to be Remaining			
Road Ownership	# Crossing Surveyed in FY 2010	# Perennial Crossing Sites Remaining within/bordering FS	Total (overall) Perennial Crossing Sites Remaining
California / Nevada Highway	9	30	71
Forest Service System Roads	102	0	0
Local (County, private, etc.)	1	48	152
Total	112	78	223

Bibliography

Belford, D. A., and W. R. Gould, 1989, An evaluation of trout passage through six highway culverts in Montana. North American Journal of Fish Management 9(4): 437-445.

California Regional Water Quality Control Board, Lahontan Region. Adopted Water Quality Control Plan Amendments, Total Maximum Daily Load for Heavenly Valley Creek. May 2002

Coffin, P.D. 1988. Nevada's native salmonid program status, distribution andmanagement. Nevada Department of Wildlife, Reno, Nevada. 400 pp.

Coffman, J. S. 2005. Evaluation of a predictive model for upstream fish passage through culverts. Master’s Thesis, James Madison Univeristy. Harrisonburg, VA.

Coleman, M.E., and V.K. Johnson. 1988. Summary of trout management at Pyramid Lake, Nevada, with emphasis on Lahontan cutthroat trout, 1954-1987. American Fisheries Society Symposium 4:107-115.

Gerstung, E.R. 1986. Fishery management plant for Lahontan cutthroat trout (Salmo clarki henshawi) in California and western Nevada water. Inland Fisheries Administrative Report No. 86-, Federal Aid Project F33-R-11, The Resources Agency, California Department of Fish and Game. 54 pp.

Gerstung, E.R. 1988. Status, life history, and management of the Lahontan cutthroat trout. American Fisheries Society Symposium 4:93-106.

Jassaby, A.D., Goldman, C.R., Rueter, J.E., and Richards, R.C. 1999. Origins and scale dependence of temporal variability in the transparency of Lake Tahoe, California-Nevada. *Limnol. Oceanogr.* 44(2):282-294

Kamerath, M., S. Chandra, and B. Allen. 2008. Distribution and impacts of warm water invasive fish in Lake Tahoe, USA Aquatic invasions. 3: 35-41.

Moyle, P. 2002. Inland Fishes of California. University of California Press. p358

Murphy, Dennis D., and Christopher M. Knopp, editors. 2000. The Lake Tahoe Watershed Assessment, Volume I. General Technical Report PSW-GTR-175. Albany, CA: Pacific Southwest Research Station, Forest Service, US Department of Agriculture.

National Marine Fisheries Service, Southwest Region September 2001, Guidelines for Salmonid Passage at Stream Crossings. Santa Rosa, CA, 14 pp.

Robison, G.E., A. Mirati, and M. Allen, 1999, Oregon Road/Stream Crossing Restoration Guide: Spring 1999, Advanced Fish Passage Training Version.

Behlke, C.E., Kane, D.L., McLean R.F., Travis M.D., 1991. Fundementals of Culvert Design for Passage of Weak-Swimming Fish, State of Alaska, Department of Transportation and Public Affiars. Fairbanks, AK.

Sumner, F.H. 1940. The decline of the Pyramid Lake fishery. Transactions of the American Fisheries Society 69:216-224.

TBRIT: Tahoe Basin Recovery Implementation Team. 2011. DRAFT Recovery Implementation Action Plan for Lahontan Cutthroat Trout in the Tahoe Basin.

USDI. 1995. U.S. Fish and Wildlife Service. Recovery plan for the Lahontan cutthroat trout. Portland, Oregon. 108 pp.

Appendix

Appendix A – Priority Culverts

Site Name	Priority Rational	Miles of Habitat Above Crossing	Structure Type
Saxon_Creek_2	Adjacent to recently removed culverts, Future channel restoration planned upstream	5.59	Pipe-arch
Marlette_Trib_1	Potential existing LCT population, Future channel restoration planned upstream	1.54	Pipe-arch
Tallac_Creek_1, 5, 6, and 7	Future lagoon restoration in conjunction with road crossing restoration	3.12	Pipe-arch
Blackwood_Trib_2	Potential LCT recovery stream, Adjacent to recent restoration projects	0.24	Circular Culvert
N_Fk_Blackwood_1	Crossing causing bank and bed erosion	1.56	Open-bottom - arch
Mdl_Fk_Blackwood_Trib_1	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	1.29	Ford- Vented (vent slots)
M_Fork_Blackwood_1	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and	0.59	Circular Culvert

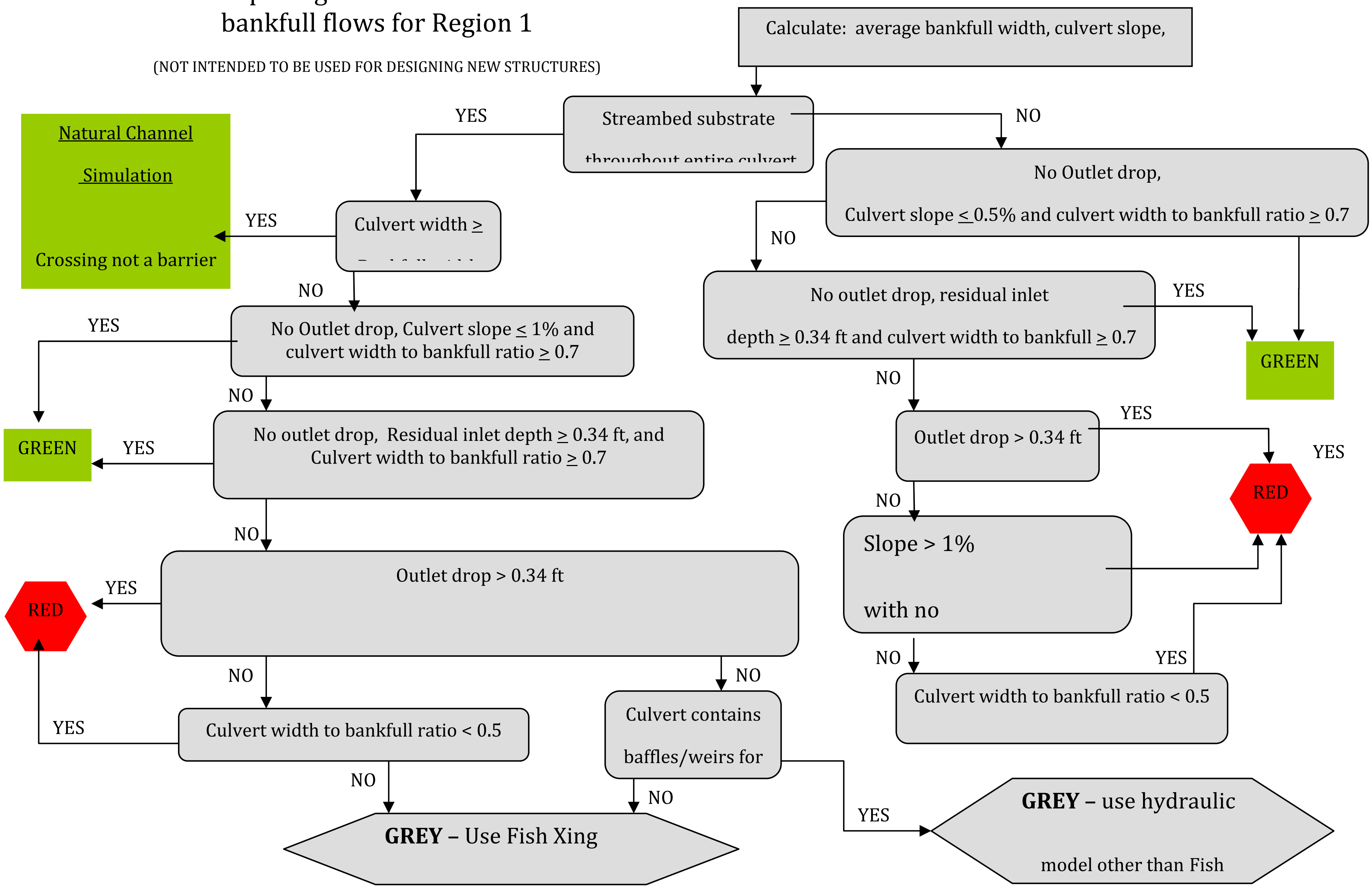
	bed erosion		
S_Fork_Blackwood_1	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	0.93	Circular Culvert (2)
M_Fork_Blackwood_2	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	0.39	Circular Culvert
M_Fork_Blackwood_2-1	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	0.19	Circular Culvert
M_Fork_Blackwood_Trib_2	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	0.45	Circular Culvert
M_Fork_Blackwood_Trib_3	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	0.45	Circular Culvert
Incline_Trib_1-14	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	0.4	Circular Culvert
Third_Creek_8	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and bed erosion	0.02	Pipe-Arch
Incline_Village_Creek_14	Potential LCT recovery stream, Adjacent to recent restoration projects, Crossing causing bank and	2.28	Box Culvert

	bed erosion		
NorthCanyon_Cr_5	Potential LCT recovery stream	3.18	Circular Culvert
NorthCanyon_Cr_9	Potential LCT recovery stream	2.67	Circular Culvert
NorthCanyon_Cr_18	Potential LCT recovery stream	0.91	Circular Culvert
Angora_Cr_Trib_2	Post Fire Restoration, Adjacent to recent restoration projects	1.25	Pipe-arch
Tallac_Creek_Trib_2_1	Adjacent AOP projects by LTBMU and CalTrans	0.43	Pipe-arch
Tallac_Creek_Trib_1_1	Adjacent AOP projects by LTBMU and CalTrans	1.84	Pipe-arch
Emerald_Bay_North_2	High Erosion	0.03	Circular Culvert
Page_Mdw_1	Potential LCT recovery stream	0.86	Pipe-arch
Saxon_Trib_1	Adjacent to recently removed culverts, Future channel restoration planned upstream	0.73	Ford
Trout_Trib_10	Adjacent to recently removed culverts, Future channel restoration planned upstream	0.29	Circular Culvert

Appendix B – Table 1:

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

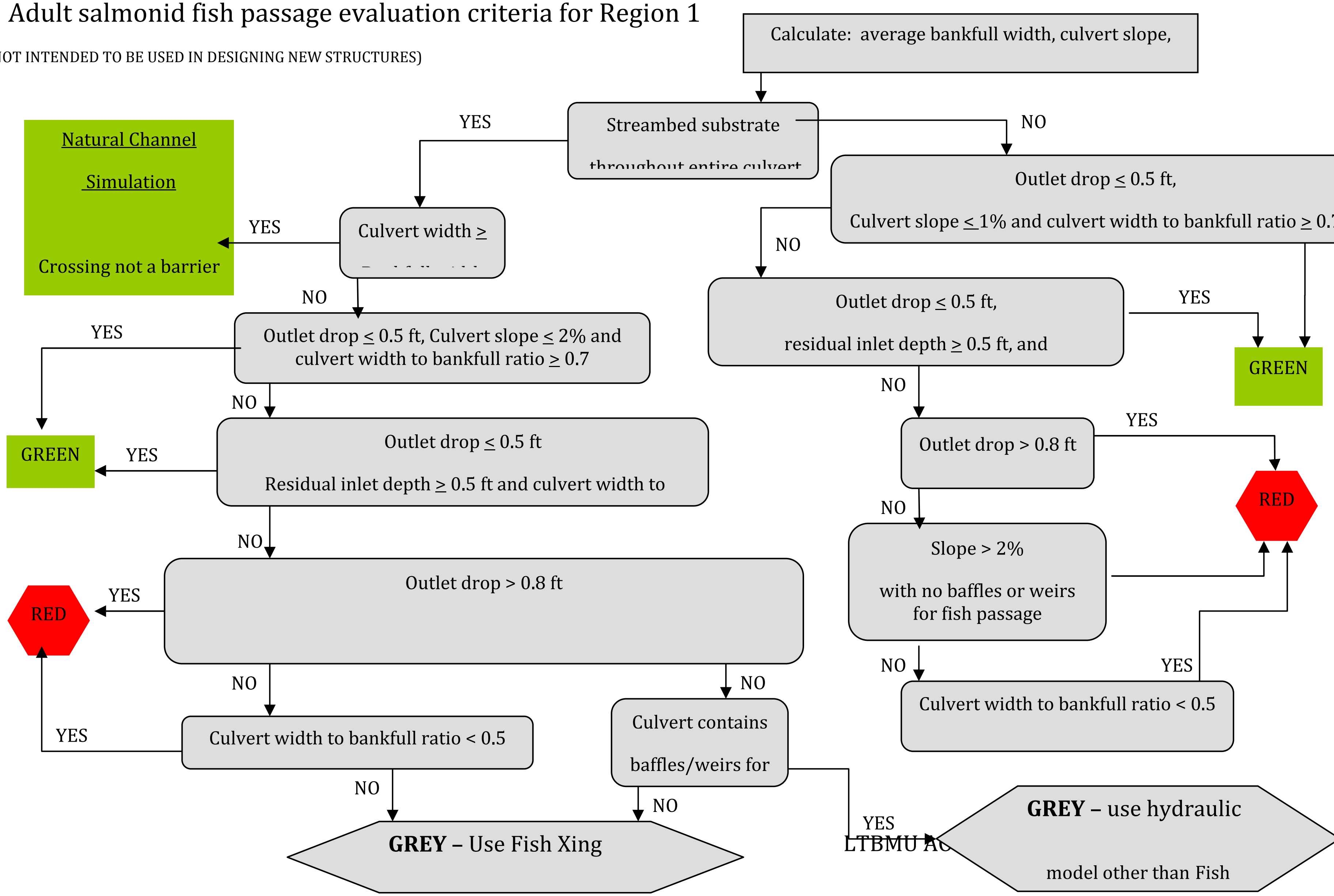
(NOT INTENDED TO BE USED FOR DESIGNING NEW STRUCTURES)



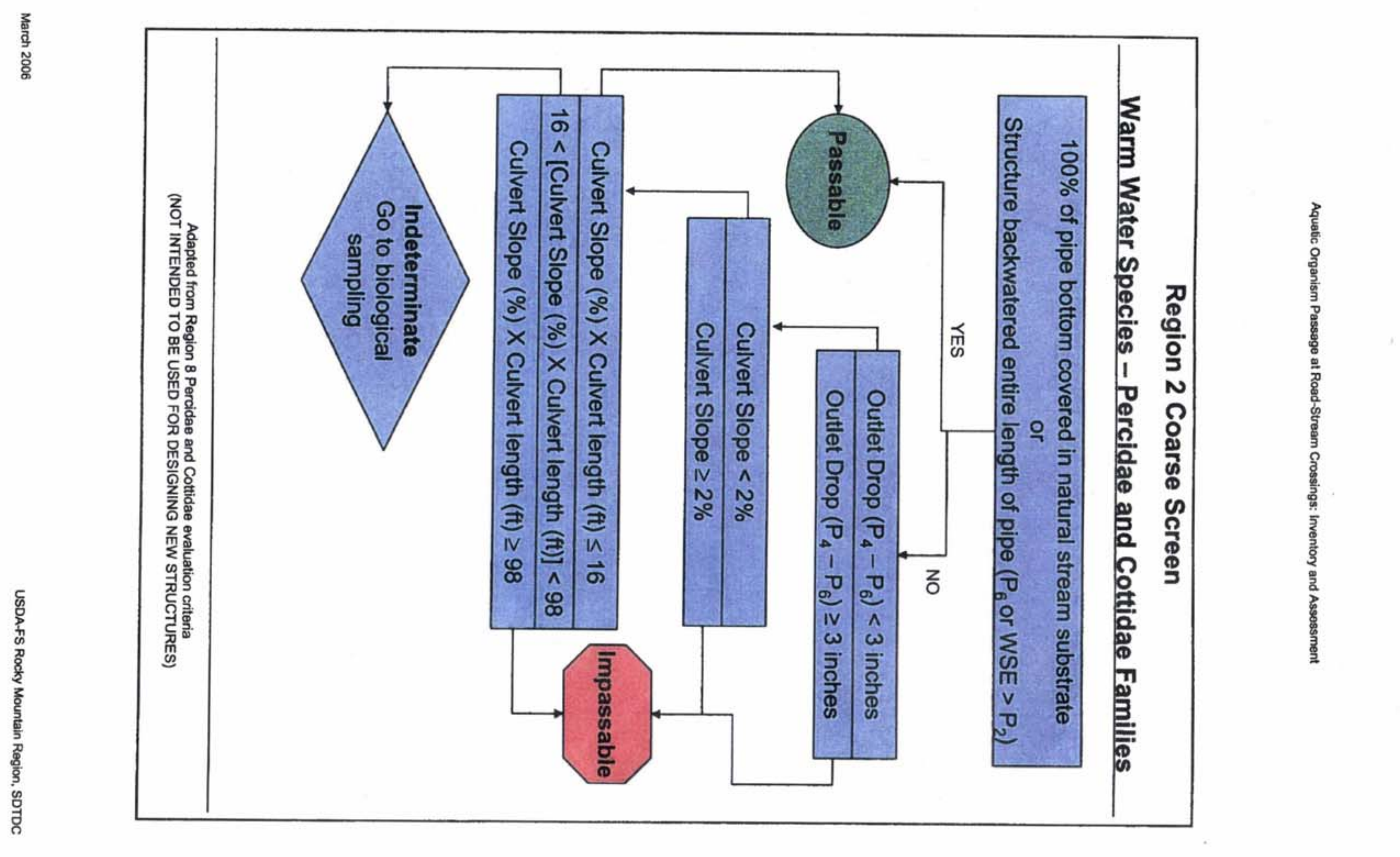
Appendix B – Table 2:

Adult salmonid fish passage evaluation criteria for Region 1

(NOT INTENDED TO BE USED IN DESIGNING NEW STRUCTURES)



Appendix B – Table 3: Sculpin Criteria



Appendix C– Inventory Data by Hydrologic Unit (HUC6)

Upper Truckee River – 160501010101							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
Angora Creek Tributary	Angora_Cr_Trib_2	Pipe-arch	Full	Forest Service	RED	RED	_
Angora Creek Tributary	Angora_Cr_Trib_3	Ford	Full	Forest Service	GREEN	GREEN	_
Grass Lake Creek – Main Stem	Grass_Lake_Creek_3	Bridge	Partial	Forest Service	GREEN	GREEN	_
Grass Lake Creek – Main Stem	Grass_Lake_Creek_4	Circular Culvert	Full	Forest Service	RED	RED	_
Grass Lake Creek – Main Stem	Grass_Lake_Creek_5	No Structure	Partial	Forest Service	GREEN	GREEN	_
Grass Lake Creek – Main Stem	Grass_Lake_Creek_7	Pipe-arch	Full	Forest Service	GREY	GREY	_
Upper Truckee River Tributary	UpperTruckee_Crk_trib 2_2	Vented Ford	Full	Forest Service	Green	Green	_

Upper Truckee River-Trout Creek – 160501010102							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
Cold Creek – Main Stem	Cold_Creek_1	Pipe-arch	Full	Local/ County	RED	RED	_
Cold Creek – Main Stem	Cold_Creek_6	No Structure	Partial	Forest Service	GREEN	GREEN	_
Cold Creek – Main Stem	Cold_Creek_7	Ford	Full	Forest Service	GREEN	GREEN	_
Cold Creek Tributary	Cold_Trib_2	Bridge	Partial	Forest Service	GREEN	GREEN	_
Cold Creek Tributary	Cold_Trib_4	Ford	Full	Forest Service	GREEN	GREY	_
Cold Creek Tributary	Cold_Trib_5	Ford	Full	Forest Service	GREY	GREY	_
Cold Creek Tributary	Cold_Trib_8	Circular Culvert	Full	Forest Service	RED	RED	_
Heavenly Valley Creek – Main Stem	Heavenly_Valley_Cr_3	No Structure	Partial	Forest Service	GREEN	GREEN	_
Heavenly Valley Creek – Main Stem	Heavenly_Valley_Cr_4	No Structure	Partial	Forest Service	GREEN	GREEN	_
Heavenly Valley Creek – Main Stem	Heavenly_Valley_Cr_5	Circular Culvert	Partial	Forest Service	N/A	N/A	_
Heavenly Valley Creek – Main Stem	Heavenly_Valley_Cr_6	Circular Culvert	Full	Forest Service	RED	RED	_

Heavenly Valley Creek – Main Stem	Heavenly_Valley_Cr_7	Circular Culvert	Full	Forest Service	RED	RED	_
Heavenly Valley Creek – Main Stem	Heavenly_Valley_Cr_8	Circular – Dam	Full	Forest Service	RED	RED	_
Heavenly Valley Creek – Main Stem	Heavenly_Valley_Cr_9	Circular Culvert	Full	Forest Service	RED	RED	_
Heavenly Valley Creek Tributary	Heavenly_Valley_Cr_Trib_1	Circular Culvert	Full	Forest Service	RED	RED	_
Heavenly Valley Creek Tributary	Heavenly_Valley_Cr_Trib_2	Circular Culvert	Full	Forest Service	RED	RED	_
Heavenly Valley Creek Tributary	Heavenly_Valley_Cr_Trib_3	Circular Culvert	Full	Forest Service	RED	RED	_
Saxon Creek – Main Stem	Saxon_Creek_1	Bridge	Partial	Forest Service	GREEN	GREEN	GREEN
Saxon Creek – Main Stem	Saxon_Creek_2	Pipe-arch	Full	Forest Service	RED	RED	RED
Saxon Creek Tributary	Saxon_Trib_1	Ford	Full	Forest Service	RED	RED	_
Trout Creek – Main Stem	Trout_Creek_4	Bridge	Partial	Forest Service	GREEN	GREEN	GREEN
Trout Creek – Main Stem	Trout_Creek_5	Open-bottom arch	Full	Forest Service	GREEN	GREEN	_
Trout Creek Tributary	Trout_Trib_10	Circular Culvert	Full	Forest Service	RED	RED	_
Trout Creek Tributary	Trout_Trib_4	Bridge	Partial	Forest Service	GREEN	GREEN	GREEN
Trout Creek Tributary	Trout_Trib_5	Circular Culvert	Full	Forest Service	GREY	GREY	GREY

Trout Creek Tributary	Trout_Trib_8	Open-bottom arch	Full	Forest Service	GREEN	GREEN	_

Lake Tahoe-East Shore Frontal / South Half – 160501010201							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
Burke Creek – Main Stem	Burke_Creek_4	Ford	Partial	Forest Service	N/A – No Flow	N/A – No Flow	_
Burke Creek Tributary	Burke_Trib_6	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	_
Burke Creek Tributary	Burke_Trib_7	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	_
Burke Creek Tributary	Burke_Trib_9	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	_
Edgewood Creek – Main Stem	Edgewood_Creek_5	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	_
Edgewood Creek Tributary	Edgewood_Creek_Trib1-10	Circular Culvert	Partial	Forest Service	N/A – No Flow	N/A – No Flow	_
Edgewood Creek Tributary	Edgewood_Trib3-5	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	_
Glenbrook Creek – Main Stem	Glenbrook_Cr_5	Pipe-arch	Full	Forest Service	RED	RED	_
Glenbrook Creek Tributary	Glenbrook_Trib_5	Pipe-arch	Full	Forest Service	RED	RED	_
Logan House Creek - Main Stem	Logan_House_Cr_1	Circular Culvert	Full	Forest Service	RED	RED	_

Logan House Creek - Main Stem	Logan_House_Cr_6	Circular Culvert	Partial	Forest Service	N/A – No Flow	N/A – No Flow	_
North Logan House Creek – Main Stem	N_Logan_House_Cr_3	Pipe-arch	Full	Forest Service	RED	RED	_
UnNamed Creek (North of Cave Rock Creek)	N_Cave_Rock_Creek_2	Circular Culvert	Partial	Forest Service	N/A – No Flow	N/A – No Flow	_
UnNamed Creek (North of McFaul Creek)	North_of_McFaul_Creek_1	Circular Culvert	Partial	Forest Service	N/A – No Flow	N/A – No Flow	_

Lake Tahoe-East Shore Frontal / North Half – 160501010202							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
Bliss Creek - Main Stem	Bliss_Creek_1	Pipe-arch	Full	Forest Service	RED	RED	_
Marlette Creek – Main Stem	Marlette_Creek_1	Box Culvert	Full	State Highway	RED	RED	_
UnNamed Creek (Marlette Lake South)	Marlette_Lake_South_1	Pipe-arch Spawning St	Partial	Forest Service	N/A	N/A	_
UnNamed Creek (Marlette Creek Tributary East)	Marlette_Lake_Trib_East_1	Ford	Partial	Forest Service	N/A – No Flow	N/A – No Flow	_
Marlette Creek Tributary	Marlette_Trib_1	Pipe-arch	Full	Forest Service	RED	RED	_
North Canyon Creek – Main Stem	NorthCanyon_Creek_18	Circular Culvert	Full	Forest Service	RED	RED	_
North Canyon Creek – Main Stem	NorthCanyon_Creek_23-1	Ford	Partial	Forest Service	N/A – No Flow	N/A – No Flow	_

North Canyon Creek – Main Stem	NorthCanyon_Creek_23-2	Ford	Partial	Forest Service	N/A – No Flow	N/A – No Flow	–
North Canyon Creek – Main Stem	NorthCanyon_Creek_23-3	Ford	Partial	Forest Service	N/A – No Flow	N/A – No Flow	–
North Canyon Creek – Main Stem	NorthCanyon_Creek_5	Circular Culvert	Full	Forest Service	RED	RED	–
North Canyon Creek – Main Stem	NorthCanyon_Creek_9	Circular Culvert	Full	Forest Service	RED	RED	–
North Canyon Creek Tributary	NorthCanyon_Trib_1	Circular Culvert	Full	Forest Service	RED	RED	–
UnNamed Creek (Northern part of Zephyr	NorthZephyrCove_1	Cobble-arch	Full	Forest Service	RED	RED	–
Secret Harbor Creek - Main Stem	SecretHarbor_Creek_1	Circular Culvert	Full	Forest Service	RED	RED	–
Secret Harbor Creek - Main Stem	Secretharbor_Creek_2	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	–

Stateline Point-Third Creek-Incline Creek– 160501010301							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
UnNamed Creek (Incline Village Creek)	Inc_Village_Creek_14	Box Culvert	Full	Forest Service	RED	RED	RED
UnNamed Trib (Incline Tributary)	Incline_Trib_1-14	Circular Culvert	Full	Forest Service	RED	RED	–
Third Creek – Main Stem	Third_Creek_7	Bridge	Partial	Forest Service	GREEN	GREEN	–

Third Creek – Main Stem	Third_Creek_8	Pipe-arch	Full	Forest Service	RED	RED	–

Burton Creek-Watson Creek-Tahoe Vista Frontal – 160501010302							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
Burton Creek – Main Stem	Burton_Creek_2	Pipe-arch	Partial	Forest Service	N/A – No Flow	N/A – No Flow	–
Burton Creek – Main Stem	Burton_Creek_3	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	–
Burton Creek – Main Stem	Burton_Creek_4	No Structure	Partial	Forest Service	*N/A – No Flow	*N/A – No Flow	–
Griff Creek – Main Stem	Griff_Creek_6	Bridge	Partial	Forest Service	GREEN	GREEN	GREEN
Griff Creek – Main Stem	Griff_Creek_7	Circular Culvert	Full	Forest Service	RED	RED	RED
Griff Creek – Main Stem	Griff_Creek_8	Circular Culvert (2)	Full	Forest Service	RED	RED	RED
Watson Creek – Main Stem	Watson_Creek_2	Circular Culvert	Full	Forest Service	RED	RED	–
Watson Creek – Main Stem	Watson_Creek_3	Open-bottom	Full	Forest Service	GREEN	GREEN	–
Watson Creek – Main Stem	Watson_Creek_4	Circular Culvert	Full	Forest Service	RED	RED	–

Ward Creek-Blackwood Creek-Eagle Rock Frontal – 160501010401							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
Blackwood Creek – Main Stem	Blackwood_Creek_1	Box Culvert	Full	State Highway	RED	RED	_
Blackwood Creek – Main Stem	Blackwood_Creek_2	Bridge	Partial	Forest Service	GREEN	GREEN	GREEN
Blackwood Creek Tributary	Blackwood_Trib_2	Circular Culvert	Full	Forest Service	RED	RED	GREEN
Blackwood Creek Tributary	Blackwood_Trib_3	Circular Culvert	Partial	Forest Service	N/A- No Flow	N/A – No Flow	_
Middle Fork Blackwood Creek	M_Fork_Blackwood_1	Circular Culvert	Full	Forest Service	RED	RED	RED
Middle Fork Blackwood Creek	M_Fork_Blackwood_2	Circular Culvert	Full	Forest Service	RED	RED	_
Middle Fork Blackwood Creek	M_Fork_Blackwood_2-1	Circular Culvert	Full	Forest Service	RED	RED	_
Middle Fork Blackwood Creek	M_Fork_Blackwood_3	Circular Culvert	Partial	Forest Service	N/A- No Flow	N/A – No Flow	_
Middle Fork Blackwood Creek Tributary	Mdl_Fork_Blackwood_Trib_1	Vented Ford	Full	Forest Service	RED	RED	_
Middle Fork Blackwood Creek Tributary	M_Fork_Blackwood_Trib_2	Circular Culvert	Full	Forest Service	RED	RED	_

Middle Fork Blackwood Creek Tributary	M_Fork_Blackwood_Trib_3	Circular Culvert	Full	Forest Service	RED	RED	–
North Fork Blackwood Creek	N_Fork_Blackwood_1	Open-bottom arch	Full	Forest Service	GREY	GREY	GREEN
South Fork Blackwood Creek	S_Fork_Blackwood_1	Circular Culvert (2)	Full	Forest Service	RED	RED	RED
UnNamed Creek (Granlibakken Creek)	Granlibakken_Creek_1	Circular Culvert	Partial	Forest Service	N/A – No Flow	N/A – No Flow	–
Madden Creek- Main Stem	Madden_Creek_1	Bridge	Partial	State Highway	GREEN	GREEN	–
UnNamed Creek (Page Meadow Creek)	Page_Mdw_1	Pipe-arch	Partial	Forest Service	N/A – No Flow	N/A – No Flow	N/A
UnNamed Trib (Page Meadow Creek Tributary)	Page_Mdw_trib_1	No Structure	Partial	Forest Service	GREEN	GREEN	GREEN
Ward Creek- Main Stem	Ward_Creek_1	Bridge	Partial	State Highway	GREEN	GREEN	GREEN
Ward Creek – Main Stem	Ward_Creek_2	No Structure	Partial	Forest Service	GREEN	GREEN	GREEN
Ward Creek Tributary	Ward_Creek_Trib_3	No Structure	Partial	Forest Service	GREEN	GREEN	–

McKinney Creek-Bliss-Eagle Creek Frontal – 160501010402							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
UnNamed Creek (Emerald Bay Creek – North)	Emerald_Bay_North_2	Circular Culvert	Full	Forest Service	RED	RED	–

General Creek – Main Stem	General_Creek_1	Circular (2) Pipe-arch (2)	Full	State Highway	GREY	RED	_
UnNamed Creek (Lonely Gulch Creek)	Lonely_Gulch_Creek_1	Circular Stand Pipe	Full	State Highway	RED	RED	_
McKinney Creek – Main Stem	McKinney_Creek_1	Pipe-arch (2)	Full	State Highway	RED	RED	_
McKinney Creek – Main Stem	McKinney_Creek_4	Bridge	Partial	Forest Service	GREEN	GREEN	_
Meeks Creek – Main Stem	Meeks_Creek_1	Box Culvert	Full	State Highway	RED	RED	_

Cascade Creek-Tallac Creek-Taylor Creek Frontal – 160501010403							
Steam Name	**Site Name**	**Crossing Type**	**Assessment Type**	**Road Ownership**	**Determination**		
					Adult	**Juvenile**	**Sculpin**
Glen Alpine Creek – Main Stem	Glen_Alpine_Creek_1	Bridge	Partial	Forest Service	GREEN	GREEN	_
Glen Alpine Creek – Main Stem	Glen_Alpine_Creek_2	Bridge	Partial	Forest Service	GREEN	GREEN	_
Tallac Creek – Main Stem	Tallac_Creek_1	Pipe-arch	Partial	Forest Service	N/A – No Flow	N/A – No Flow	N/A
Tallac Creek – Main Stem	Tallac_Creek_2H	Pipe-arch	Full	State Highway	RED	RED	N/A
Tallac Creek – Main Stem	Tallac_Creek_3	Bridge	Partial	Forest Service	GREEN	GREEN	GREEN
Tallac Creek – Main Stem	Tallac_Creek_4	No Structure	Partial	Forest Service	GREEN	GREEN	GREEN

Tallac Creek – Main Stem	Tallac_Creek_5	Circular Culvert	Partial	Forest Service	N/A – No Flow	N/A – No Flow	N/A
Tallac Creek – Main Stem	Tallac_Creek_6	Circular Culvert	Partial	Forest Service	N/A – No Flow	N/A – No Flow	N/A
Tallac Creek – Main Stem	Tallac_Creek_7	Pipe-arch	Partial	Forest Service	N/A – No Flow	N/A – No Flow	N/A
Tallac Creek Tributary	Tallac_Creek_Trib1_1	Pipe-arch	Partial	Forest Service	N/A – No Flow	N/A – No Flow	N/A
Tallac Creek Tributary	Tallac_Creek_Trib2_1	Pipe-arch	Full	Forest Service	RED	RED	RED

* N/A – No Flow - These sites lack a structure and/or a defined channel with a flow regime.

Appendix D – Heavenly Valley Creek Natural Barriers

Barrier ID	UTM N	UTM E	Barrier Description	Drop (ft)	Notes
Weir #2	4312760	766153	Cascade	1.7	Riprap placed at outlet, pool 1.5' deep
B2	4312745	766127	Cascade	2.1	Barrier created by woody debris jam
B3	4312714	766073	Cascade	1.5	Debris cascade. Site of an old bridge crossing
B4	4312384	765845	Cascade	1.7	Barrier created by woody debris jam, pool 0.5' deep
B5	4312375	765838	Cascade	3.9	Boulder cascade, pool depth 0.6', additional 2' cascades above and below site
B6	4312360	765823	Cascade	5.3	Boulder complex cascade / waterfall
B7	4312333	765800	Cascade	2.2	Boulder and woody debris cascade, additional 2' cascades below site