Fish Passage Assessment at Road/Stream Crossings
Nounan Reach of the Bear River
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RESULTS SUMMARY

Inventory

In 2014, the USDA Forest Service (USFS) conducted the Nounan Reach Fish Passage Assessment and evaluated a total of 13 road/stream crossings located on Eightmile, Stauffer, and Georgetown creeks. These streams have been identified as important spawning tributaries for fluvial Bonneville cutthroat trout (BCT) in the Nounan Reach of the Bear River. The objective of the assessment was to evaluate fish passage at road/stream crossings and identify which crossings are fish barriers that may limit system connectivity for the fisheries resource. This assessment provides a better understanding of system connectivity to be used in conjunction with other fisheries monitoring efforts to develop future conservation actions to benefit the fisheries resource in the Nounan Reach.

The Fish Passage Assessment utilized two complimentary methods including the San Dimas National Inventory and Assessment Procedure (NIAP, Clarkin et al, 2003) and FishXing V3 software (USDA Forest Service) to assess fish passage at road/stream crossings. The NIAP outlined the field survey methods and provided the site data to assess fish passage based on the physical and hydraulic characteristics of the stream crossing. A regional Fish Passage Criteria Screen developed by the USFS (Figures 3 and 4, Appendix B) was used to rate fish passage at the stream crossing, based on the crossings physical attributes collected using the NIAP. Lastly, FishXing software was used to model fish passage based on a combination of physical and hydrologic site variables. FishXing allows the user to model target fish species capabilities against culvert hydraulics across a range of expected stream discharges.

Three metrics were used in the Nounan Reach Fish Passage Assessment to rate road/stream crossings in the Nounan Reach. Two of the metrics were used to rate fish passage at site and third metric was used to rate infrastructure resiliency. A description of the metrics and summary of the results are located below.

Regional Fish Passage Criteria Rating and Results

Road/stream crossings were rated as RED (fish barrier), GREEN (passable) or CHANNEL SIMULATION, and GRAY (undetermined) using the Region 1 Fish Passage Criteria Screen (Figures 3 and 4, Appendix B). Each site was rated for both juvenile and adult salmonid fish passage. Ratings were based on physical attributes of the road/stream crossing including: outlet drop, residual inlet depth, culvert slope, and the culvert width to bankfull ratio. These ratings provide a conservative assessment of fish passage at a site solely based on structures physical attributes. This screening criteria was developed as an efficient method of evaluating fish passage for a large number of sites. The fish passage evaluation criteria screening process is used to quickly classify existing crossings as either meeting, needing refined hydraulic analysis, or failing to meet fish passage criteria for a chosen fish species, lifestage, and flow in a standardized and consistent manner. By utilizing passage evaluation criteria, the number of crossings that require an in-depth passage evaluation can be reduced.

Of the 13 crossing assessments 85% of these crossing sites were rated as RED and do not meet the criteria to pass juvenile and adult BCT and also may inhibit movement of other non-game species. Two sites (15% of sites) were rated as GRAY and need more evaluation to determine fish passage. None of the sites were rated as GREEN where physical attributes of the structure were determined to provide fish passage.

FishXing Hydraulic Analysis and Results

Road/stream crossings were further analyzed using FishXing to model fish passage for adult BCT at various discharge rates and Hydrologic Predictions. The range of discharge rates used for each site was analyzed using StreamStats (USGS 2012). Fish passage was modeled for all discharge rates encompassed in the 90% prediction interval for the 1.5 year event to develop the Fish Passage Ratings. Fish Passage Ratings were compared to Hydrologic Predictions including the PK1.5 to PK25 discharge events and the Rust Line event. The Rust Line event provides a site specific prediction that can be used to correlate or compare PK1.5 predictions from StreamStats. The Rust Line, PK 1.5, and PK 2 discharge events represent a range of flows when fish passage is critical and biologically important. The FishXing Hydraulic Analysis results have been summarized below.

At sites assessed on Eightmile and Stauffer creeks the hydrologic modeling was adequate to compare Fish Passage Ratings and Hydrologic Predictions. On these systems, Rust Line discharge predictions correlated with the PK1.5 prediction at 71% of the sites. Fish passage during Rust Line discharge was also expected at 71% of the sites (5 out of 7 sites). While fish passage during PK1.5 discharges was expected at 57% of the sites (4 out of 7 sites). It is important to note that Rust Line and PK1.5 Hydrologic Predictions likely represent a range of discharges at a site and that these ranges were generally the upper limits of expected fish passage at most sites.

The Rust Line and PK1.5 discharge events provide a critical biological range when fish passage is necessary. In Eightmile Creek two road/stream crossing (Eightmile_2.42, Eightmile_7.69) were determined to be impassable during Rust Line events and during PK 1.5 events. The most downstream crossing, Eightmile_2.42, likely limits BCT migration into this drainage during these critical spawning periods. Fish Passage Ratings and Hydrologic Predictions for Eightmile Creeks are displayed in Figures 8 and Table 1.

In Stauffer Creek all road/stream crossings were determined to be passable during Rust Line events and only one site (Stauffer_7.71) was unpassable at the PK 1.5 event. This middle crossing, likely limits BCT migration into the headwaters of this drainage during critical spawning periods. Fish Passage Ratings and Hydrologic Predictions for Stauffer Creek are displayed in Figure 10 and Table 2.

Unfortunately, the hydrologic modeling was not suitable for use on Georgetown Creek. The hydrology of Georgetown Creek doesn't fit the StreamStats model due to the large drainage area, spring influences, dewatered or losing reaches in the headwaters, and highly altered hydrology in the lower reaches (irrigation and hydropower uses). Fish Passage Ratings at road/stream crossings on Georgetown Creek could not be compared to Hydrologic Predictions and Rust Line predictions could not be used to validate the PK1.5 prediction.

Of the six sites assessed on Georgetown Creek it is evident that fish passage is highly limited at 50% of the sites. At three sites fish passage is not expected at Rust Line events. At a fourth site, fish passage is likely limited above the PK1.5 event (used Stauffer Creek PK1.5 event range as a surrogate). Two sites have positive (passable) Fish Passage Ratings and likely provide passage during events larger than the PK1.5.

The Rust Line and PK1.5 discharge events provide a critical biological range when fish passage is necessary. In Georgetown Creek three of the six road/stream crossings were determined to be impassable during these periods. The most downstream crossing, Georgetown_0.04, likely limits all

BCT migration into this drainage during these critical spawning periods. Fish Passage Ratings and Hydrologic Predictions for Georgetown Creek are displayed in Figure 12 and Table 3.

In summary all 13 road/stream crossings assessed in this analysis limit fish passage. Many of the crossings assessed likely provide fish passage when stream discharge is below the PK1.5 event. At three sites, it is evident that fish passage is restricted during base flow conditions.

Road/Stream Crossing Resiliency Rating and Results

Road/stream crossings were further assessed based on the resiliency of the crossing infrastructure. Bankfull channel and structure widths were used to determine if the road/stream crossing constricted channel flows and flood capacity. Structures were either rated as Adequate or Undersized. Adequate sites had structures widths that either met or exceeded channel bankfull width measurements. Undersized sites had structures widths that were less than channel bankfull width measurements.

Of the 13 road/stream crossing sites 100% of these crossing were rated as Undersized. All of these crossings constrict channel flows and may not provide adequate flood flow capacity. These structures could jeopardize the safety and longevity of the road network in these drainages and negatively impact stream function and aquatic species.

STUDY SCOPE

The scope of the Nounan Reach Fish Passage Assessment was limited to three tributaries of the Nounan Reach of the Bear River including Eightmile, Stauffer, and Georgetown creeks (Figure 1). The objective of the Nounan Reach Fish Passage Assessment was to locate and assess road/stream crossings on three of the largest tributaries within the Nounan Reach. Eightmile, Stauffer, and Georgetown creeks were also selected because they are important spawning tributaries for fluvial Bonneville cutthroat trout that reside in the Nounan Reach of the Bear River.

The Nounan Reach Fish Passage Assessment complements range-wide management actions and priorities included in the Management Plan for Conservation of BCT in Idaho (Teuscher and Capurso, 2007). The Plan includes general range-wide management actions including:

"Identify fish passage barriers. Complete fish passage surveys at all road crossings and irrigation diversions within the range of Bonneville cutthroat trout in Idaho. Coordinate with land management agencies and private landowners to provide fish passage at irrigation diversion dams and road culverts. Connecting populations is a priority, but in some circumstances barriers prevent non-native fish expansion and will be considered in decision making."

The Plan also lists conservation action priorities by stream and management unit. For the Nounan Reach, Priority 1 actions for Eightmile and Stauffer creeks includes: *Investigate habitat connectivity with Bear River.*

The Nounan Reach Fish Passage Assessment was limited in scale to three tributaries. The Nounan Reach contains 27 tributaries that drain into the Bear River and this type of passage assessment study could be expanded to determine fish passage barriers on all tributaries within this reach (Figure 1).

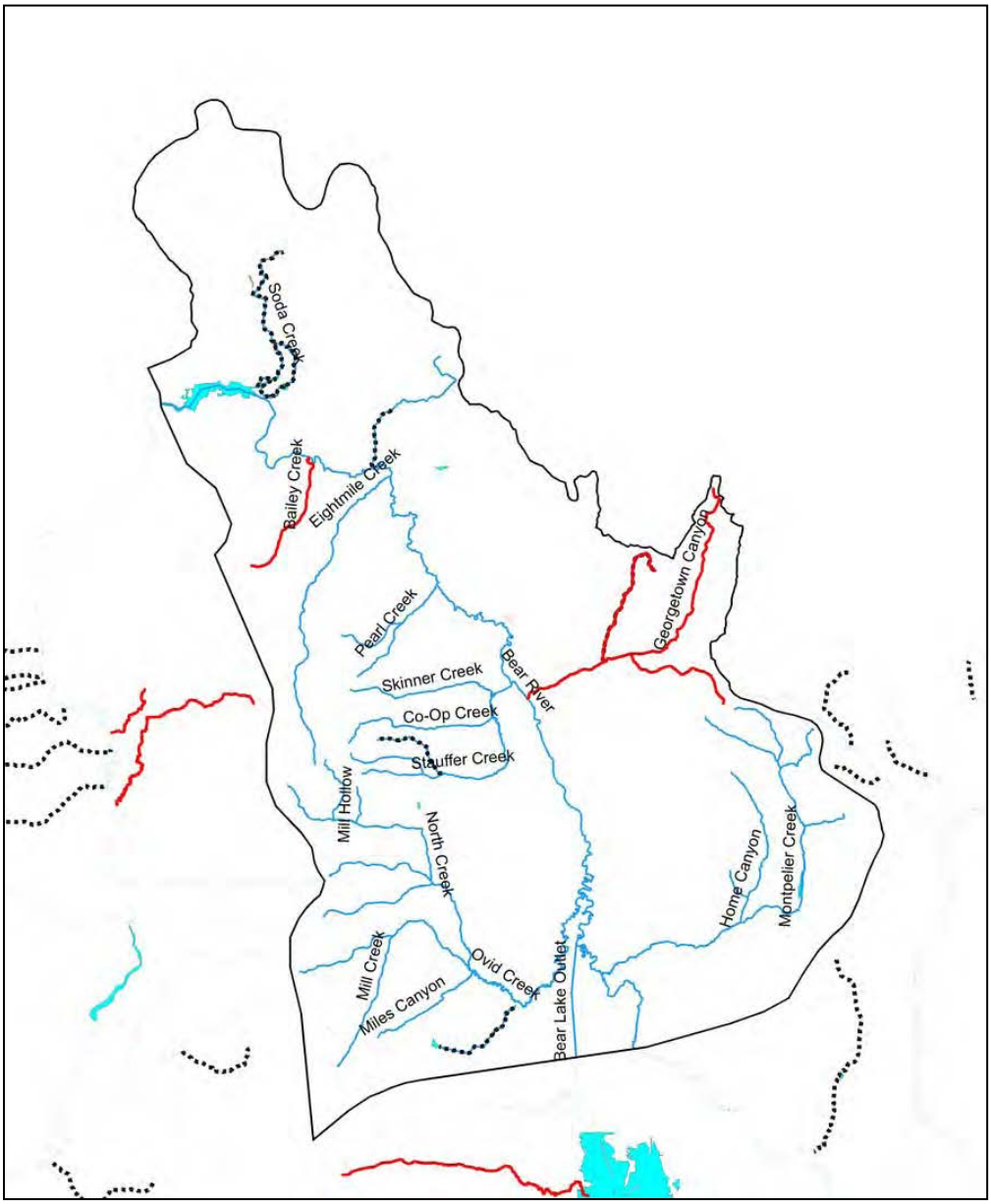
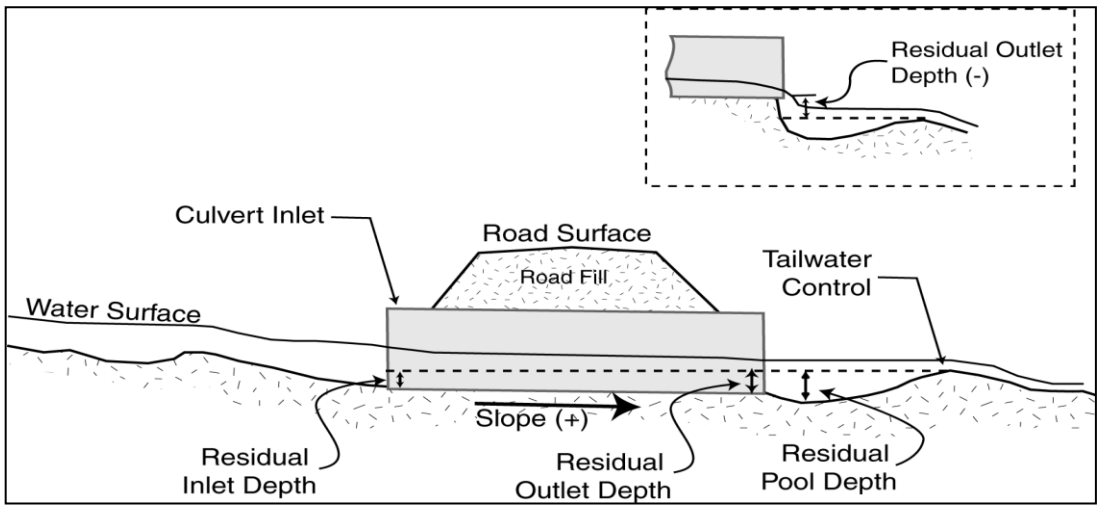


Figure 1. Nounan Valley Management Unit includes the Bear River from Stewart Dam downstream to Soda Dam. There are a total of 27 perennial tributaries that drain into this reach (From Teuscher and Capurso, 2007).

METHODS & ASSUMPTIONS

San Dimas National Inventory and Assessment Procedure (NIAP)

The NIAP (Clarkin et al, 2003) provides a frame work for surveying road/stream crossings. The assessment is data-intensive and provides enough site information to assist in analyzing fish passage and aid in developing preliminary site restoration design. The NIAP captures site data associated with the road way, crossing, and stream channel. The majority of the survey effort is capturing a longitudinal survey of the stream corridor and crossing structure and a cross-section of the tailwater control. These measurements are used to develop site information such as culvert slope, outlet drop, and residual inlet depth that can be applied to regional fish screen criteria or FishXing to further analyze fish passage at a site (Figure 2).



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

Figure 2. Measurements used in evaluation criteria (from Taylor and Love, 2001).

Regional Fish Passage Criteria Rating

The USFS Region 1 Fish Passage Evaluation Criteria screening process was used to classify existing crossings as meeting, needing further hydraulic analysis, or failing to meet fish passage criteria for selected resident fish species. Region 1 constructed two flow charts (Figures 3 and 4) for juvenile and adult cutthroat. These flowcharts attempt to define whether passage is provided through existing structures at the time of survey.

The following evaluation categories were used to classify road/stream crossings for juvenile and adult cutthroat for Region 1:

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

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

GRAY: Conditions may not be adequate for the analysis species life stage 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 life stage; assumed to be a barrier for that life stage.

Assumptions

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 life stage 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 identify and redefine these crossings appropriately.

The passage evaluation criteria flowcharts do not cover passage requirements for all species that may persist in the drainages. In general species diversity is somewhat low in these drainages and more fish sampling should be done to determine what species diversity and gradients that may exist. It is known that sculpin are found in Eightmile Creek on the Forest and are also found in the lower reaches of Georgetown Creek but not on the Forest. Lower Stauffer Creek supports Utah suckers and speckled dace.

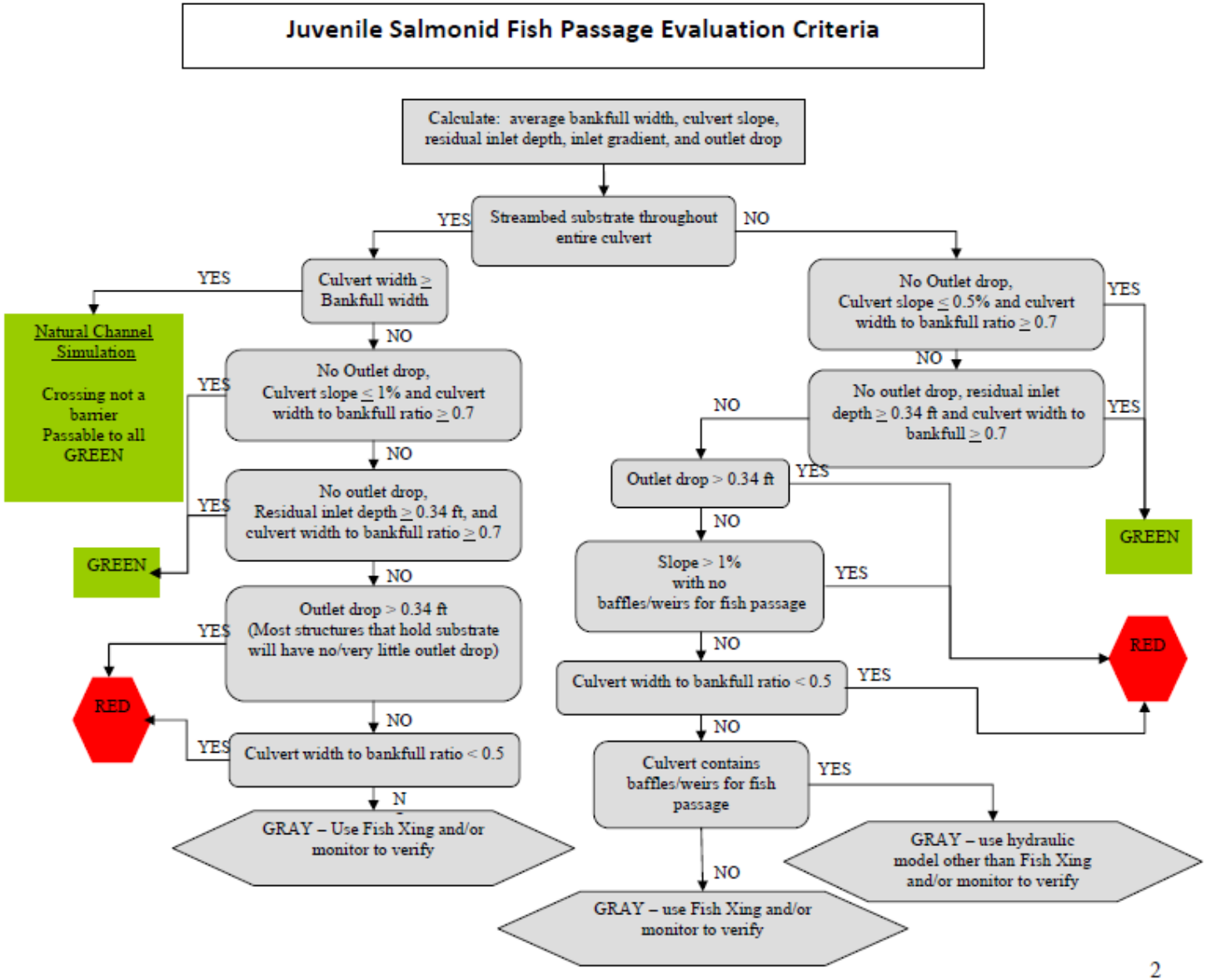


Figure 3. Fish passage evaluation criteria for juvenile salmonids (developed by USDA Forest Service Region 1).

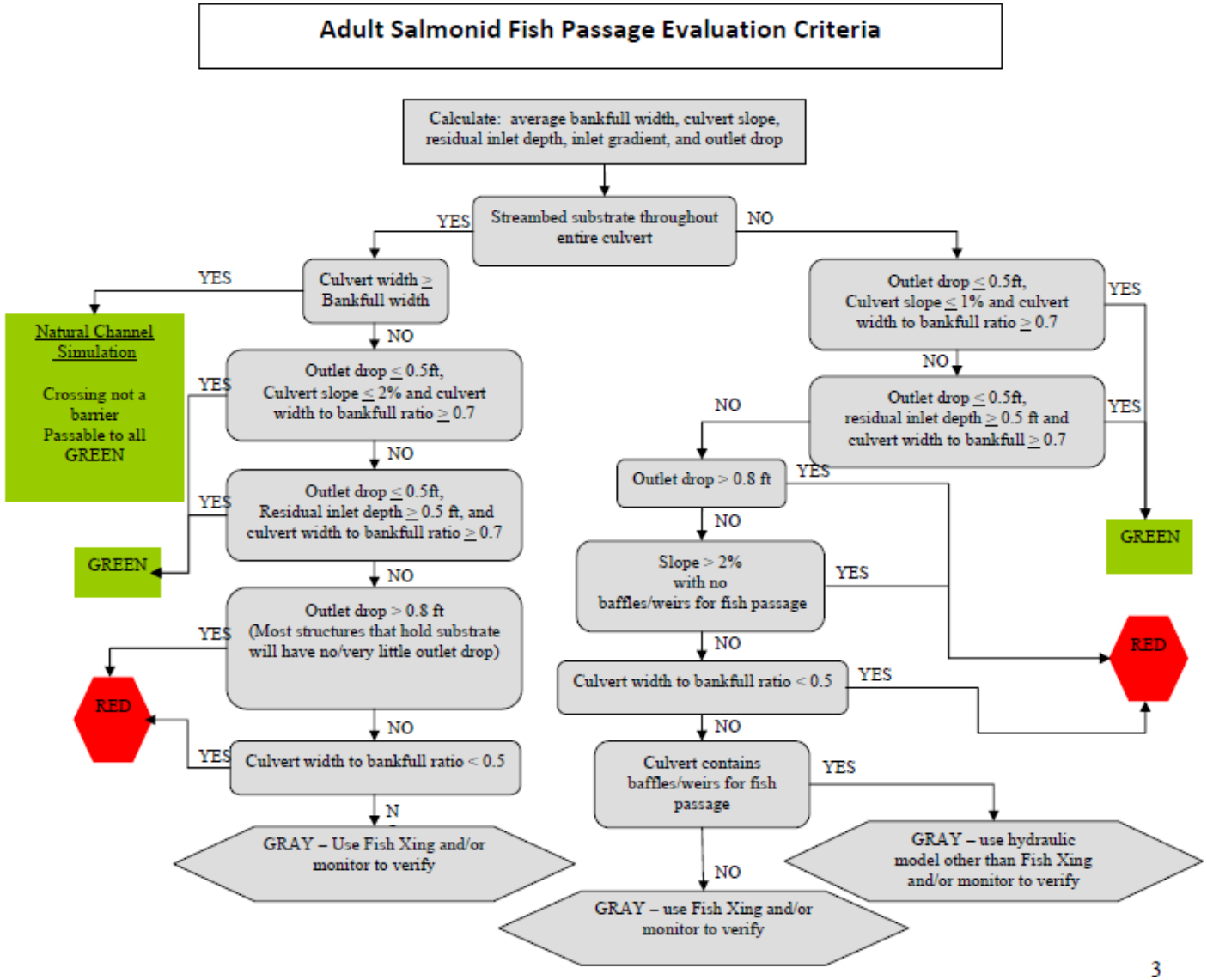


Figure 4. Fish passage evaluation criteria for adult salmonids (developed by USDA Forest Service Region 1).

FishXing Hydraulic Analysis

The FishXing software was designed by the USFS to assist engineers, hydrologists, and fisheries biologists in the evaluation and design of culverts for fish passage. FishXing models the complexities of culvert hydraulics and fish performance for a variety of species and crossing configurations. The module allows the user to input culvert information, fish information, tailwater information, velocity reduction factors, and a range of fish passage flows (Figure 5).

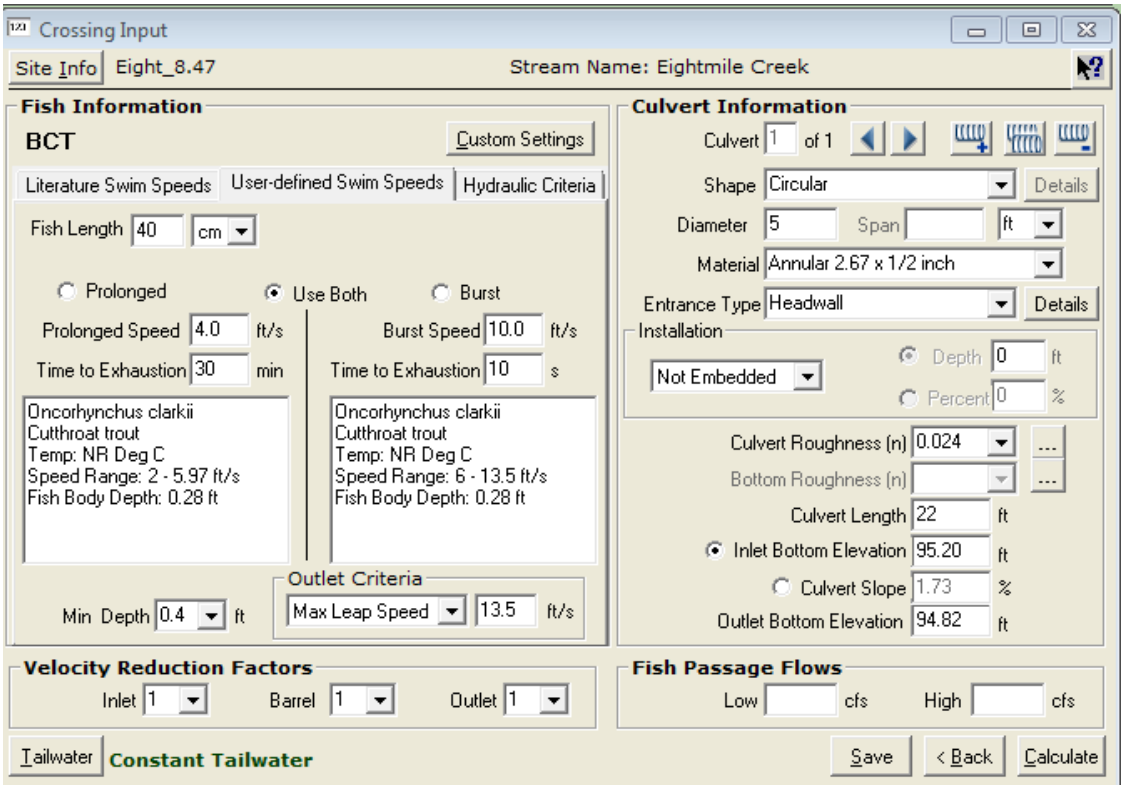


Figure 5. FishXing crossing input screen whre a majority of the site information and analysis parameters are entered.

Culvert Information

The culvert information section in the FishXing module included all of the physical aspects of the structure. The module has options for evaluating multiple crossings at a site. Culvert roughness is populated by the module and is based on the structure material. At some sites that contained squashed pipes, the closest size structure available in the module were used to evaluate the crossing.

Fish Information

The fish information section in the module allows users to select a target fish species to be used in the Fish Passage Rating. FishXing allows the user to select from a catalog of literature swim speeds (contained in the model by species), input user-defined swim speeds, or enter hydraulic criteria. Users can also select what swim speed criteria is used in the evaluation (prolonged, burst, or both).

For this assessment the literature swim speed for cutthroat trout (*Oncorhynchus clarkii*) provided by FishXing was used as a surrogate for the target species Bonneville cutthroat trout (BCT). Literature swim speeds provided in FishXing for cutthroat trout were sourced from the Army Corps of Engineers Fisheries Handbook of Engineering Requirements and Biological Criteria (Bell 1991).

Swim speed data listed in the Bell reference is commonly cited in recent fish passage and hydraulic studies. More recent studies included Aedo (2008) where flume tests were conducted using sub-adult (39-70 mm length fish) hatchery Bonneville cutthroat trout. Swim speeds presented in the thesis were much lower than adult swim speeds presented in Bell and were not used in this analysis. The Region 1 Fish Passage Evaluation Criteria (Appendix B) also cites a different swim speed source for cutthroat trout that could not be located. The source lists adult (150 mm) rainbow and cutthroat trout burst and prolonged swim speeds that are lower than the Bell reference. These swim speeds are about half the stated speeds used in the analysis and it is not clear if the reference was based on a particular size class or if the swim speeds were even species specific.

For this analysis the Bell literature swim speeds for cutthroat trout were utilized and are shown in Figure 6. Both prolonged and burst speeds for the target species were used to analyze fish passage abilities. Prolonged swim speed used in the analysis was 4.0 ft/s (speed range: 2 -5.97 ft/s) at a time to exhaustion of 30 minutes. Burst speed used in the analysis was 10.0 ft/s (speed range: 6 – 13.5 ft/s) at a time to exhaustion of 10 seconds. Max Leap Speed was analyzed at 13.5 ft/s (maximum range of swimming ability for cutthroat trout) and was used to account for fish speeds when leaping into a perched culvert. Fish Length was set for a larger adult size at 40 cm (15.74 in), with a body depth of 0.28 ft. Fish Length was not a factor in adjusting literature swim speeds in the analysis as the Bell reference was for adult cutthroat trout and was based on the center of the range of the species abilities. Minimum Depth in the culvert for fish passage was set 0.4 feet for the analysis. This depth is greater than the body depth of the target fish size (0.28 ft) and encompasses a greater range in fish sizes to be included in the passage analysis for low flow conditions.

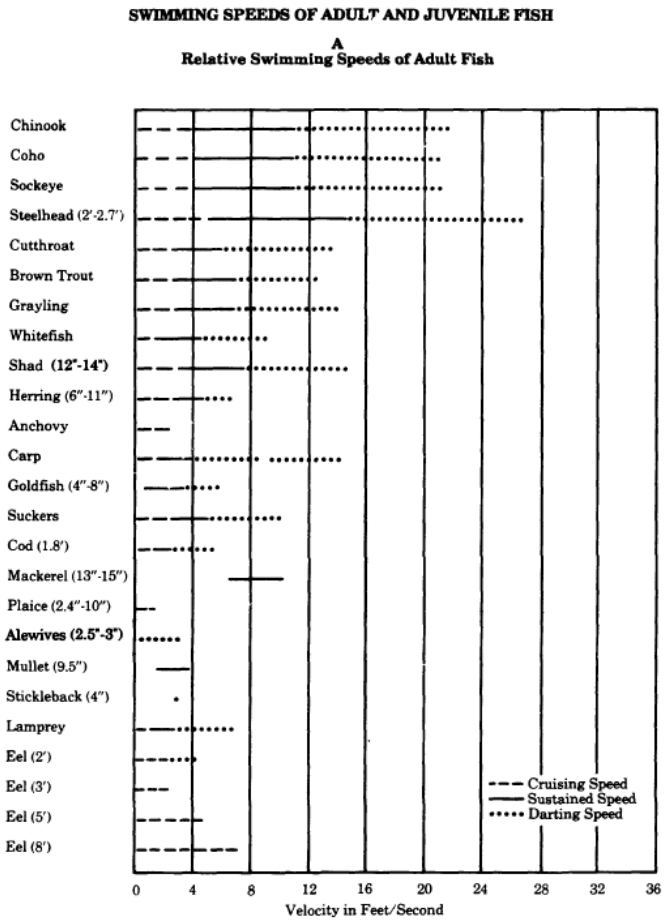


Figure 6. Adult sized fish swimming speeds (from Bell 1991).

Velocity Reduction Factors

Velocity Reduction Factors allow the user to account for areas of reduced velocity within the inlet, barrel, and outlet of a crossing. It is known that fish seek areas of lower velocities when migrating through an obstacle and these factors can be adjusted to account for the swimming abilities of smaller fish. No Velocity Reduction Factors were applied to sites in this analysis.

Tailwater

FishXing allows the user to define the tailwater elevation using three methods including the Constant Tailwater Method, User Defined Rating Curve Method, and Channel Cross Section Method. The water surface blow the culvert outlet is referred to the tailwater and the tailwater elevation can have a significant influence on passage conditions. The tailwater changes with varying flows and can influence culvert backwatering or perch of the culvert. For this analysis a majority of the tailwater controls were defined using in the Channel Cross Section Method, where the channel cross section data was inputted into the module. In some cases the Constant Tailwater Method was used by inputting the pool surface elevation and outlet pool bottom elevation.

Fish Passage Flows

The range of Fish Passage Flows used in the FishXing hydraulic analysis were developed using StreamStats (USGS 2012). StreamStats allows the user to delineate watersheds based on stream location or collection point. The application determines basin characteristics and uses a multiple-regression analysis to relate specific streamflow statistics. The Hydrologic Predictions provided by StreamStats for ungagged sites may not be reliable if sites do not meet a drainage area min and max values (minimum of 6.6 square miles), stream is regulated, or stream has reaches with significant gains or losses (both natural and human influenced). StreamStats predictions are more reliable for estimating the high monthly stream flow statistics than low streamflow statistics (Hortness and Berenbrock, 2001).

Hydrologic Predictions obtained from StreamStats were used to predict a range of Fish Passage Flows for the FishXing analysis. In this analysis the 90% prediction interval for PK 1.5 event was used to set the upper bounds of Fish Passage Flows at a site. The 90% prediction interval for PK 1.5 was used because the range encompassed all Peak-Flow Statistic Flows stated for the PK 1.5 through the PK 25 events therefore allowing a wider range of Fish Passage Flows to be analyzed at a site. Overall the lower range of Fish Passage Flows used in the analysis sometimes triggered Depth Barrier calls due to the Minimum Depth used (0.4 ft). Because a conservative Minimum Depth was used, no emphasis was placed on depicting Fish Passage Ratings for low flow periods or analysis of Depth Barrier calls.

Hydrologic Predictions have also been included as a reference point for the range of Fish Passage Flows used in this analysis. Peak-Flow Statistic Flows for the PK 1.5 through the PK 25 events were obtained from StreamStats and are addressed in the results section. These Hydrologic Predictions have a high prediction error (between 63 -74 %). Rust Line discharge has also been included as a Hydrologic Prediction that provides a unique site specific reference to a discharge stage that is common and above base flow conditions. The Rust Line Prediction allows for correlation and comparison of the PK 1.5 prediction provided by StreamStats. Overall, the Rust Line, PK 1.5, and PK 2 events represent a range of flows that can be expected at a site annually and coincide with BCT spawning migrations.

Rust Line discharge was calculated using the Manning's equation for open pipe flow. These discharge rates were calculated using a roughness coefficient (supplied by FishXing), culvert slope, pipe diameter, and hydraulic radius. An ellipse area and circumference formulas were used to generate the flow area and hydraulic radius for squashed pipes. This modified approach for determining the hydraulic radius and area for squashed pipes was also compared to a circular open pipe where the pipe dimensions were added and divided by two. The range of discharge expected at the Rust Line for squashed pipes are considered an approximate range and should correlate with an approximate range of the PK 1.5 event. This Hydrologic Prediction is further discussed in the Assumptions and the Results sections.

Assumptions

The range of Fish Passage Flows was assessed using StreamStats. These systems are not gaged and Fish Passage Flows used in this analysis should be considered as an approximate range of flows. StreamStats Hydrologic Predictions for Georgetown Creek were not considered valid and are likely over-estimated. Georgetown Creek does not fit the StreamStats model because it is a large drainage area with unique hydrology (large springs present and losing reaches in the headwaters) and has highly manipulated flows from diversions that influence the annual hydrograph. The two upper sites on Stauffer Creek (Stauf_7.71 and Stauf_8.66) did not meet the minimum drainage area (6.6 square miles) required by StreamStats. Hydrologic Predictions for upper Stauffer Creek, at these two sites, may not be as accurate as other sites included in this analysis.

Using the Rust Line as a Hydrologic Prediction was based on a discharge stage and was not related to quantitative flow measurements at this discharge for each site. Depth measurements in the culvert were taken during the site surveys to determine the stage at the rust line. These measurements were not correlated to discharge measurements which would have increased the accuracy of the prediction. Overall the Rust Line predictions used in this analysis correlated to the PK1.5 event. At sites where the prediction did not match the PK1.5 event, culvert slope was usually a factor. Culvert slope is a weighted variable when using the Manning's Open Pipe Flow equation. Pipes with a steep slope (>3%) can transmit higher velocities resulting in a higher prediction of discharge rates associated with the Rust Line stage.

Predicting discharge for the Rust Line using the Manning's equation for open pipe flow is not the most quantitative method. As stated before using actual discharge measurements at a site and creating a stage discharge relationship would have resulted in more accurate predictions. However this approach is more time consuming at would have elongated the surveys effort. The Manning's Equation for pipe flow is better served as a tool for determining open pipe capacity that predicting discharge in a small length of culvert at a road/stream crossing.

Accurately predicting Rust Line discharge at sites with squashed culverts is complicated because these types of pipes are not uniform is width and rise. Detailed measurements of the pipe would be needed to accurately define pipe area and hydraulic radius at the Rust Line. Using an ellipse or a modified round pipe area configuration provided a range of discharge rates for the Rust Line that could further be improved upon.

Swim speeds for BCT were modeled using cutthroat trout as a surrogate. The Bell reference used the center of the range for this species to develop burst and prolonged for adult sized fish. With that said, fish length was not a weighted variable in this analysis and it is known that larger fish can have higher burst and prolonged swim speeds.

The minimum culvert depth of 0.4 ft triggered Depth Barrier calls at several crossing sites. It is understood that this was a conservative Minimum Depth and therefore not much weight should be placed on these calls.

The hydraulic analysis does not include passage requirements and abilities for all species that may persist in the drainages. Swim speed literature is limited for non-game species. In general species diversity is somewhat low in these drainages and more fish sampling should be done to determine what species diversity and gradients may exist. It is known that sculpin are found in Eightmile Creek on the Forest and are also found in the lower reaches of Georgetown Creek but not on the Forest. Lower Stauffer Creek supports Utah suckers and speckled dace.

Road/Stream Crossing Resiliency Rating

Road/stream crossings were further assessed based on the resiliency of the crossing infrastructure. Bankfull channel and structure widths were used to determine if the road/stream crossing constricted channel flows and flood capacity. Structures were either rated as Adequate or Undersized. Adequate sites had structures widths that either met or exceeded channel bankfull width measurements. Undersized sites had structures widths that were less than channel bankfull width measurements.

Bankfull channel widths can provide a quick metric to measure channel constriction at road/stream crossings. In order to reduce bias these measurements need to be collected in the immediate vicinity of the crossing but outside the influence of the crossing. Typically channel dimensions immediately upstream and downstream of the crossings can be influenced by the crossing. These areas may be subject to alteration, channel scour, and erosion.

Bankfull channel constriction can provide an initial look at the resiliency of a crossing. Typically a bankfull event equates to a two year flow event in magnitude, however every stream channel and drainage are different. Stream channel discharge can vary by drainage in timing and magnitude and channel capacity can be influenced by the Rosgen channel type. Events above bankfull are not easily depicted by channel measurements even if additional site indicators are present (low and high terraces).

Structure resiliency has been defined by multiple agencies in the form of policy statements regarding installation of new road/stream structures. In the Idaho Forestry Best Management Practices Field Guide (Barkley et al, 2015) Rule 040.02.e states *"design culverts for stream crossings to carry the fifty year peak flow"*. In addition the USDA Forest Service Transportation Structures Handbook (FSH 7709.56b Chapters 50 and 70) provides road/stream structure sizing guidance that states *"All structures should, at a minimum, be designed to withstand a 100-year flood with additional vertical clearance for the passage of woody debris and ice"*.

Overall road/stream crossing resiliency is difficult to define at a site when looking at events larger than the bankfull event. In many cases it is understood that at a minimum the road/stream crossing should not constrict the stream channel and therefore should meet or exceed the bankfull width and provide capacity for the two year event. It is also understood that floodplains associated with stream channels are important features that help dissipate energy from larger events and provide flood capacity when channel capacity has been exceeded. With that said there is not a universal metric or measurement to analyze or guide the proper sizing of road/stream structures to handle larger events, as each site is unique. The Idaho Forestry BMP Field Guide provides a Culvert Sizing Table to guide culvert sizing based on the 50 year peak flow with a headwater-to-diameter ratio of one. This

sizing guide does not include recommendations for larger watersheds where culvert sizing exceeds a diameter of 10 ft (120 in).

RESULTS

In 2014, the USFS conducted the Nounan Reach Fish Passage Assessment and evaluated a total of 13 road/stream crossings located on Eightmile, Stauffer, and Georgetown creeks. These tributaries have been identified as important spawning tributaries for fluvial Bonneville cutthroat trout (BCT) in the Nounan Reach of the Bear River. The objective of the assessment was to identify fish passage barriers in these Nounan Reach tributaries that may limit system connectivity for the fisheries resource. This information provides a better understanding of system connectivity to be used in conjunction with other fisheries monitoring efforts to develop future conservation actions to benefit the fisheries resource in the Nounan Reach.

The Nounan Reach Fish Passage Assessment utilized two complimentary methods including the NIAP (Clarkin et al, 2003) and FishXing V3 software (USDA Forest Service) to assess fish passage at road/stream crossings. The NIAP outlined the field survey data collection needs and provided the needed site data to assess fish passage based on the physical and hydrological characteristics of the stream crossing. A regional Fish Passage Criteria Screen developed by the USFS (Figures 3 and 4) were used to rate fish passage at the road/stream crossing, based on the crossings physical attributes collected using the NIAP. Lastly, FishXing software was used to model fish passage based on a combination of physical and hydrologic site variables. FishXing allows the user to model target fish species capabilities against culvert hydraulics across a range of expected stream discharges.

Three metrics were used in the Fish Passage Assessment to rate road/stream crossings in the Nounan Reach. These metrics cover fish passage and infrastructure resiliency. A description of the metric and an analysis of each metric are located below.

Regional Fish Passage Criteria Rating and Results

Road/stream crossings were rated as RED (fish barrier), GREEN (passable) or CHANNEL SIMULATION, and GRAY (undetermined) using the Region 1 Fish Passage Criteria Screen (Figures 3 and 4, Appendix B). Each site was rated for both juvenile and adult salmonid fish passage. Ratings were based on physical attributes of the road/stream crossing including: outlet drop, residual inlet depth, culvert slope, and the culvert width to bankfull ratio. These ratings provide a conservative assessment of fish passage at a site solely based on structures physical attributes. This screening criteria was developed as an efficient method of evaluating fish passage for a large number of sites. The fish passage evaluation criteria screening process is used to quickly classify existing crossings as either meeting, needing refined hydraulic analysis, or failing to meet fish passage criteria for a chosen fish species, lifestage, and flow in a standardized and consistent manner. By utilizing passage evaluation criteria, the number of crossings that require an in-depth passage evaluation can be reduced.

Of the 13 crossing assessments 85% of these crossing sites were rated as RED and do not meet the criteria to pass juvenile and adult BCT and also may inhibit movement of other non-game species. Two sites (15% of sites) were rated as GRAY and need more evaluation to determine fish passage. None of the sites were rated as GREEN where fish passage is likely. All crossings analyzed had the same passage calls for both juvenile and adult salmonids.

Of the four crossings analyzed on Eightmile Creek the three lower crossings were rated RED and the uppermost crossing (Eightmile_8.47) was rated as GRAY (Figure 7). All three crossings assessed on Stauffer Creek were rated as RED (Figure 9). Of the six crossings assessed on Georgetown Creek five crossings were rated as RED and the second lowest crossing (Georgetown_0.07) was rated as GRAY (Figure 11).

Crossings rated as RED (fish barrier) typically had multiple site characteristics including bankfull ratio, culvert slope, and outlet drop that triggered these calls. More information for each site can be found in Appendix A, Assessment Data by Site.

A total of five road/stream crossings on Eightmile and Georgetown creeks were previously surveyed in 2005 and 2007 during the Forest Fish Passage Assessments (Lyman 2005, 2007). These assessments were brought forward and further analyzed in this analysis. Collectively the Nounan Reach Fish Passage Assessment had similar findings to these Forest-wide surveys. In 2005 and 2007 sites rated RED for at least one lifestage were high (75 – 81%). Sites rated as GRAY for at least one lifestage were also low, but common (15 -19%). And sites rated as GREEN for at least one life stage were very low (4 – 6%).

FishXing Hydraulic Analysis and Results

Road/stream crossings were further analyzed using FishXing to model fish passage for cutthroat trout at various discharge rates and Hydrologic Predictions. The range of discharge rates used for hydraulic analysis for each site was obtained using StreamStats (USGS 2012). Fish passage flows were developed for each site using the range of discharge rates encompassed in the 90% prediction interval for the PK 1.5 year event. This range also encompassed the PK 1.5 to PK 25 Peak-Flow Statistic Flows provided by StreamStats. Fish Passage Ratings were compared to Hydrologic Predictions including the PK1.5 to PK25 discharge events and the Rust Line event. The Rust Line event provides a site specific prediction that can be used to correlate or compare PK1.5 predictions from StreamStats. The Rust Line, PK 1.5, and PK 2 discharge events represent a range of flows when fish passage is critical and biologically important.

When comparing Fish Passage Ratings to Hydrologic Predictions at a site it is important to validate the hydrologic predictions. The Rust Line Predictions allows for a comparison and validation of the PK 1.5 event obtained from StreamStats. It is assumed that the Rust Line Prediction and the PK 1.5 Prediction should represent similar hydrologic conditions and ranges. However, it is recognized that the Rust Line event does not represent the entire range or stage of a bankfull or PK 1.5 event but likely represents the lower stage of bankfull or PK 1.5 event. It is also noted that both the Rust Line and StreamStats Hydrologic Predictions should be used as a range and not an absolute target.

The FishXing Hydraulic Analysis results have been summarized below by stream. An emphasis has been placed on Passage Ratings during Rust Line and PK1.5 events. Site specific data used in the analysis is located by crossing in Appendix A.

Eightmile Creek

Eightmile Creek flows in a northeast direction with the headwaters located on the National Forest Land. On private lands the valley bottom is used mostly for cultivated agriculture and pasture with limited residential. The road network in this drainage is fairly limited in scale and five major road/stream crossings have been identified and assessed (Figure 7). The lowest crossing in the drainage is a fairly new precast concrete bridge that is not a fish passage concern. An additional

three private crossings were identified using aerial photography (two bridges and a ford). These crossings were farm or residential and were not assessed for fish passage in this analysis.

Four road/stream crossings on Eightmile Creek were analyzed using FishXing. Hydrologic Predictions for each site including Peak-Flow Statistic Flows (PK 1.5 through the PK 25) and Rust Line events are included in Table 1. Fish Passage Ratings were compared to Hydrologic Predictions in Figure 8. This graphic representation allows a direct comparison of varying hydrology and fish passage at a site.

In Eightmile Creek three of the four sites had Rust Line predictions that correlated with the PK 1.5 event (Figure 8). At these sites the predictions were within a range of 4-28 cfs. At the lowest site (Eightmile_2.42) the Rust Line and PK1.5 Predictions varied by 74 cfs, which could mean that the StreamStats PK 1.5 prediction for this lower crossing was overestimated.

Fish Passage Ratings were positive (passable) for Rust Line and PK 1.5 discharge events at 50% of the sites (Eightmile_5.81, Eightmile_8.47) on Eightmile Creek. However, 75% of the sites (Eightmile_2.42, Eightmile_7.69, Eightmile_8.47) on Eightmile Creek, had negative (not passable) Fish Passage Ratings for discharge events above the PK 1.5 event. Only one site (Eightmile_5.81) had positive Fish Passage Ratings above the PK 1.5 event (Figure 8).

The Rust Line, PK1.5, and PK 2 discharge events provide a critical biological range when fish passage is necessary. In Eightmile Creek two road/stream crossing (Eightmile_2.42, Eightmile_7.69) were determined to be impassable during Rust Line events and during PK 1.5 events. The most downstream crossing, Eightmile_2.42, likely limits BCT migration into this drainage during these critical spawning periods. Fish Passage Ratings and Hydrologic Predictions for Eightmile Creeks are displayed in Figure 8 and Table 1.

For low flow Fish passage Ratings, the FishXing hydraulic analysis assigned a Depth Barrier to one site (Eightmile_7.69). This call was a result of the conservative Minimum Depth used in the analysis and not much weight is placed on this call.

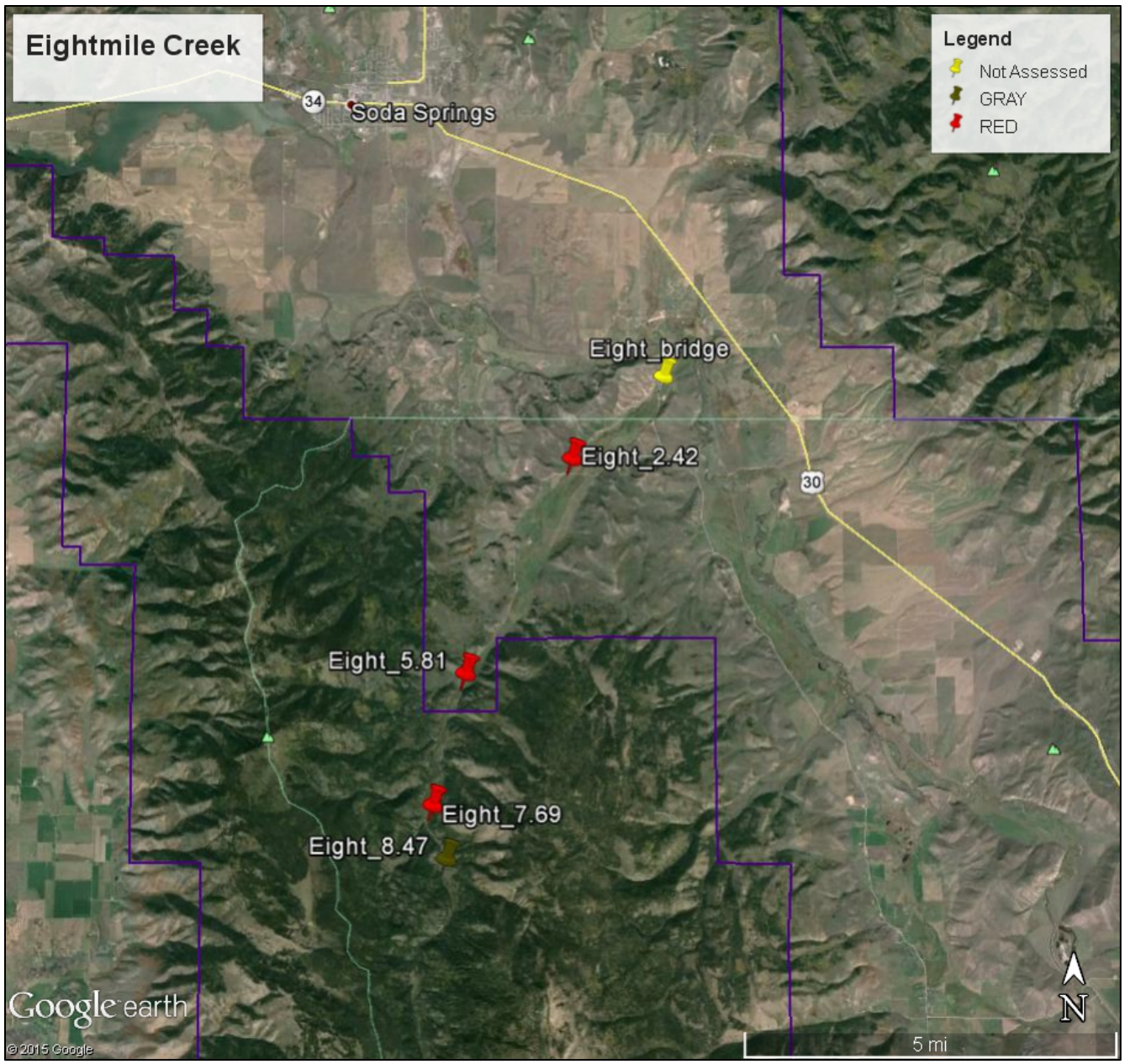


Figure 7. Locations of road stream crossings assessed on Eightmile Creek. The lower three crossings were rated as RED (Barrier) and the uppermost crossing was rated as GRAY (Needs Further Hydraulic Analysis) using the NIAP. The lower Eightmile_bridge location was not assessed for passage because an adequately sized bridge is present.

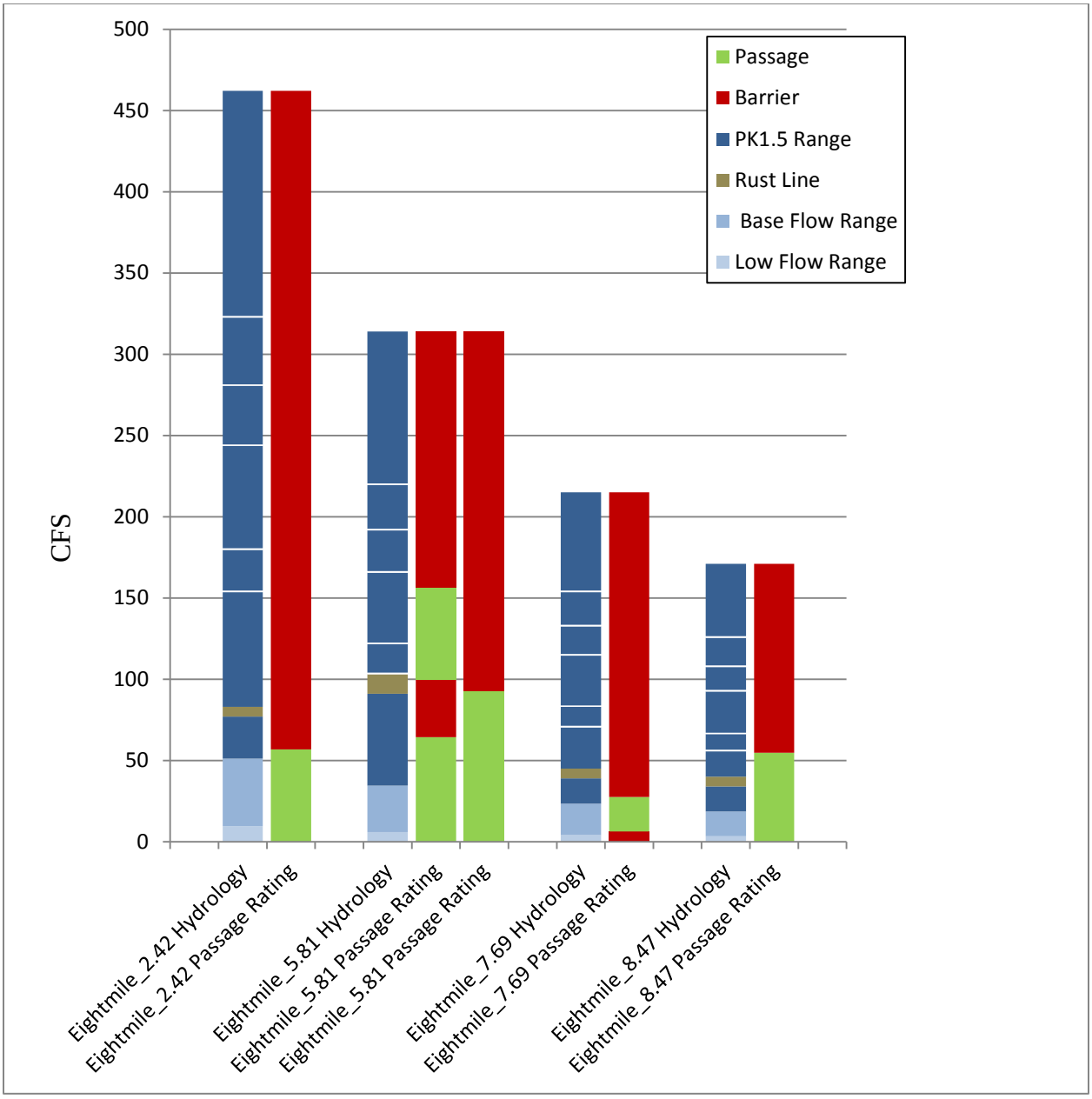


Figure 8. Graph contrasting Hydrologic Predictions and Fish Passage Ratings, by site, for the four road/stream crossings assessed on Eightmile Creek. Site Eightmile_2.42 is the most downstream crossing and site Eightmile_8.47 is the most upstream crossing.

	Hydrologic Prediction (cfs)									Fish Passage Rating (cfs)				
Site	Low Flow	Base Flow	Q1.5 Range	Rust Line	PK1.5	PK2	PK5	PK10	PK25	Depth Barrier	Passage	Velocity Barrier	Passage	Velocity Barrier
Eightmile_2.42	0 - 9.58	9.58 - 51.1	51.1 - 462	80	154	180	244	281	323	None	0 - 56.69	56.69 and up		
Eightmile_5.81 Culvert 1	0 - 5.98	5.98 - 34.5	34.5 - 314	94	104	122	166	192	220	None	0 - 64.33	64.33 - 100	100 - 156.28	156.28 and up
Eightmile_5.81 Culvert 2	0 - 5.98	5.98 - 34.5	34.5 - 314	100	104	122	166	192	220	None	0 - 92.92	92.92 and up		
Eightmile_7.69	0 - 3.99	3.99 - 23.3	23.3 - 215	42	70.8	83.4	115	133	154	0 - 6.25	6.25 - 27.43	27.43 and up		
Eightmile_8.47	0 - 3.26	3.26 - 18.5	18.5 - 171	37	56.1	66.6	92.9	108	126	None	0 - 54.77	54.78 and up		

Table 1. Hydrologic Predictions and Fish Passage Ratings data for the four road/stream crossings, located on Eightmile Creek, presented in Figure 8. Hydrologic Predictions, for each site, were obtained using StreamStats (USGS 2012). FishXing (USDA Forest Service) was used to analyze Fish Passage Ratings at each site.

Stauffer Creek

Stauffer Creek flows in a easterly direction from its the headwaters located on the National Forest Land, then runs north through Nounan Valley before heading East through the Nounan Gap. On private lands the valley bottom is used mostly for cultivated agriculture and pasture with limited

residential. The road network in this drainage is fairly limited in scale and three major road/stream crossings have been identified and assessed (Figure 9). Two major crossings, one on Nounan Road and one near the confluence with the Bear River were not assessed in this analysis. The sites have adequate backwatering and were determined not to be fish passage concerns. Additional private crossings were identified using aerial photography. These crossings were farm or residential and were not assessed for fish passage in this analysis.

Three road/stream crossings on Stauffer Creek were analyzed using FishXing. Hydrologic Predictions for each site including the Peak-Flow Statistic Flows (PK 1.5 through the PK 25) and Rust Line events and are included in Table 2. Fish Passage Ratings were compared to Hydrologic Predictions in Figure 10. This graphic representation of the FishXing analysis allows a direct comparison of varying hydrology and fish passage at a site.

In Stauffer Creek two of the three sites had Rust Line predictions that correlated with the PK 1.5 event (Figure 10). At these sites the predictions were within a range of 0.4-8 cfs. The Rust Line prediction was fairly close even with the two uppermost sites not meeting the minimum drainage area requirement for the StreamStats model. At the lowest site the Rust Line and PK1.5 predictions varied by 30 cfs.

Fish Passage Ratings were positive (passable) for Rust Line discharge events at 100% of the sites assessed on Stauffer Creek. However, only 66% of these sites had positive Fish Passage Ratings for the PK 1.5 event. In addition, 100% of the sites on Stauffer Creek, had negative (not passable) Fish Passage Ratings for discharge events above the PK 1.5 event (Figure 10).

The Rust Line, PK1.5, and PK 2 discharge events provide a critical biological range when fish passage is necessary. In Stauffer Creek all road/stream crossings were determined to be passable during Rust Line events and only one site (Stauffer_7.71) was unpassable at the PK 1.5 event. This middle crossing, likely limits BCT migration into the headwaters of this drainage during critical spawning periods. Fish Passage Ratings and Hydrologic Predictions for Stauffer Creek are displayed in Figure 10 and Table 2.

For low flow Fish passage Ratings, the FishXing hydraulic analysis assigned a Depth Barrier to all three sites on Stauffer Creek. These calls were a result of the conservative Minimum Depth used in the analysis and not much weight is placed on these calls.

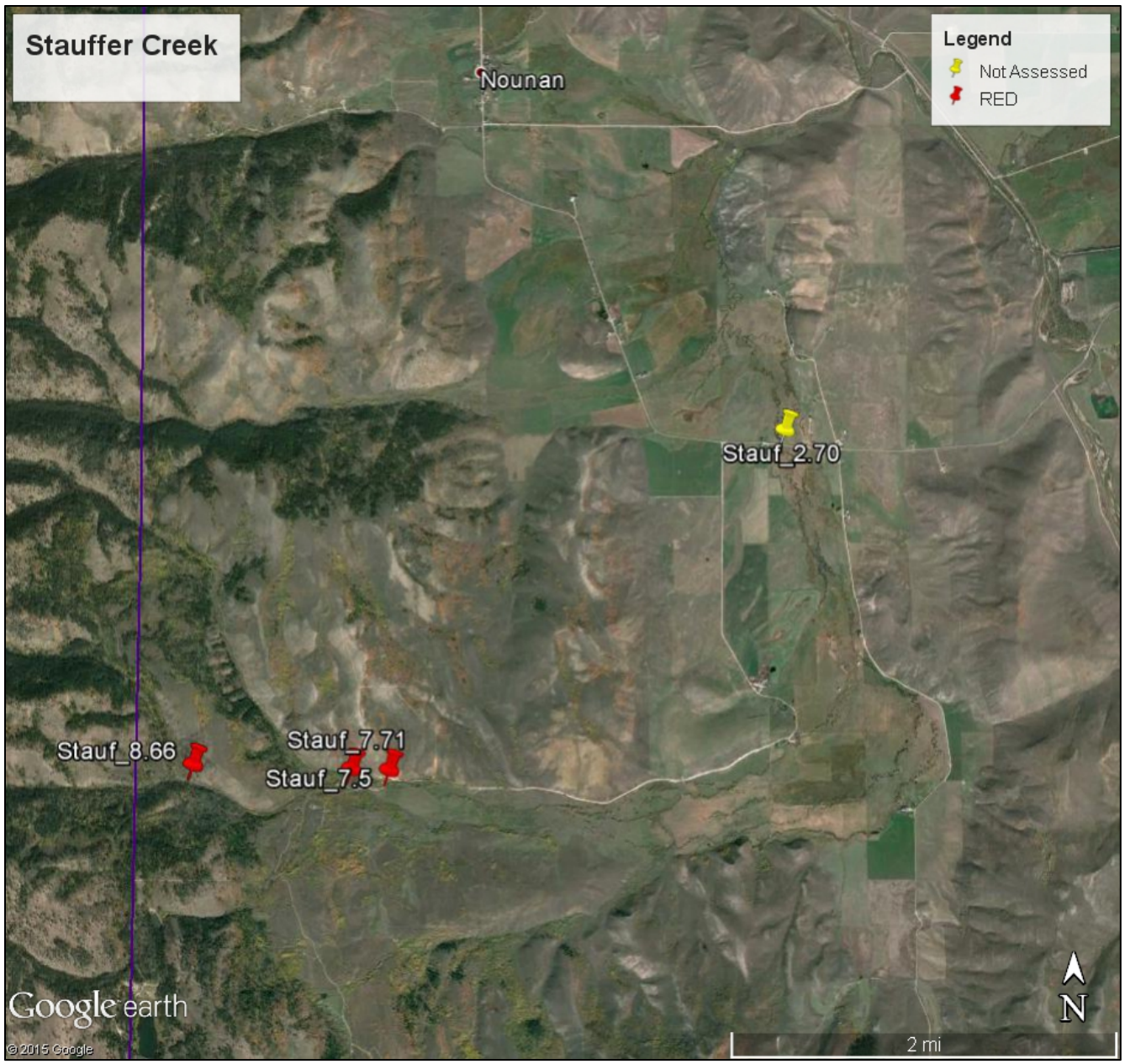


Figure 9. Locations of the three road stream crossings assessed on Stauffer Creek. All three crossings were rated as RED (Barrier) using the NIAP. The lower Stauffer_2.70 location was not assessed for passage because the site contains two large pipes in low gradient stream section that is adequately backwatered and stream velocities are low.

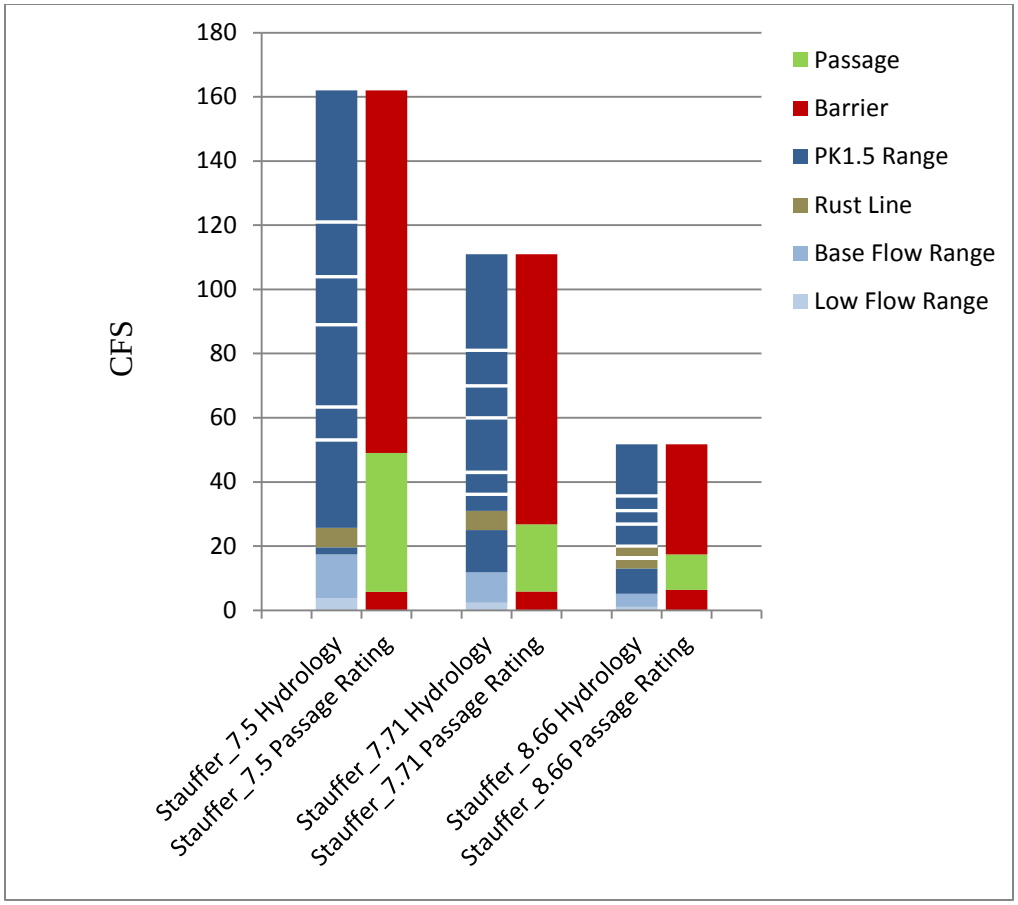


Figure 10. Graph contrasting Hydrologic Predictions and Fish Passage Ratings, by site, for the three road/stream crossings assessed on Stauffer Creek. Site Stauffer_7.5 is the most downstream crossing and site Stauffer_8.66 is the most upstream crossing located on the North Fork of Stauffer Creek.

	Hydrologic Prediction (cfs)									Fish Passage Rating (cfs)		
Site	Low Flow	Base Flow	Q1.5 Range	Rust Line	PK1.5	PK2	PK5	PK10	PK25	Depth Barrier	Passage	Velocity Barrier
Stauffer_7.5	0 - 3.81	3.81 - 17.4	17.4 - 162	22.66	53.1	63.4	89	104	121	0 - 5.79	5.79 - 49.05	49.05 and up
Stauffer_7.71	0 - 2.4	2.4 - 11.8	11.8 - 111	28	36.2	43	60	70	81	0 - 5.83	5.83 - 26.84	26.84 and up
Stauffer_8.66	0 - 1.08	1.08 - 5.21	5.21 - 51.7	16	16.4	19.5	26.9	31.1	35.7	0 - 6.39	6.39 - 17.43	17.43 and up

Table 2. Hydrologic Predictions and Fish Passage Ratings data for the three road/stream crossings, located on Stauffer Creek, presented in Figure 10. Hydrologic Predictions, for each site, were obtained using StreamStats (USGS 2012). FishXing (USDA Forest Service) was used to analyze Fish Passage Ratings at each site.

Georgetown Creek

Georgetown Creek flows in a southwest direction with the headwaters located on the National Forest Land. On private lands the valley bottom is used mostly for cultivated agriculture and pasture with residential areas paralleling the stream course. The road network in this drainage is more extensive in scale than Eightmile and Stauffer creeks. Six major road/stream crossings have been identified and assessed (Figure 11). Two major crossings including under Highway 30 and under the Left Fork Road were not assessed. The Highway 30 crossing is cement box culvert that is scheduled for replacement in the next five years. The Left Fork crossing needs further assessment and is likely a fish barrier. Additional crossings were identified between the Bear River and Forest Service Lands using aerial photography. These crossings were farm or residential and were not assessed for fish passage in this analysis.

Six road/stream crossings were analyzed on Georgetown Creek using FishXing. Hydrologic Predictions for each site including the Peak-Flow Statistic Flows (PK 1.5 through the PK 25) and

Rust Line events and are included in Table 3. Fish Passage Ratings were compared to Hydrologic Predictions in Figure 12. This graphic representation allows a direct comparison of varying hydrology at a site and fish passage.

Unfortunately, the hydrologic modeling was not suitable for use on Georgetown Creek. The hydrology of Georgetown Creek doesn't fit the StreamStats model due to a combination of factors including the large drainage area, spring influences, dewatered or losing reaches in the headwaters, and highly altered hydrology in the lower reaches (irrigation and hydropower uses). Fish Passage Ratings at road/stream crossings on Georgetown Creek could not be compared to Hydrologic Predictions and Rust Line predictions could not be used to validate the PK1.5 prediction.

Of the six sites assessed on Georgetown Creek it is evident that fish passage is highly limited at 50% of the sites. At three sites fish passage is likely not expected at Rust Line events (Georgetown_0.04, Georgetown_4.06, and Georgetown_4.85). At a fourth site (Georgetown_2.19), fish passage is likely limited above the PK1.5 event (used Stauffer Creek PK1.5 event range as a surrogate). Two sites (Georgetown_0.07, Georgetown_1.35) have positive (passable) Fish Passage Ratings and likely provide passage during events larger than the PK1.5.

The Rust Line, PK1.5, and PK 2 discharge events provide a critical biological range when fish passage is necessary. In Georgetown Creek three of the six road/stream crossings (Georgetown_0.04, Georgetown_4.06, and Georgetown_4.85) were determined to be impassable during these periods. The most downstream crossing, Georgetown_0.04, likely limits all BCT migration into this drainage during these critical spawning periods. Fish Passage Ratings and Hydrologic Predictions for Georgetown Creek are displayed in Figure 12 and Table 3.

For low flow Fish passage Ratings, the FishXing hydraulic analysis assigned a Depth Barrier to two sites (Georgetown_1.35, Georgetown_2.19). These calls were a result of the conservative Minimum Depth used in the analysis and not much weight is placed on these calls.

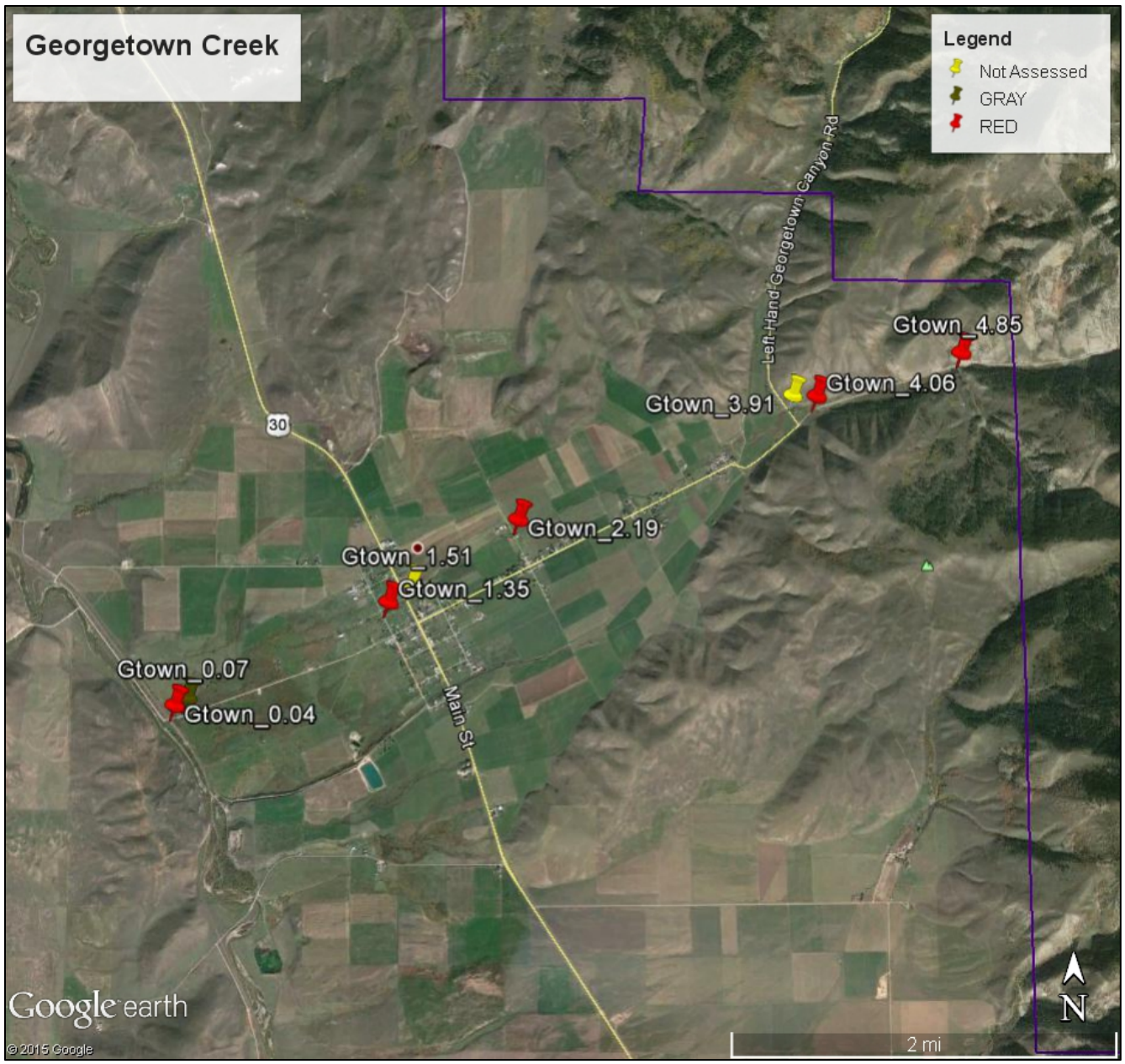


Figure 11. Locations of the six road/stream crossings assessed on Georgetown Creek. Five crossings were rated as RED (Barrier) and the second crossing (Georgetown-0.07) was rated as GRAY (Needs Further Hydraulic Analysis) using the NIAP. The Georgetown_1.51 location was not assessed for passage because the site contains a box culvert on the Hwy 30 that is scheduled for replacement in the next five years. The Georgetown_3.91 location was not assessed for passage because the site contains a large amount of fill volume. This site is under the Left Fork Road and needs to be assessed for fish passage at a later date.

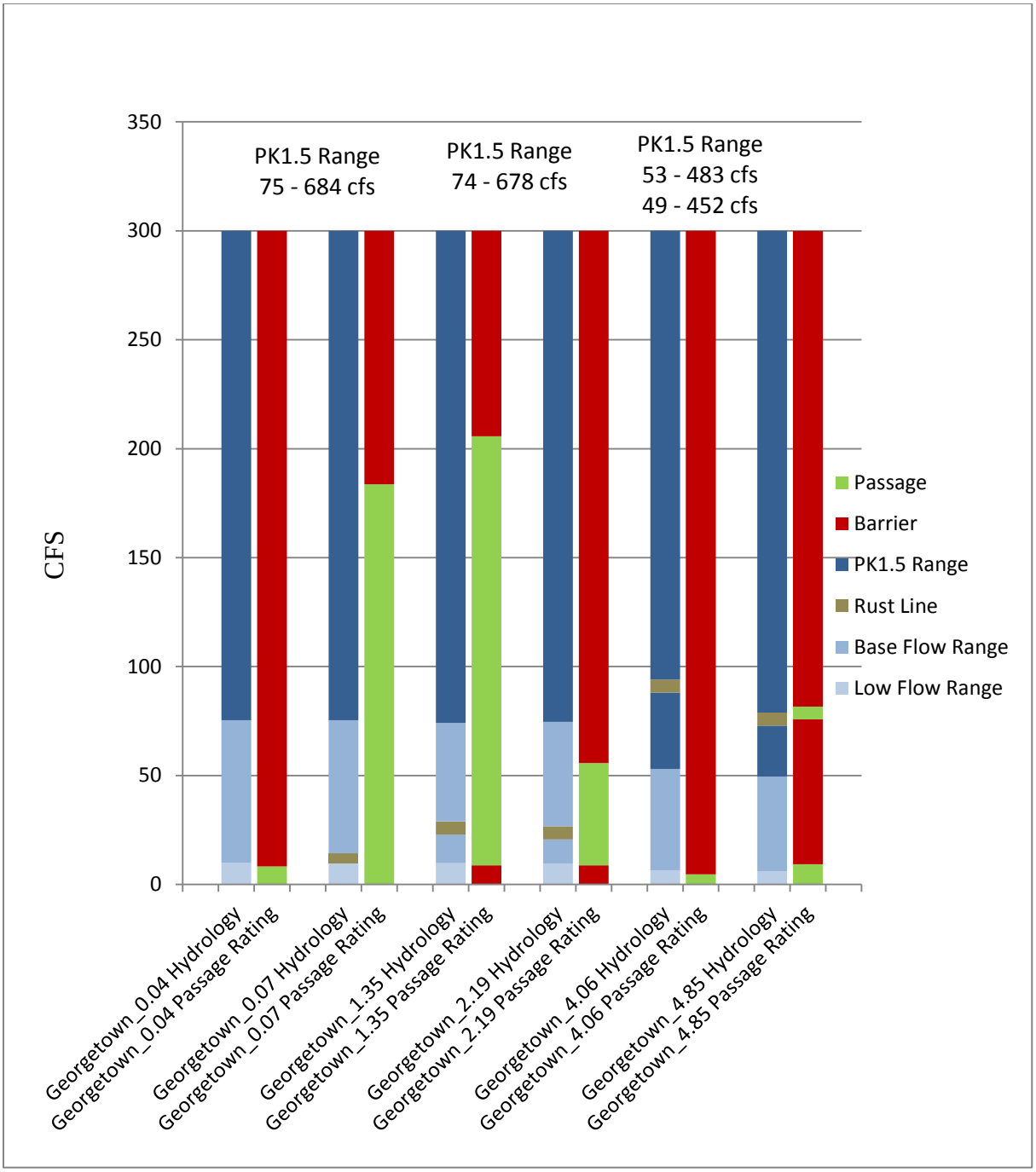


Figure 12. Graph contrasting Hydrologic Predictions and Fish Passage Ratings, by site, for the six road/stream crossings assessed on Georgetown Creek. Site Georgetown_0.04 is the most downstream crossing and site Georgetown_4.85 is the most upstream crossing. Streamflow statistics

	Hydrologic Prediction (cfs)									Fish Passage Rating (cfs)				
Site	Low Flow	Base Flow	Q1.5 Range	Rust Line	PK1.5	PK2	PK5	PK10	PK25	Depth Barrier	Passage	Velocity Barrier	Passage	Velocity Barrier
Georgetown_0.04	0 - 9.87	9.87 - 75.4	75.4 - 684	NA	227	261	348	398	453	None	0 - 8.30	8.31 and up		
Georgetown_0.07	0 - 9.87	9.87 - 75.4	75.4 - 684	11.3	227	261	348	398	453	None	0 - 183.64	183.64 and up		
Georgetown_1.35	0 - 9.77	9.77 - 74.1	74.1 - 673	26	223	257	340	388	441	0 - 8.83	8.83 - 205.69	205.69 and up		
Georgetown_2.19	0 - 9.5	9.5 - 74.6	74.6 - 678	23.7	225	259	345	395	451	0 - 8.77	8.77 - 55.75	55.75 and up		
Georgetown_4.06	0 - 6.47	6.47 - 53	53 - 483	91	160	185	250	289	332	None	0 - 4.61	4.62 and up		
Georgetown_4.85	0 - 6.1	4.85 - 49.5	49.5 - 452	75.84	150	173	233	269	308	None	0 - 9.30	9.30 - 76	76 - 81.88	81.88 and up

Table 3. Hydrologic Predictions and Fish Passage Ratings data for the six road/stream crossings, located on Georgetown Creek, presented in Figure 12. Hydrologic Predictions, for each site, were obtained using StreamStats (USGS 2012). FishXing (USDA Forest Service) was used to analyze Fish Passage Ratings at each site.

Road/Stream Crossing Resiliency Rating and Results

Road/stream crossings were further assessed based on the resiliency of the crossing infrastructure. Bankfull channel and structure widths were used to determine if the road/stream crossing constricted channel flows and flood capacity. Structures were either rated as Adequate or Undersized. Adequate sites had structures widths that either met or exceeded channel bankfull width measurements. Undersized sites had structures widths that were less than channel bankfull width measurements.

Of the 13 road/stream crossing sites 100% of these crossing were rated as Undersized. All of these crossings constrict channel flows and may not provide adequate flood flow capacity. These structures could jeopardize the safety and longevity of the road network in these drainages and may negatively impact aquatic ecosystems.

Proper design of road/stream crossings requires an interdisciplinary approach and defined site objectives. Objectives should consider site constraints, resource concerns, and hydrologic capacity. Typically an engineering or hydrologic modeling approach for structure design focuses on structure capacity with an objective of meeting a specific flood flow stage. The Idaho Forestry BMP Field Guide (Barkley et al, 2015) provides a structure sizing guide to facilitate design capacity at a PK50 event. The guide does not provide recommendations for larger watersheds with culvert sizing exceeding 120 inches.

Currently, 100% of the sites surveyed in 2014 do not provide hydrologic capacity for the PK50 event (Table 4). Seven of the sites could not be rated using the BMP culvert sizing guide, but structure widths at these sites were smaller than the 120 inch recommendation for smaller watersheds.

Site	Watershed Area (Acres)	Idaho Forestry BMP Culvert Design Capacity (cfs)	Idaho Forestry BMP Required Culvert Diameter (in)	Existing Culvert Diameter (in)
Eightmile_2.42	17,113	Not rated, culvert sizing would be >120 inches		73.2*
Eightmile_5.81	11,033	675	120	108
Eightmile_7.69	7295	370	96	72*
Eightmile_8.47	5,740	370	96	60
Stauffer_7.5	5,900	370	96	57.6*
Stauffer_7.71	3,859	260	84	72*
Stauffer_8.66	1,715	112	60	54*
Georgetown_0.04	22,387	Not rated, culvert sizing would be >120 inches		114*
Georgetown_0.07	22,387	Not rated, culvert sizing would be >120 inches		72
Georgetown_1.35	22,143	Not rated, culvert sizing would be >120 inches		62*
Georgetown_2.19	21,875	Not rated, culvert sizing would be >120 inches		66*
Georgetown_4.06	14,924	Not rated, culvert sizing would be >120 inches		48
Georgetown_4.85	14,009	Not rated, culvert sizing would be >120 inches		48

Table 4. Idaho Forestry Best Management Practices Culvert Sizing Guidelines compared to existing site culvert widths. More than half of the sites assessed have larger watershed areas and the BMP guide does not provide a sizing recommendation. Squashed pipes were denoted using an asterisk (*) and only the structure width was listed.

The BMP culvert sizing guide provides a hydrologic or capacity sizing reference based on watershed area. This approach does not incorporate stream simulation technology and should not be

used for designing fish passage structures. An aquatic organism passage design approach would consider site characteristics including bankfull widths to create a design that mimics the stream channel and floodplain features at the site. Typically the Caribou-Targhee National Forest has implemented a structure sizing ratio of 1.5 times bankfull using bridges or open-bottom arch structures that provide stream simulation.

DISCUSSION

All 13 of the road/stream crossing inventoried in the Nounan Reach Fish Passage Assessment limit fish passage to some degree. Many of the crossings assessed likely provide fish passage when stream discharge is below the PK1.5 event. At three sites, it is evident that fish passage is restricted during base flow conditions.

In addition, all of the 13 road/stream crossings inventoried in the Nounan Reach Fish Passage Assessment were rated as Undersized. All of these crossings constrict channel flows and may not provide adequate flood flow capacity. These structures could jeopardize the safety and longevity of the road network in these drainages and may negatively impact aquatic ecosystems.

Aquatic Organism Passage (AOP) restoration actions have been started within the last ten years in the Nounan Reach, with much work still to do. Since 2010, Caribou-Targhee National Forest has partnered with agencies to remove or address several fish barriers on Georgetown Creek. Two culverts have been removed on the Forest, a fishway has been installed at the Georgetown Irrigation structure and the Alleman Diversion Dam was removed. In addition, the Idaho Transportation Department will be replacing the Highway 30 crossing on Georgetown Creek in the next couple of years. On Skinner and Co-op creeks, three aquatic organism passage projects have been completed at road/stream crossings. To date, fish passage work has not been implemented on Eightmile or Stauffer creeks.

When looking at the results from this assessment it is evident that road/stream crossings on Eightmile, Stauffer, and Georgetown creeks currently fragment stream habitat. When looking at road/stream crossings, stream habitat is less fragmented on Eightmile and Stauffer creeks than it is on Georgetown Creek. Currently, it would be more economical to implement system-wide AOP restoration on Eightmile and Stauffer creeks than on Georgetown Creek. In addition these two tributaries currently support populations of BCT, while Georgetown Creek does not.

On Stauffer Creek the highest passage priority is likely not a road/stream crossing but is an agricultural diversion located above the Nounan Gap. It would be beneficial to implement restoration actions at this site in addition to rectifying road/stream passage barriers.

On Georgetown Creek it may be beneficial to designate reaches of importance for BCT population restoration, and then work towards implementing complimentary AOP restoration actions. An important reach for resident BCT population restoration is on the Forest lands above the Georgetown Irrigation Company Diversion. In addition the lower reaches of Georgetown Creek may be an important reach for fluvial BCT spawning and AOP restoration activities could be implemented in this lower reach.

Overall, AOP restoration work in the Nounan Reach should be strategic and encompass partnerships, as the cost of road/stream crossing replacement can be high. Depending on the scale of the system and the type of structure used (open-bottom arches for smaller systems and bridges for larger systems) can cost between $45,000 and $150,000 per site. Working with partners

including Bear Lake and Caribou Counties to develop strategic but complimentary projects has been beneficial on other AOP projects on Skinner and Co-op creeks.

Lastly, it is also important that an interdisciplinary approach be applied to the prioritization and design of AOP restoration projects. It is important to consider both the hydrologic and biologic aspects when developing projects. Fisheries biologists should play a key role in defining AOP priorities for BCT conservation while weighing other biological factors (stream system connectivity versus the potential of non-native fish invasions). While engineers and hydrologists can provide design criteria that adequately size structures to promote AOP while maximizing structure lifespan and resiliency.

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