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Assessment of Aquatic Organism Passage at Road/Stream Crossings for the Northern Region of the USDA Forest Service

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EXECUTIVE SUMMARY

The Northern Region of the USDA Forest Service completed a comprehensive survey and assessment of fish passage at road-stream crossings. The surveys were done over 3 years at a cost of $270 per site. Approximately 2900 culverts were surveyed on 50,000 miles of Forest Development Roads in Montana, northern Idaho and eastern North and South Dakota. Those surveys were assessed based on passage of adult and juvenile westslope and yellowstone cutthroat trout. Findings indicate that approximately 80% of the surveyed culverts impede passage of cutthroat at some life stage or during certain flows. Of those barriers, 576 culverts impede all fish passage and represent total barriers, thus isolating fish populations. These barriers represent a significant issue for fragmentation and viability of cutthroat populations in the Region. This assessment provides the Region with a tool to build a strategic program to improve aquatic organism passage across the Northern Region.

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Introduction

An assessment of aquatic organism passage at stream and road intersections in the Northern Region is critical to address restoration needs for aquatic organisms. The Northern Region has 28,000 miles of stream and 52,000 miles of road. Those intersections of roads and streams often have culverts that are affecting migration of fish in those systems. Fragmentation of fish populations is one of the key factors to address in recovery planning of threatened, endangered and sensitive fish species including bull trout, steelhead trout, chinook salmon, westslope cutthroat trout and yellowstone cutthroat trout. In 2002, the Northern Region Engineering Director identified the need for a regional assessment of stream crossing barriers to aquatic organism passage. This information was necessary to better define the magnitude of the issue in the Region and the anticipated program of work.

This report summarizes survey efforts for aquatic organism passage in the Northern Region from 2002 to 2005. During this time period more than $750,000 in Regional Office funding was spent inventorying 2,865 culverts at potential fish-bearing stream and road crossings on 13 National Forests and Grasslands. Additional funding may have been provided by the Forest, Grassland or outside partners. This data has been aggregated to determine the extent of fish passage issues. These surveys were performed primarily on National Forest System roads and do not represent private, state, and county roads systems. Surveys were conducted using the guidelines of the National Inventory and Assessment Procedure for Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings (Clarkin et. al. 2003). Data is stored in an Access database that is located at each Forest/Grassland and is also available on the Regional Aquatic Organism Passage intranet website (*http://fsweb.r1.fs.fed.us/wildlife/wwfrp/fisheries/Fish_Passage_Web_Page.htm*).

Background

Isolation and Fish Populations

Declines in native fish populations in the intermountain west are noted by listings under the Endangered Species Act of steelhead trout, chinook salmon and bull trout. In addition, the native ranges of westslope and yellowstone cutthroat trout have also declined dramatically. Westslope cutthroat trout currently occupy only 59% of its historic range while Yellowstone cutthroat populations occupy only 43% of the historic range (Shepard et al. 2003, May et al. 2003).

Past design practices for stream crossings on National Forest System Roads focused on minimizing cost while maximizing water transport. This design was very effective for moving water under the road bed, however it often produced an effective barrier to upstream migrating fish.

Fragmentation of populations and habitat is one of the reasons for declines in fish species and other aquatic organisms. Fish movement is necessary to link populations and habitats required for spawning, growth and refuge from

Lolo National Forest culvert - before replacement

Lolo National Forest culvert - after replacement

harsh conditions over a diverse stream network. The need to improve upstream passage for adult anadromous fish has been an issue for several years. However recent research indicates that movement is also important for resident and migratory inland fish populations, as well as adult and juvenile individuals.

Movement may be the key to population persistence in variable and changing environments (Fauch et al. in press). Isolated populations are at a higher risk of extinction due to: loss of genetic variability, loss of resilience, demographic and environmental stochasticity.

Culverts As Barriers

Culverts can block fish passage in different ways. If a culvert outlet is perched above the stream, various size classes of fish may not be able to make the jump into the culvert. The higher the jump to reach the culvert, the more difficult the passage is for fish. In addition, lack of an outlet pool prevents a "resting place" prior to the fish attempting to jump into the pipe. Inadequate outlet pool depth also limits the physical ability of the fish to leap. Velocity of the water moving through the culvert can also impede fish passage by creating water velocities that exceed the swimming capabilities of the fish. Velocity barriers are created by 1) too steep a slope, 2) roughness reduced through the culvert, 3) reduction of channel cross-sectional area, and 4) a combination of culvert length and velocity may exceed the fishes swimming capabilities. Swimming capabilities are determined by fish species and fish length. Juvenile fish are weaker swimmers than adults and culverts that allow adult passage may not provide it for juveniles. Low water depth through culverts may also prevent passage of fish through the pipes. Shallow water may result in the fish not being fully submerged, preventing adequate swimming power to pass through the structure.

Washed out culvert, Helena National Forest

Legal and Policy Issues

The Forest Service has several legal mandates and policy guidance that requires us to address fish passage at road-stream crossings.

- Northern Region Guidance (12/04/2003) "All designs should provide passage for aquatic species and life stages present at that location, unless there is a biological and/or hydrological rationale to support the approach."
- Forest Service Manual 7721.12 "consider the protection and enhancement of watersheds, fish-producing streams, wildlife habitat…"
- Forest Service Handbook 7709.56b "guidelines for fish passage structures"
- National Forest Management Act (36 CFR 219.19)
"…fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area."
"…no management practices causing…blockages of water courses, or deposits of sediment shall be permitted…"
"…preserve ad enhance the diversity of plant and animal communities…so that it is at least as great as that which would be expected in a natural forest."
- Forest Plans (INFISH, PACFISH) "Provide and maintain fish passage at all road crossings of existing and potential fish-bearing streams."
- Clean Water Act, Section 404(f)(1)(e) If using the silvicultural exemption (40 CFR 232.3) for storm water discharge permits "The design, construction and maintenance of the road crossing shall not disrupt the migration or other movement of those species of aquatic life inhabiting the water body."
- Endangered Species Act "Each Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency (hereinafter in

this section referred to as an "agency action") is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat."

Methods

Survey Methods

Surveys were completed on National Forest System Roads (NFSR) and cost-shared roads. Other road systems (i.e state highways, county roads) were surveyed as time and priority permitted.

The Northern Region has over 52,000 miles of inventoried roads. In order to determine which road crossings to inventory the Forests/Grasslands used Geographic Information Systems (GIS) to determine the location of potential structures. To address which crossings may have fish present the Forests modeled stream slope data. If stream gradients were greater than 15-25% fish were presumed absent and those stream crossings were eliminated from the survey.

Starting in 2002 in coordination with the San Dimas Technology and Development Center (SDTC), the Region trained Forest staff and field crews in a consistent protocol for surveying culverts for aquatic organism passage issues (Clarkin et al 2003). Structures were surveyed, tagged with a unique number and locations recorded with a global positioning system (GPS).

Data collected with the survey included: crossing shape, crossing dimensions, inlet/outlet configuration, structure stream bed material, stream channel longitudinal profiles, stream channel cross-section(s), and stream bankfull widths. The data collected for the longitudinal profile provides information to calculate: culvert slope, upstream/downstream slopes, residual inlet depth, and outlet drops.

A total of 2865 surveys were completed in the Northern Region between the years of 2002-2005.

The Northern Region allocated survey dollars (seed money) to Forests in fiscal years 2002 and 2003. A total of $755,800, with an average of $270 per structure, was spent by the region to complete the surveys. This survey cost included: crew time to determine culvert priorities and locations, travel to sites, and crew time to collect and enter data. This figure does not show additional money that was allocated by individual Forests or time and expenses that partners may have accrued.

Partnerships

To supplement the Forest Service funding, many Forests developed partnerships to collect additional surveys on NFS lands and adjacent private lands. Culvert inventories were cooperatively conducted between the Forest Service and the Nez Perce Tribe both on the Clearwater and Nez Perce National Forests. Montana State University students participated in training and shared information collected on the Lolo National Forest (Cahoon et al 2005). Also the Northern Region and specific Forests coordinated inventories with Montana Department of Natural Resources and Plum Creek Timber Company.

Fish Passage Definitions

The first step to assess a culvert for fish passage is the development of a consistent definition for "passage." The definition must contain the following elements: swimming performances for a fish species or a group of species, lifestage of the target fish (juvenile, adult or both), lifeform of the target species (resident or migratory), and a desired stream flow or range of flows necessary for the passage of that target species. Changing any one of these parameters will change the definition and the results of the analysis. Results of this assessment reflect a very specific target species or target family.

The definition used by the Northern Region represents a single target species and does not represent all aquatic organisms found throughout the Region. This definition is not intended to be used for designing replacement structures. The Northern Region has provided written guidance for replacement structures to provide for aquatic organism passage at all fish bearing stream and road crossings (USDA 2003a).

Salmonid habitat for the Dakota Prairie Grasslands and portions of the Custer National Forest is non-existent. For this portion of the Region a different definition, that is more reflective of prairie fishes, is in development. Once

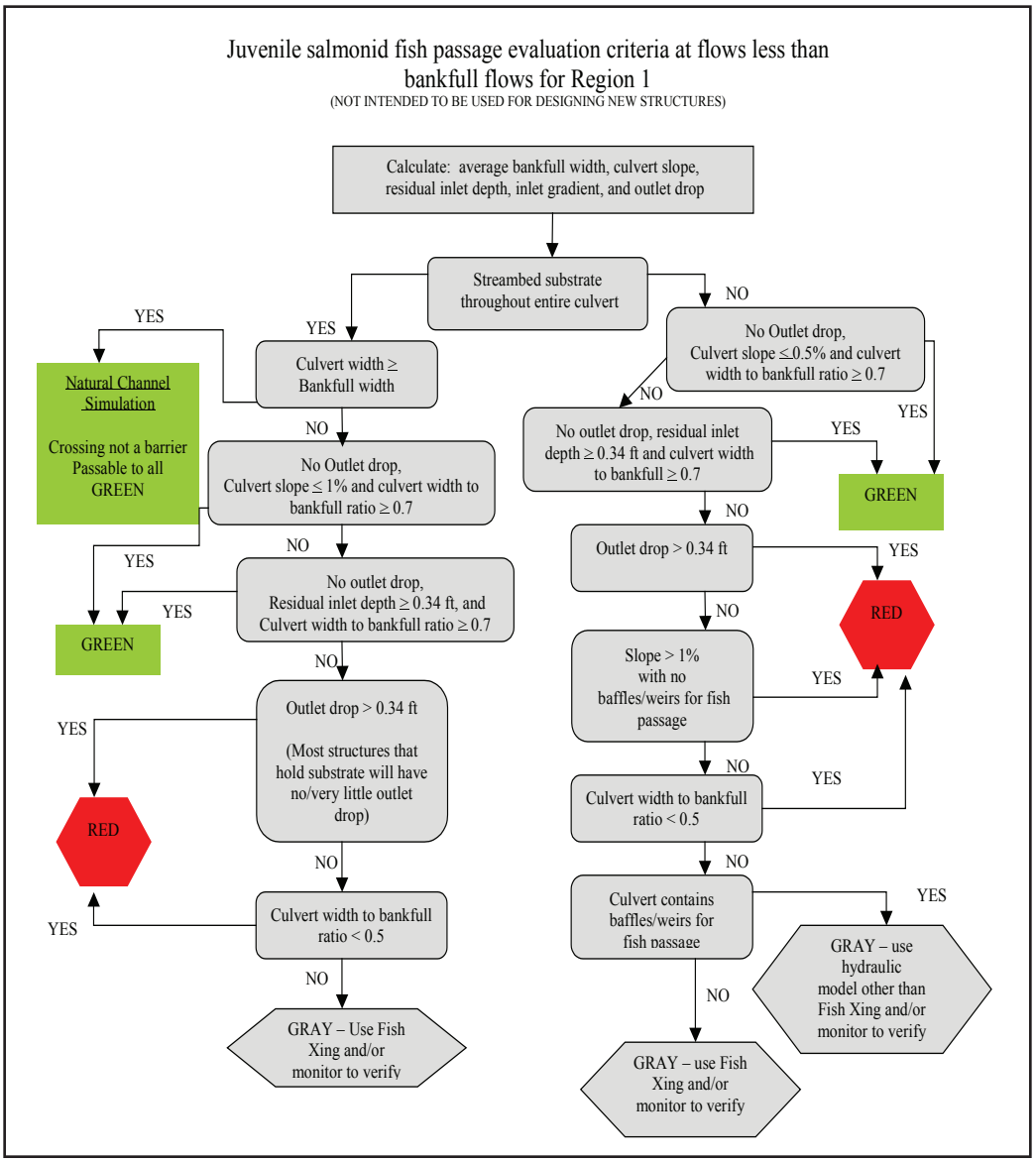
a passage definition is identified a supplement to this document will be provided.

The Northern Region chooses to use resident-adult and resident-juvenile yellowstone or westslope cutthroat trout as the target salmonid to assess fish passage at existing stream crossings. This gives a conservative approximation of fish passage capabilities using juvenile cutthroat as the target species/life stage. This particular species and lifestage represents a broad range of fish species present in the Northern Region. The range of flows used in this definition are: high flow is the 10% monthly exceedence flow during the month of migration, May or June, for the period of recorded flows, and low flow represented by the 95% annual exceedence flow for the period of record. This range of flows allows structures to be analyzed against 85% of the recorded flows that affect fish passage.

The Northern Region is also working on a 'Hydrology and Flow Requirements for Region 1 Stream Crossing" (Jacobsen et al, draft) that will help define how to use exceedance flows for fish passage assessment work.

The process of calculating exceedence flows requires the use of continuous gage data, data extrapolated from a nearby gaged stream, or generated from regression equations. Thus it is labor intensive and requires a substantial amount of time to generate exceedence flows for a large number of

Figure 1. Northern Region Juvenile Salmonid Course Passage Screen

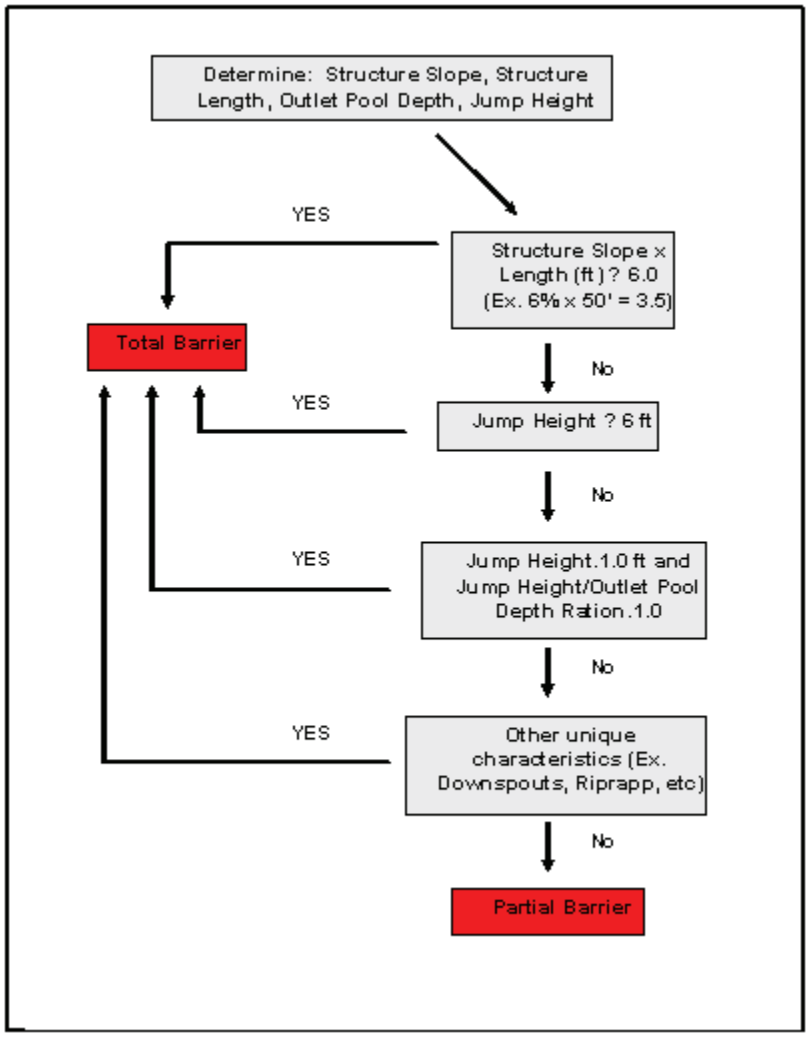


streams. To minimize the workload, the Northern Region developed a course filter (screen) to determine fish passage for adult and juvenile salmonid (USDA 2003b). Figure 1 is the screen used to determine if a structure passed fish (green) or was a barrier to upstream movement (red). Some culverts could not be assessed using this method (gray) and require a more detailed hydraulic analysis. These gray culverts can be modeled with programs such as FishXing (V2.2), which considers fish swimming capabilities, culvert parameters, and stream flow requirements to determine whether the structure is a barrier or not.

A second definition for aquatic passage was developed to determine culverts that are barriers to all species, all lifestages and all flows. This definition separates culverts that are acting as partial barriers from those that are total barriers (Figure 2).

This total barrier definition is based on a series of assumptions that relate culvert characteristics to biological capabilities or physical limitations. The first screening step is to determine the product of the culvert structure length to the structures slope. This is attempting to combine length and slope as a surrogate for water velocity and fish swimming capabilities. The next step is a Jump Height criteria or screen that is based on the physical limitation of a fish's capability to jump under ideal conditions. The third step is to determine if an adequate jump pool is present. Any one of these or a combination of these criteria may lead to the determination of the structure acting as a total barrier to upstream movement.

Figure 2. Northern Region Definition for Full Barriers to Fish Passage



Data Analysis

Data from each Forest was acquired by the Region and aggregated at the regional scale. The data was checked for consistency and incomplete data was deleted from the dataset. However, incomplete data was not automatically deleted and efforts were made to make a passage determination based on the limited information collected. Stream crossings that consisted of bridges and fords were also deleted from the regional dataset since they allow the channel to exhibit natural characteristics and do not inhibit fish passage.

A Microsoft Access database was used to store the culvert survey data. This database is programmed to calculate culvert slope, stream slope, culvert/bankfull constriction ratios, jump heights, and residual inlet depths. The program takes these calculated variables for each culvert and runs them through the Northern Region Fish Passage Screen (USDA 2003) to determine if they are red, gray, or green.

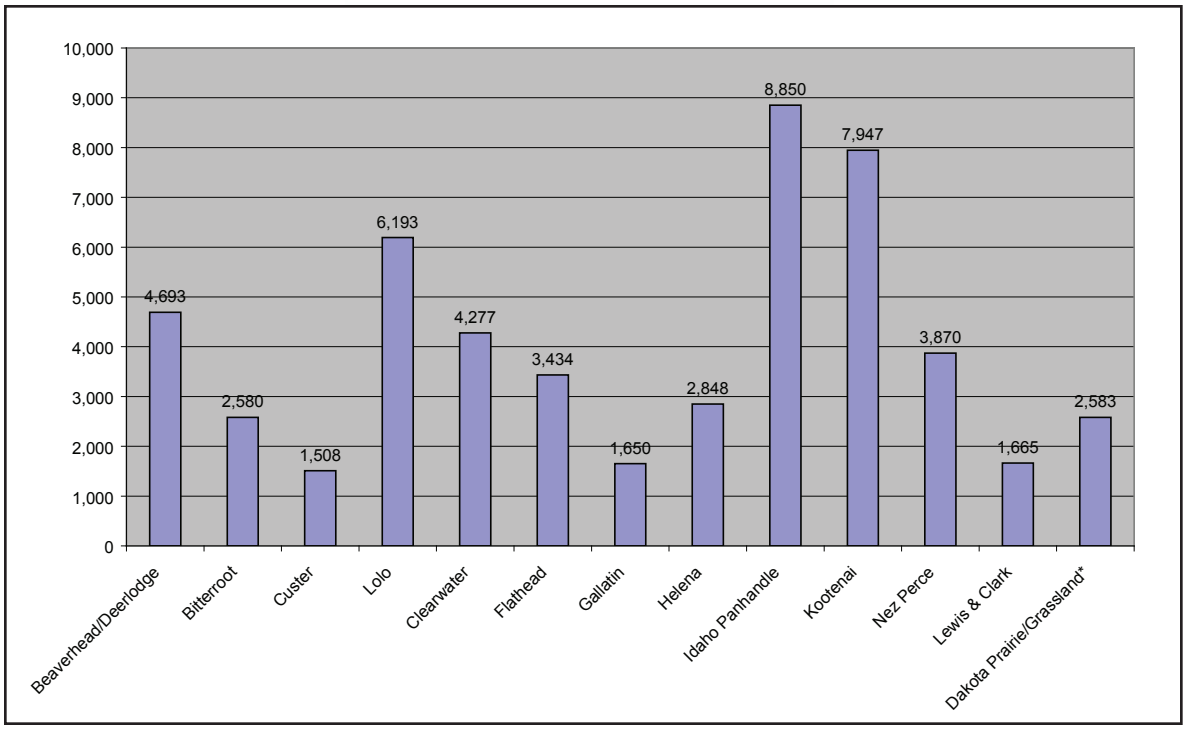
Results

General Discussion on Barrier Results

The Northern Region surveyed road-stream crossing structures on over 52,000 miles of Forest Development Roads. In general it would be expected that more road miles would equate to a higher number of stream crossings and subsequent number of fish passage barriers. Figure 3 demonstrates the distribution of road miles among the different forests.

Approximately 2,800 culverts have been inventoried and assessed for fish passage within the Northern Region, these results are summarized in Table 1 and Figure 4 for juvenile salmonids. Summary of the juvenile results indicate 84% of the crossings in the region are an upstream barrier to migrating juvenile cutthroat trout during some timeframe throughout the year, 9% are indeterminate, and 7% are passable. Results for adult salmonids indicate that approximately 80% of the inventoried crossings are barriers,

Figure 3. Total Miles of Road on Northern Region Forests



13% are indeterminate, and 7% are not considered barriers. The Lolo National Forest completed a hydraulic assessment for their Gray culverts and used the calculated flow values with the FishXing program. FishXing determined that approximately 80% of the Indeterminate (gray) culverts modeled as barriers (red).

If you assume those results are similar region wide, approximately 313 additional culverts are barriers (red) in the region.

It became apparent that prioritizing a large set of barriers across the Region, Forest, or watershed is difficult without a common way of separating different types of barriers. Having this large number of barriers divided into partial, total, or non-barriers will better facilitate the prioritization. Identifying total barriers gives an idea of those areas where barriers may be preventing upward movements of exotic species, thereby marinating genetic integrity of natives in those systems. Having the total barrier structures identified allows timelines to be adjusted in order to collect more information such as: genetics, diseases risks, and species composition.

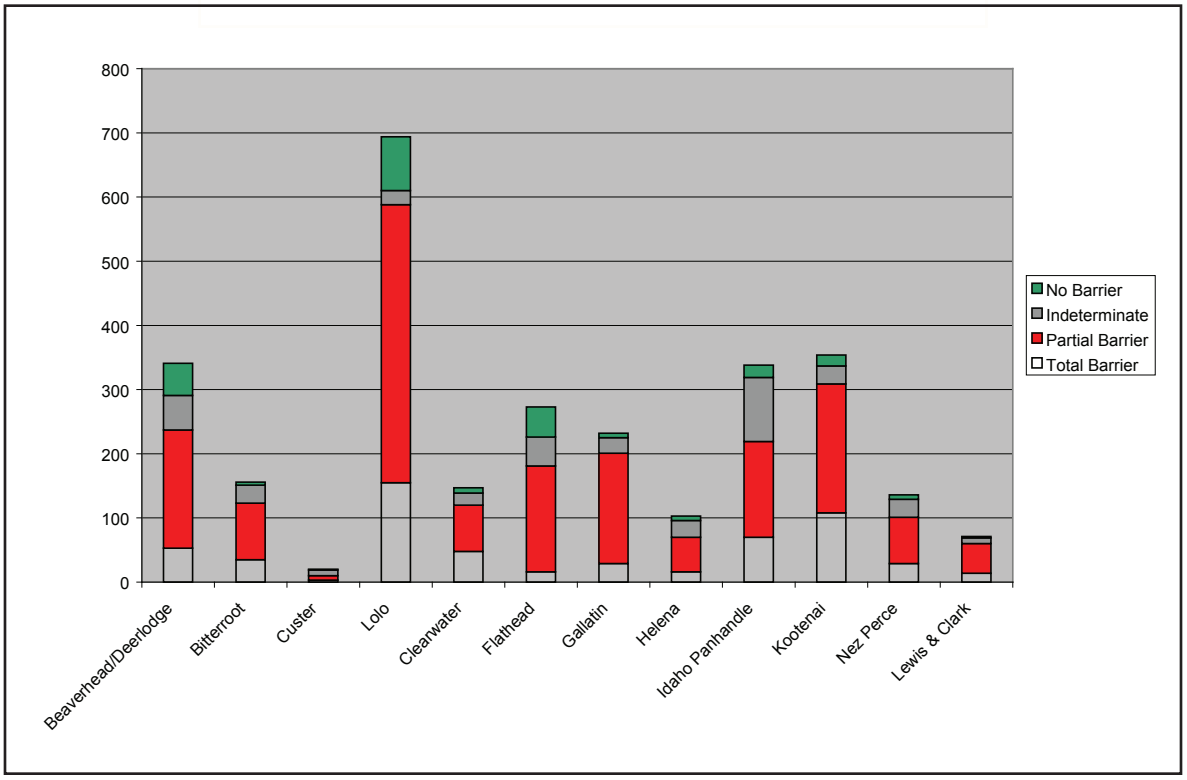
Data for the Custer National Forest and the Dakota Prairie Grasslands do not account for passage in prairie stream environments. That data will be provided in an addendum to this report.

Again, the results are specific to the definition of fish passage

Table 1. Summary of Stream-Road Crossings for Juvenile Salmonids in the Norther Region

Forest	Total Barrier (blue)	Partial Barrier (red)	Indeterminate Barrier (gray)	No Barrier (green)	Total Culverts Surveyed	Percent Forest Surveyed	Total Miles of Road
Beaverhead Deerlodge	53	184	54	50	341	95	4693
Bitterroot	35	88	28	5	156	95	2580
Custer	3	7	9	1	20	95	1508
Lolo	155	433	22	84	694	95	6193
Clearwater	48	72	19	8	147	40	4277
Flathead	16	165	45	47	273	95	3434
Gallatin	29	172	24	7	232	95	1650
Helena	16	54	26	7	103	95	2848
Idaho Panhandle	70	149	100	19	338	70	8850
Kootenai	108	201	28	17	354	90	7947
Nez Perce	29	72	28	7	136	25	3870
Lewis & Clark	14	46	9	2	71	95	1665
Dakota Prairie Grassland*	NA	NA	NA	NA	NA	NA	2583
TOTAL	576	1643					
	2219		392	254	2865		
Percentage	77.5%		13.7%	8.9%			

Figure 4. Northern Region Road-Stream Crossing Barriers to Juvenile Cutthroat Trout



chosen by Northern Region.. This definition chooses a weaker and smaller salmonid species and lifeform therefore the results are more conservative than if a chinook salmon or nonnative-rainbow trout were used instead. Therefore, the results of a structure being a barrier to juvenile or to an adult cutthroat trout, does not indicate that this same structure is a total barrier to all species. The map at the end of this report provides a visual display of the results for the surveyed culverts for the Region.

Discussion on Structures in the Northern Region

In addition to the barrier determinations, summaries of general culvert measurements were also run for the regional data. The following Table 2 shows averages of the selected data.

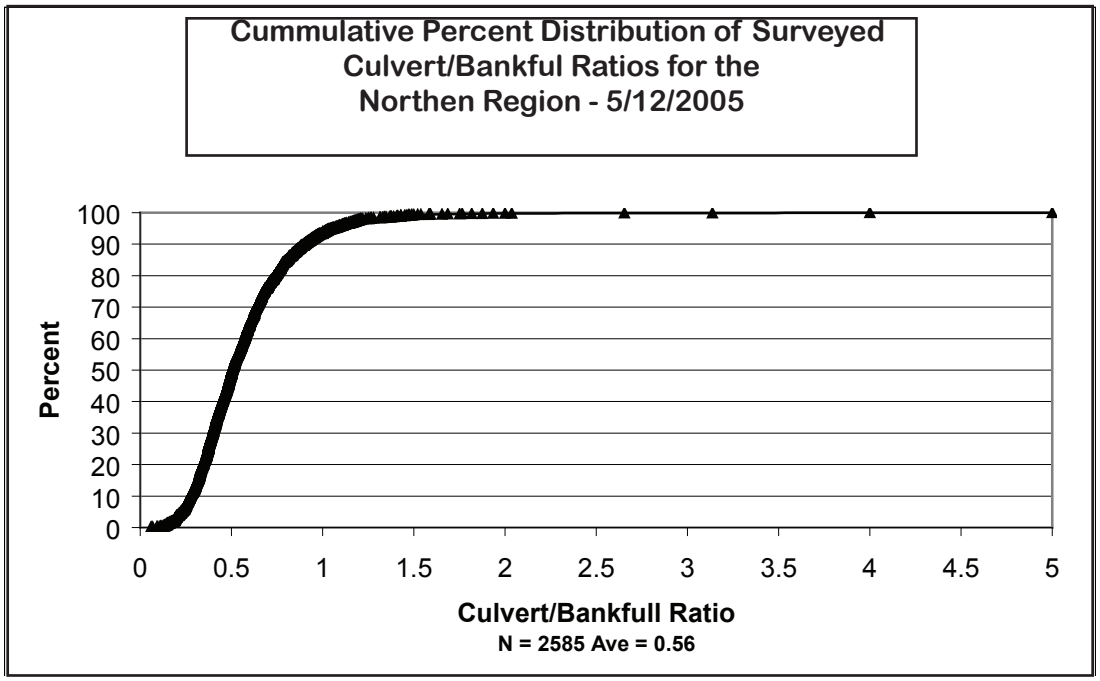
The constriction ratio is the product of dividing the culvert width by the bankfull width. This ratio gives an idea of how much a crossing structure is constricting the bankfull width and the flow associated with that bankfull width. As constriction ratios become smaller the potential for culvert failure increases as does the likelihood of high velocity through the structure. For example, a five-foot culvert installed in a ten-foot wide stream has a constriction ratio of 0.5 or 50%. The data displayed in Figure 5 show that 93% of the surveyed culverts constrict stream channels to some degree and 50% of the culverts constrict the channels to a ratio of 0.5 or less. Constriction Ratios less than 0.5 rank as either high or extreme risk of failure.

Water velocities within stream channels are affected many natural factors such as slope, stream substrate, width, depth, etc. Considering these factors the average stream velocity in the region is between three and six feet per second during

Table 2. Culvert Characteristics for the Northern Region

Average Culvert Slope	5.3%
Average Culvert Length	47 feet
Average Culvert Width	48 inches
Average Bankfull (Stream) Width	9.2 feet
Median Bankfull (Stream) Width	7.7 feet

Figure 5. Culvert/Bankfull Ratio Graph



normal flows. Fish species swimming capabilities have also evolved with these same streams and their associated water velocities. As stream crossing structures alter the streams physical components the result is often increasing water velocity and/or jump heights that exceed the fishes capability.

Discussion:

The survey and assessment of all the stream-road crossings in the region was intended to provide a comprehensive and broad-scale look at the issues related to aquatic organism passage. This is the first step in an effort to create a strategic approach to prioritizing replacement of culverts to provide for movement of fish at all life stages and all flows.

The assessment indicates that fish passage at road-stream crossings is a significant issue in the Northern Region. With an indicated 2400 culverts that need to be replaced with passage friendly structures, the magnitude and cost associated with the work is an issue the Region will need to address. If an average replacement cost of $75,000 per structure is applied, replacement of all the known partial and full barriers would cost $180 million.

The assessment indicates that of the surveyed culverts, the distribution of the problem is not even across the region. Montana national forests have a total of 428 full barriers and 1461 partial barriers, while Idaho forests have 145 full and 333 partial barriers. In Montana, the Lolo National Forest has the most with 155 full and 437 partial barriers, due primarily to the landscape and the total miles of roads within proximity to riparian areas. The Kootenai and the Beaverhead Deerlodge National Forests also have a significant number of barriers with 108 and 53 full, and 53 and 225 partial barriers, respectively. In Idaho the Idaho Panhandle National Forest leads with 69 full and 176 partial barriers.

The habitat that is blocked from access in the Region is significant and clearly indicates that these barriers are affecting viability of native and important non-native populations. By preventing the expression of full life histories, limiting migration for spawning, feeding, refuge and fragmenting populations the barriers are impacting population persistence. However, some of these barriers

may also be isolating cutthroat populations from non-native introgression and may give us some time to determine long term strategies for connecting those populations. Rocky Mountain Research Station has developed a model to assess risk to populations from barriers that will be used to address the viability of populations (Peterson et al. In press).

This data also yields information on the risks of failure of the structures (culverts) themselves. Summary of the constriction ratios indicate that 93% of the surveyed culverts constrict stream channels to some degree and 50% of the culverts constrict the channels by a ratio of 0.5 or less. Constriction ratios less than 0.5 rank as high or extreme risk of failure. Failures at stream crossings can cause significant damage to the road and erode the stream bed, adversely affecting the aquatic species in that stream.
The surveys for stream-road crossings are not complete on all the Forests in the Region and efforts will be made to get those finished. There is also additional work needed to address non-salmonid species that inhabit streams in eastern Montana and western North and South Dakota. When that criteria for passage is developed, that data will be analyzed for fish passage and appended to this report.

The Region will also need to complete a prioritization strategy for improvements in collaboration with our partner agencies and adjacent land owners. Priorities will be based on fish species and habitat needs, culvert failure risk, partnership opportunities, and available funding. Information from this assessment will allow a more strategic approach. The data is also useful to the Forests to identify priorities and look for opportunities with ongoing and proposed projects. Regionally, the assessment allows for a more complete picture of the program of work, necessary training, funding and skills needed to implement the strategy. This assessment will also allow us to address fish passage at a watershed scale and allows more effective use of all available funding for the correction of fish passage barriers.

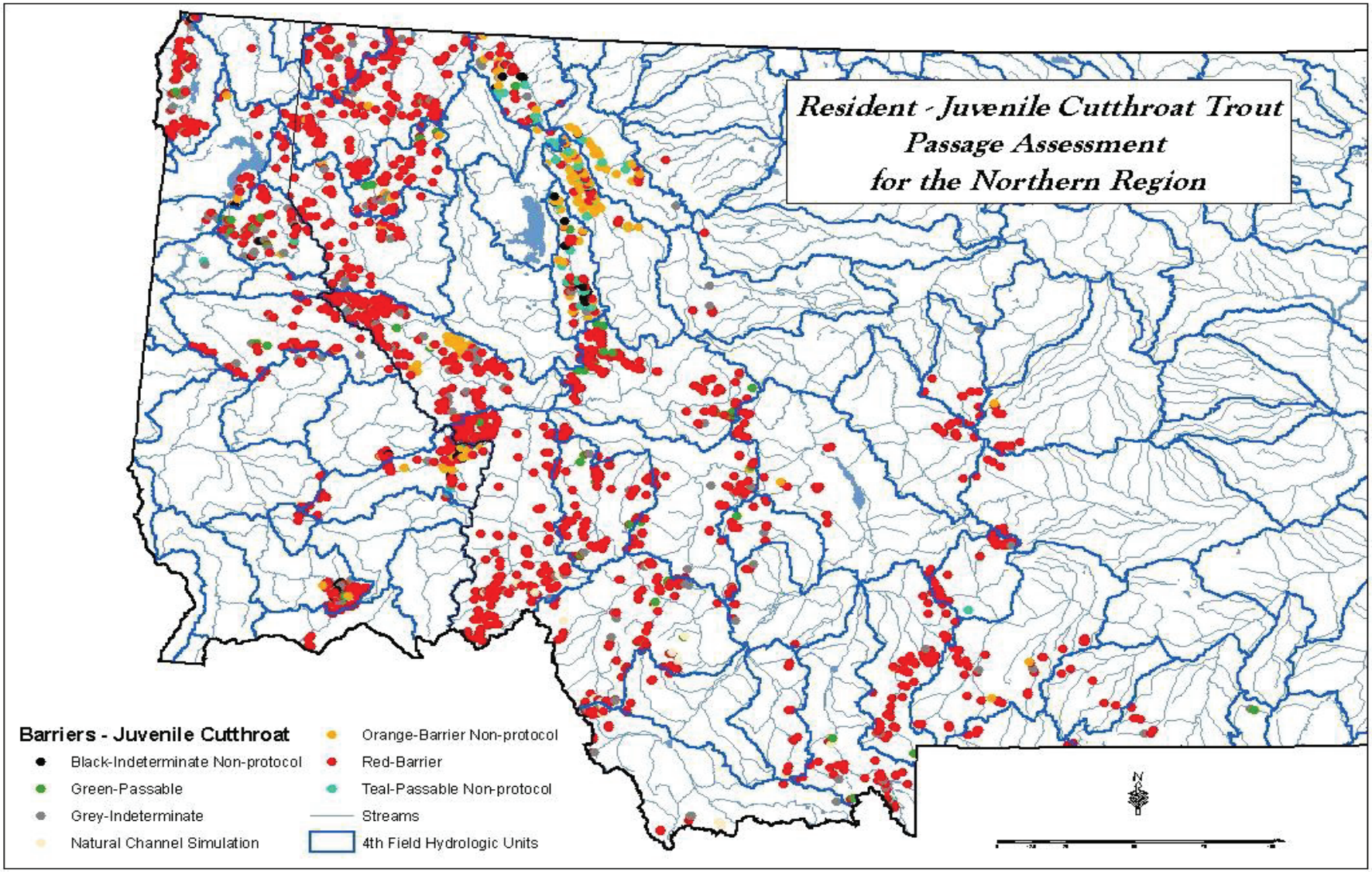
It is important to emphasize that this assessment is very specific to barriers of a target species of westslope and yellowstone cutthroat juveniles. As the Region replaces culverts emphasis is on stream simulation and allowing a functional stream to pass through the crossing structure while maintaining a seamless transition for aquatic organisms. Using that approach allows us to address the viability of many other aquatic species including amphibians, macroinvertebrates and non-salmonid fish species. Stream simulation also has benefits of extending the life of the structure, minimizing long term maintenance and addressing safety issues on National Forest System roads.

Tools For the Region:

- Distribution Maps for westslope and Yellowstone cutthroat
- FishXing 3.0
- Risk Assessment Tool (Rieman, Peterson 2006)
- Strategies for Conserving Native Salmonid Populations at Risk from Nonnative Fish Invasions (Fausch et al. 2006)
- Northern Region Aquatic Passage Website
- San Dimas Technology Development Center Culvert Inventory Protocol

Rich Creek culvert before replacement.
Kootenai National Forest

Rich Creek culvert after replacement.
Kootenai National Forest


Resident - Juvenile Cutthroat Trout
Passage Assessment
for the Northern Region
Barriers - Juvenile Cutthroat
Black-Indeterminate Non-protocol
Green-Passable
Grey-Indeterminate
Natural Channel Simulation
Orange-Barrier Non-protocol
Red-Barrier
Teal-Passable Non-protocol
Streams
4th Field Hydrologic Units
N

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