MONTANA AREA OFFICE DECISION DOCUMENT
ST. MARY DIVERSION DAM
ST. MARY UNIT, MILK RIVER PROJECT

PURPOSE OF PAPER: Recommend a preferred structural alternative for continued analysis for the replacement of the St. Mary Diversion Dam and Headworks which considers minimizing public safety concerns, providing bull trout passage and entrainment protection, and concerns raised by the Milk River Project stakeholders.

BACKGROUND: The St. Mary Diversion Dam, located near Babb, Montana, is a feature of the St. Mary Unit of the Milk River Project. The diversion and canal intake structure were constructed in 1915 on the St. Mary River. In 1999, the U.S. Fish and Wildlife Service listed the bull trout as a threatened species under the Endangered Species Act (ESA). The bull trout is native to the St. Mary River drainage and are negatively affected by operation of the dam and canal. The diversion dam acts as a barrier to upstream migration of bull trout. Due to the poor condition of the diversion structure and the need to address identified bull trout entrainment and passage issues, Reclamation is planning a complete replacement of this feature.

During the 60% design phase for the replacement of the diversion dam, Reclamation became concerned that the concrete dam configuration created a hydraulic jump, which under some circumstances creates a condition that traps and recirculates anything that floats. This condition is a public safety hazard and has the potential to cause people to drown if they unknowingly go over the dam and become stuck in this recirculating current.

In response to these issues, Reclamation has been working with the Blackfeet Tribe, the U.S. Fish and Wildlife Service's Biological Review Team (BRT), and the Technical Service Center (TSC) to design a dam that delivers contract water, provides bull trout passage and entrainment protection, and eliminates as much as possible critical backwash conditions. The current 60% design incorporates a fish ladder for the passage of bull trout, but does not address this potential public safety issue. Reclamation decided to further explore alternative dam configurations that incorporates fish passage features, diverts contract water to the irrigation canal and addresses the recirculating current safety concern.

TSC's Technical Memorandum Number 15-SMD-8150-STY-2017-7: "St. Mary Diversion Dam; Concrete Dam and Rock Ramp Design Update" provides an update for the two preferred dam options and is attached as Exhibit A. This document describes the two alternatives in detail and compares the advantages and disadvantages of each. The BRT's "Bull Trout Passage at the St. Mary Diversion Dam: A summary and response from the St. Mary Bull Trout Biological Review Team" offers Reclamation with biologically-based recommendations regarding their review of the Design Team's current engineering plans. This document is attached and referred to as Exhibit B.

CURRENT STATUS: Reclamation staff from TSC initially utilized computer models to test 17 alternative dam configurations and to investigate public safety related design issues. The configurations evaluated included a rock ramp, concrete aprons with varying end sill heights, varying downstream energy dissipaters, and varying weir treatments such as notches and a stilling basin. Each alternative was tested with a range of flow rates to primarily evaluate exposure time (how long a person going over the dam would be caught in the recirculating current created by the dam/weir configuration). From a review of these options on November 18, 2016, the Montana Area Office (MTAO) selected the rock ramp and asked the TSC to select and further develop one concrete dam option that best addressed the public safety concern. On January 25, 2017, the TSC design team held a teleconference with the BRT, MTAO, and a representative of the Blackfeet Tribe to present the design options.

Options /Alternatives: Refer to Exhibit A.

Based on technical analysis of Options 1A and 1B, either option will work in conjunction with an in-canal fish screen and bypass system.

Alternative Option 1A - Concrete Apron: This option is a concrete broad-crested weir with a concrete apron with an elevation drop of about 5 feet. Due to the large drop, a fish ladder is required to be constructed to allow for fish passage. The required fish ladder will require yearly maintenance and does not allow for full river width passage (fish can only pass using the fish ladder), but does meet required passage criteria and provides an easier method to monitor fish passage.

Alternative Option 1B – Rock Ramp: This option includes a concrete broad-crested weir with rock ramp that does not contain a vertical drop. Instead, large boulders are placed on a slope from the top of the weir to the downstream natural grade. Since there is no vertical drop, a fish ladder is not required. As identified in Exhibit B, the velocities are low enough to allow bull trout and other fish species to migrate upstream. The rock ramp provides more of a natural environment for the fish and allows for full river width passage during normal and high flows. In order for bull trout to pass during low flows (below approximately 100 cfs), a notch in the weir will need to be designed. This will create a low flow channel capable of holding a sufficient water depth for bull trout and potentially other fish to pass.

POSITION OF INTERESTED PARTIES:

Biological Review Team (BRT)

The BRT has participated in the design process since the early 2000s and has reviewed and commented on a number of passage and entrainment protection measures. The Blackfeet Tribe has participated in all of the BRT meetings and voiced their opinions but has requested not to be listed as members of the team. The BRT concluded on May 5, 2017 that either of the proposed passage options will successfully pass Bull Trout (see exhibit B). There is less concern with attraction flows with the rock ramp that incorporates a low flow channel notch. The low flow channel also provides a more natural passage feature and can be adaptively managed.

For these reasons the BRT members preferred the rock ramp alternative for additional design and modeling.

If the traditional fish ladder is selected, it should be noted that the Blackfeet Tribe and Glacier National Park staff have requested all species passage, all species screening, and a selective trap within the fish ladder to allow selective passage to minimize future aquatic invasive species (primarily Walleye).

Water Users

The Milk River Project Water Users current O&M cost allocation is 73.96% of the costs of the new diversion dam. They have expressed concern with this commitment. They contend that the previous diversion dam designs, and in particular the multi-species fish ladder, included excessive features that were not necessary as part of the ESA requirements and drive the costs up.

RECOMMENDATION: Move forward with the physical modeling and 60% design changes of the preferred Alternative Option 1B – Rock Ramp.

EXHIBITS: **A)** Technical Memorandum Number 15-SMD-8150-STY-2017-7 - St. Mary Diversion Dam: Concrete Dam and Rock Ramp Design Update
B) Bull Trout Passage at the St. Mary Diversion Dam: A summary and response from the St. Mary Bull Trout Biological Review Team

Recommended (and Concurred):

Ryan Colloton Project Manager	Date 6-28-17	Jerry Benock Project Manager's Supervisor	Date 6-28-17
Mike Hilliard Facility Representation	Date 6-28-17		
Steve Darlinton O&M Representative	Date 7/5/17	Chris Gomer O&M Representative's Supervisor	Date 7/11/17
Justin Kucera Environmental Specialist	Date 7/12/17	Jeff Baumberger Environmental Specialist's Supervisor	Date 27 July 2017
Tom Sawatzke Deputy Area Manager	Date 7/28/17		

Concurred:

Steve Davies
Area Manager

Date 8/2/2017

Exhibit A

Bull Trout Passage at the St. Mary Diversion Dam

A summary and response from the
St. Mary Bull Trout Biological Review Team

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Montana Fish and Wildlife Conservation Office
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Bull Trout Passage at the St. Mary Diversion Dam

A summary and response from the St. Mary Bull Trout Biological Review Team

Relevant meetings:

June 9, 2015 – Denver Technical Service Center (1)
January 25, 2017 – Creston Fish Hatchery (2)

Participants:

BRT Team Members
Jim Mogen – Fish Biologist – USFWS (1 & 2)
Justin Kucera – Natural Resource Specialist - USBR Montana Area Office (1 & 2)
Chris Downs – Fish Biologist - Glacier National Park (1 & 2)
Kevin Aceituno – Consultation Biologist – USFWS (1 & 2)
Andrew Gilham – Fish Biologist – USFWS (1 & 2)
Eric Best – Fish Biologist – USBR Technical Service Center (2)
Charles Hueth - Fish Biologist – USBR Technical Service Center (1)
Larry Lockard – Consultation Biologist – USFWS (1)

TSC Design and Hydrology Engineers
Jason Wagner – Civil Engineer USBR Technical Services Center (1 & 2)
Bryan Heiner – Reclamation Hydraulic Engineer (1 & 2)
Kit Shupe – Reclamation Hydraulic Engineer (1 & 2)

Introduction:

The primary role of the St. Mary Bull Trout Biological Review Team (BRT) is to provide the USBR Project Design Team with biologically-based recommendations regarding potential impacts to ESA-listed Bull Trout (USFWS 1999) at the proposed St. Mary Diversion and other Milk River Project sites. With the objective of increasing the likelihood of project success, BRT meetings provide a forum where Bull Trout biologists can collectively review the Design Team's current engineering plans; identify concerns; and offer insights, comments, criteria or questions where appropriate. The BRT met on June 9, 2015 at the USBR Denver Technical Service Center (TSC) and again on January 25, 2017 at Creston National Fish Hatchery near Kalispell, MT. The group assembled to discuss and compare two preferred alternatives for ensuring effective passage of ESA-listed Bull Trout at the proposed St. Mary Diversion. Specifically, the team was tasked with reviewing design plans and recent modeling results from the TSC physical model and developing final recommendations for both a traditional concrete Fish Ladder (Alternative A) and a river-wide Rock Ramp (Alternative B).

Since several of the BRT members have also participated in the Value Planning and Value Engineering stages of the design process, many of the biological concerns regarding project impacts to fisheries have already been addressed. In addition to the two passage alternatives discussed here, the BRT previously provided input on design plans for several other canal-related project structures, including the Headworks, Trash Rack, Fish Screen and Bypass.

The BRT recommends that both alternatives include the original, in-canal, flat-panel Fish Screen composed of wedge wire spaced according to the National Marine Fisheries Service (NMFS) criteria for fingerling salmonids (Table 1). These criteria will ensure effective screening of all salmonids greater than 60 mm and are consistent with juvenile Bull Trout emigration, which typically occurs at age 2 and older (Fraley & Shepard 1989, Goetz 1989, Riehle et al. 1997, Downs et al. 2006). Further, no Bull Trout shorter than 100 mm were captured during entrainment investigations (2002-2006) at the St. Mary Canal Headworks (Mogen et al. 2011). The fish screening facility should also incorporate a Bypass return situated at the downstream end of the Fish Screen and all screened fish should be safely returned through the Bypass to the river at a location downstream from the diversion dam as per NMFS Criteria (Table 1). Lastly, the BRT recommends a four-inch spacing minimum on the Trash Rack to reduce the likelihood of impingement while allowing two-way volitional movements of fish through the rack.

At this time the BRT supports the current proposed Fish Screen and Bypass designs as effective for Bull Trout screening and has no further comment on the Fish Screen, Bypass or any other canal-related structures. The remainder of this document is concerned only with the dam itself and our recommendations for effectively passing Bull Trout and other native fishes.

Purpose:

The purpose of this document is to summarize results of the two BRT meetings and to provide biologically-based, data-driven recommendations for both passage alternatives (A and B).

The original project plans positioned the Fish Ladder on the east side of the St. Mary River (river-right) opposite the canal Headworks, to keep passing fish as far as possible from the threat of entrainment. However; due to concerns with attraction in the Fish Ladder (i.e., the chemical make-up or “smell” of natal Boulder Creek water vs. Lower St. Mary Lake water), as well as access limitations and higher O&M costs, the Fish Ladder was moved to the river-left and modelled in 2015. The primary purpose of the June 9, 2015 BRT meeting was to observe the updated TSC model and address entrainment concerns with placing the Fish Ladder in the new location; more importantly, positioning the Fish Ladder exit immediately adjacent to the Headworks.

Concerns with public safety and downstream energy dissipation, specifically the creation of a dangerous submerged hydraulic jump that could trap swimmers or boaters and cause excessive scour below the dam, prompted additional TSC modelling in 2016. Two options emerged as viable alternatives that meet safety and structural requirements while effectively passing fish. These include a concrete broad-crested weir with concrete apron and a river-left traditional concrete Fish Ladder (Alternative A) and a river-wide Rock Ramp with a notched Low-Flow Channel or “Fishway” (Alternative B). The primary purpose of the January 25, 2017 BRT meeting was to provide recommendations and specific criteria (depth and velocity) for the Rock Ramp and compare and contrast the two preferred alternatives (A & B).

Table 1. NMFS criteria for fingerling (greater than 60 mm) salmonid screening and bypass (NMFS 2008).

NMFS Criteria for Salmonid Fingerling (≥60 mm)	
SCREENING	
Structure Placement	In-canal screens require an effective bypass return.
Approach Velocity	The component of the velocity vector that is perpendicular to the screen face shall not exceed 0.8 feet per second.
Sweeping Velocity	The component of the velocity vector that is parallel and adjacent to the screen face shall be GREATER than the approach velocity.
Screen Face Material/Size	Stainless steel wedge wire spacing shall not exceed ¼-inch (6.35 mm) in width and shall provide at least 40% open area.
Structural Consideration 1	The face of all screen surfaces (panels) shall be placed flush with structural supports to allow unimpeded movement parallel to the screen and provide ready access to the bypass entrance.
Structural Consideration 2	Screen surfaces shall be constructed at an angle to the approaching flow, with the downstream end terminating at the bypass entrance.
Structural Consideration 3	The structure shall provide screen protection from large debris through the use of trash racks (BRT recommends a 4-inch (100-mm) spacing minimum on the trash rack to reduce potential "gilling" of larger fish), log booms, sediment sluices or other measures as needed.
Structural Consideration 4	Designs shall minimize undesirable hydraulic effects that may delay or injure fish, or provide predator opportunities (eddies, stagnant flow, turbulence, etc.).
BYPASS	
Bypass Layout	The screen and bypass shall work in tandem to move entrained fish back to the river with minimum injury or delay. Screens shall be constructed with the downstream end of the screen terminating at the bypass entrance.
Bypass Entrance	Must extend from floor to water surface.
Bypass Entrance	Requires independent flow control capability.
Bypass Entrance	The bypass entrance velocity must equal or exceed the maximum flow velocity vector resultant upstream of the screens.
Bypass Entrance	Ambient lighting conditions are required from the bypass entrance to the bypass flow control.
Bypass Channel/Conduit	Require smooth interior bypass surfaces to minimize turbulence, debris accumulation, and the risk of injury to juvenile fish.
Bypass Channel/Conduit	Bends shall be avoided to reduce debris clogging and injury to fish.
Bypass Channel/Conduit	Require a minimum depth of flow of 0.75 ft (0.23 m) or greater.
Bypass Channel/ Conduit	Require a width/diameter of 24 inches (0.610 m) or greater.
Bypass Channel/ Conduit	Require d a pipe velocity of 2.0 fps (0.610 mps) or greater.
Bypass Outfall	Ambient river velocities should be greater than 4.0 fps (1.2 m/s).
Bypass Outfall	Located and designed to minimize avian and aquatic predation in areas free of eddies, reverse flow, or known predator habitat.
Bypass Outfall	Designed to avoid fish attraction or injuries from attempts to enter.

Bull Trout Movement as it relates to St. Mary Diversion Operations:

Different species and their various life-stages move different ways for different reasons and at different times of year, and those movements may be upstream, downstream or both. For example, many adult salmonids undergo a very distinct flow-, temperature- and sex-driven spawning migration and typically ascend fluvial systems by utilizing the lower velocity corridors along stream margins and taking advantage of the various resting and staging areas provided by bank structure. Conversely, out-migrating juveniles generally exhibit a broader period of emigration and often move downstream more passively in the faster flowing thalweg rather than along the margins. In general, juveniles and smaller fish do not swim as strongly as larger fish or healthy adults of the same species. Since the timing and frequency of fish movement vary among species and watershed, knowledge of the specific behaviors of the target species is vital to the development and operation of a successful passage structure. A primary step in the passage and screening design process is gathering all available information for the target species relating to life history requirements, movement patterns, and propulsion capabilities (NRCS 2007, NMFS 2008, FSOC 2012). The following is a brief description of those characteristics of the St. Mary Bull Trout and how they relate to operations of the proposed St. Mary Diversion Fish Screening and Passage Facility.

An upstream passage impediment is defined by NMFS (2008) as any artificial structural feature or project operation that causes adult or juvenile fish to be injured, killed, blocked, or delayed in their upstream migration, to a greater degree than in a natural rivers setting. Diversion dams often create significant passage impediments that fragment fish populations, isolating them from critical habitats and other upstream populations. This is true in the case of the St. Mary Diversion during the irrigation season (typically April –September) when the sluiceways are closed creating an upstream impoundment and a 6-ft high barrier to the upstream migration of fish. However, during the non-irrigation period (October-March) the sluiceway is opened allowing the river to flow freely through the dam with no upstream impoundment. Passage via the opened sluiceway, however, is certainly less than ideal. Although we have no information on water velocity through the sluiceway, the BRT has concerns with how the swift laminar flow over the entire length of sluiceway will affect upstream passage during non-diversion periods, especially during periods of elevated flows (i.e. heavy rain and snow-melt events) in the early spring and fall. Associated velocities are likely prohibitive for some smaller and less adapt swimmers.

Throughout the six months of irrigation at the St. Mary Diversion, when the dam is actually functioning as an barrier, juvenile and adult Bull Trout regularly attempt to move, albeit in opposite directions, past the diversion during their respective migrations. Studies of this population (Mogen and Kaeding 2005 a and b), as well as others (Fraley & Shepard 1989, Goetz 1989, Riehle et al. 1997, Downs et al. 2006), indicate most juveniles of migratory Bull Trout populations remain in natal streams at least two to three years before emigrating downstream to lake or large river habitats. This is consistent with what was observed during entrainment investigations at the St. Mary Diversion (2002-2006), where the majority of Bull Trout caught in the nets were of the sizes corresponding to age-2 and -3, and none were less than 100 mm in total length (Mogen et. al, 2011). During that study, downstream emigration of juveniles occurred throughout the diversion period, but the highest entrainment rates occurred in the spring (April-May) coinciding with increasing river temperatures and discharge prior to peak runoff. Other studies have documented similar patterns in juvenile emigration (Riehle et al. 1997 and Downs et al. 2006).

In contrast, adult migratory Bull Trout are typically moving upstream towards spawning tributaries during the diversion period. Mogen and Kaeding (2005a and 2005b) reported that adult Bull Trout residing in the St. Mary River (Montana and Alberta) began migration in early May, with increasing seasonal runoff. Migration peaked in June on the descending limb of the stream hydrograph, but extended through July and occasionally into late-August. The adults typically stage in tributaries throughout August and commence spawning in early to mid-September. Post-spawning downstream migration extends from mid-September through November, peaking in October. Fortunately, downstream irrigation diminishes and the headgates are closed before the majority of adult outmigration begins, precluding entrainment of most post-spawn downstream migrants. Other studies have described similar patterns in pre- and post-spawning migration (McLeod and Clayton 1997, Swanberg 1997, Howell et al. 2009).

Lastly, sub-adult Bull Trout (i.e. individuals that have already emigrated from tributaries to larger lake and river habitats but have not yet reached sexual maturity) remain fairly stationary within the larger habitat while they grow and mature with no innate need to move. This pattern is also consistent with what Mogen (2008) observed during late-July surveys in the St. Mary River, 2005-2007. Boat electrofishing along several reaches of river (about two miles total) between the Diversion and the Bureau's Camp Nine facilities (roughly 9 miles downstream) revealed eight species of fish (Appendix Figure 1). With most adults already in spawning tributaries, Bull Trout (14 total) accounted for less than three percent of the total catch in all years. Only one adult (475 mm total length) was captured with the remainder being sub-adults (233−351 mm). Mountain Whitefish dominated the catch, followed by Suckers, Salmonids and Burbot. Numerous small fish were observed but not captured, including Sculpins, Dace, Trout-perch and juveniles of the other species.

In addition to understanding the migration patterns of the target species, knowledge of their physical capabilities is equally vital to the design process. Any proposal for passage (and screening) must not impose artificial conditions that exceed those natural locomotive abilities of the target species (NMFS 2008).

NRCS (2007) defines the swimming characteristics of a fish as:

"Burst or Darting" –	Fastest swimming speeds with endurance less than 20 second and ending in extreme fatigue.
"Cruising" –	Intermediate swimming speeds with endurance from 20 to 200 seconds and ending in fatigue
"Sustained" –	Slowest swimming speeds with endurance maintained for extended periods of time with little to no fatigue.

Although comparable propulsion statistics are available for many northwestern salmonids (Figure 1), limited information exists on the specific swimming capabilities of Bull Trout. Mesa et al. (2008) reported maximum (burst/darting) swimming speeds of 4.3 to 7.5 ft/s in their study of sprint swimming performance of wild Bull Trout. FSOC (2012) provides prolonged (sustained) swimming speeds for both adults (1.3-2.8 ft/s) and juveniles (1.5-1.7 ft/s) but did not determine burst or cruising speeds for Bull Trout. In the absence of specific swimming performance information for target species, NRCS (2007) recommends using reliable data from similar species with comparable swimming and behavioral characteristics.

Within the St. Mary watershed, Bull Trout appear to be dominant in terms of swimming ability. They are often observed higher in the system, capitalizing on their climbing capabilities by exploiting habitats above significant gradient and velocity obstacles. For example, Canyon

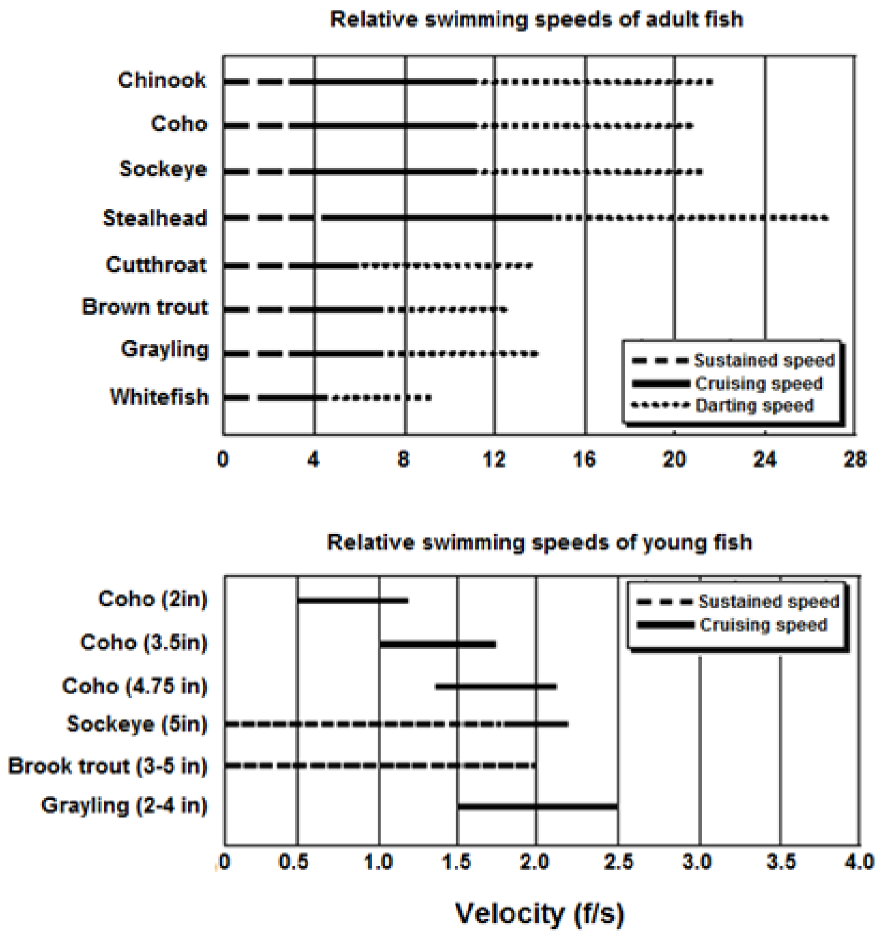

Figure 1. Relative swimming speeds of various salmonids of the northwest United States (NRCS 2007).

Creek, a tributary to Sherburne Reservoir, contains some high-velocity/high-gradient reaches near its mouth that evidently preclude passage of the abundant Brook Trout and Mountain Whitefish residing immediately downstream. Similar situations exist in the Otatso and Kennedy drainages with Cutthroat Trout and Mountain Whitefish. Although the actual species/sub-species were not identified, burst swimming speeds reported for adult Cutthroat and Whitefish ranged from 9.8 to 13+ ft/s and 2.6 to 9+ ft/s, respectively (NRCS 2007, FSOC 2012), while the smaller (3-5 in) Brook Trout swim at about 2 ft/s during bursts (NRCS 2007).

Passage Alternatives:

Both passage alternatives (Fish Ladder and Rock Ramp) allow for the diversion of 850 cfs of water and safe downstream energy dissipation, while providing effective screening and passage for Bull Trout and potentially other native fishes. Both options use identical canal-related features including Headworks, Trash Racks, Transition Flumes, Fish Screens and Bypasses. Both options also use identical Sluiceway structures, except that under the Rock Ramp alternative, the Fish Ladder is removed leaving the Sluiceways immediately adjacent to the left river bank. Lastly, both options adhere to NMFS (2008) Screening and Passage Specifications where appropriate (Table 2).

Table 2. NMFS passage criteria for stream salmonids at ladders and rock ramps (NMFS 2008).

SALMONID PASSAGE	
Passage Depth	Depths greater than 1 foot.
Fishway Entrance	Must be located at points where fish can easily locate the attraction flow and enter the fishway.
Fishway Entrance	The minimum fishway entrance width should be 4 feet
Fishway Attraction	Attraction flows of at least 5% of design high flow. The higher the percentage of total flow, the better.
Hydraulic Drop	Must be maintained between 1 and 1.5 feet and designed to operate from 0.5 to 2.0 feet of hydraulic head.
Ladder Velocity	Velocity in ladders through fishway entrances and over fishway weirs must be between 1.5 and 4.0 ft/s.
Roughened Channel Velocity	Also referred to as rock ramps, the average chute velocity should be less than 5 ft/s.
Passage Impediment	Defined as water depths less than 10-inches or flow velocity greater than 12 ft/s over 90% of the stream channel cross section.

Preferred Alternative A **– Fish Ladder**

This alternative includes a concrete broad-crested weir with an elevation drop of about 5 feet to the invert of a 15-foot concrete apron (Figure 2; USBR 2016). The vertical obstacle will prohibit upstream fish movement under most flow conditions Passage will be restored through the construction of a concrete all species Fish Ladder (0.25-ft drops) or one built only to Bull Trout standards (1-ft drops) as specified by NMFS (Table 2). Alternative-A simply moved the Fish Ladder from its former river-right position to a new river-left location immediately downstream from the Headworks. This new position should provide better Bull Trout attraction as it now contains source water from Boulder Creek, the most likely spawning destination for upstream migrating adults. The BRT previously provided recommendations on the specifics of the Fish Ladder that were subsequently incorporated into its design. Technically nothing more has changed concerning the ladder and we have nothing more to add on that regard.

Moving the ladder to its new location, however, revived our previous concerns with entrainment of upstream moving fish. Specifically, we had concerns with placing the Ladder Exit immediately adjacent to the Canal Headgates which would presumably offer up tired and disoriented fish to entrainment as they exited the ladder. Although the in-canal Fish Screen and Bypass should safely return the fish to the river, the potential for canal fallback, unnecessary delay and unsuccessful passage seemed likely. BRT concerns about the Fish Ladder exit were addressed at the 2015 Denver TSC model visit where neutrally buoyant water beads were introduced into the physical model upstream of the diversion headworks and observed as they dispersed downstream at various flows and diversion rates. Although some beads (~25%) were entrained by the headworks as they passed, the majority of beads tended to float past the gate openings and down the ladder or was circulated back upstream along the retaining wall. Bead behavior demonstrated that the “pull” of the canal inflow, which is ultimately controlled by the downstream Fish Screen and Check Gates, was considerably less than expected at all flows. Colored dye and velocity modelling similarly suggested minimal entrainment potential at the headgates. Lastly, velocities measured through the Trash Rack at the typical diversion rate of 650 cfs were sufficiently slow (~1 ft/s) to minimize impingement of larger fish and allow two-way volitional movements of fish through the Trash Rack (4-inch spacing minimum).

Figure 2. Photos of 1:12 scale physical model of proposed St. Mary diversion Dam at USBR Denver Technical Service Center (TSC). **Preferred Alternative A** (top photo) – showing crest of dam, 5 ft. vertical drop and 15-ft. wide downstream energy-dissipation apron. A Fish Ladder (not shown in the foreground) has been chosen to provide fish passage with this alternative. **Preferred Alternative B** (bottom photo) – showing crest of dam with river-wide Rock Ramp extending downstream at 10 % grade. This alternative would provide in-river fish passage and would not require a fish ladder. Dam sluiceway sits in the foreground.

The BRT believes that a river-left Fish Ladder built according to NMFS (2008) criteria with a secure flow allocation, submerged openings (i.e. ladder exit positioned 2 ft. lower than the dam crest elevation) and sufficient attraction flow should adequately pass fish under normal annual flow extremes. As we have stated in past BRT recommendations on the specifics of the Fish Ladder, we do have concerns with the size of the ladder entrance (2 ft x 3 ft), which does not meet NMFS criteria of at least 4 ft in width, and the lack of adequate attraction flow conveyed through the ladder during higher flows, again not meeting NMFS attraction flow criteria of at least 5% of total flow. However, providing additional attraction flow through piping or the upstream Sluicegates to the Ladder Entrance should aid in guiding fish to the undersized opening.

Preferred Alternative B **– Rock Ramp:**

Instead of a vertical drop onto a concrete apron which requires a more traditional ladder type passage structure, Alternative-B incorporates a river-wide Rock Ramp that slopes from a concrete broad-crested weir downstream to the river's natural grade (Figure 1; USBR 2016). This design better emulates the river, providing fish with a more-natural, channel-like connection to upstream habitats while minimizing channel scour and safely dissipating downstream energy. In theory, this more-natural option should also provide passage to a wider variety of life stages and fish species.

Fish Passage structures must be functional over a broad range of flows and must be adapted to the variations of upstream and downstream water levels. This is true at the St. Mary Diversion where typical mean annual instream flows vary from highs near 3,000 cfs to equally important sustained annual base flows of less than 100 cfs (Figure 3). Whereas Alternative-A (Fish Ladder) should function effectively at most St. Mary River flow levels experienced during the diversion period, the effectiveness of Alternative-B (Rock Ramp) may be more closely tied to flow conditions - particularly sustained flow extremes.

The ramp will be composed mostly of large boulders (36-inch minus angular stone) with the upper third of the ramp surface being grouted (20 of 60 ft.) and is designed to withstand and pass large flows with minimal structural damage. This roughened-channel design should offer Bull Trout (and potentially other fishes) full-river passage during higher flows. However, because of the extreme variability in flow that occurs annually at the diversion, a uniform Rock Ramp may not pass fish under all river stages. High flows can create velocity barriers, especially when accelerated over a lengthy in-cline while low flows may not be sufficient to saturate the porous ramp and provide adequate swimming depths along its entire length.

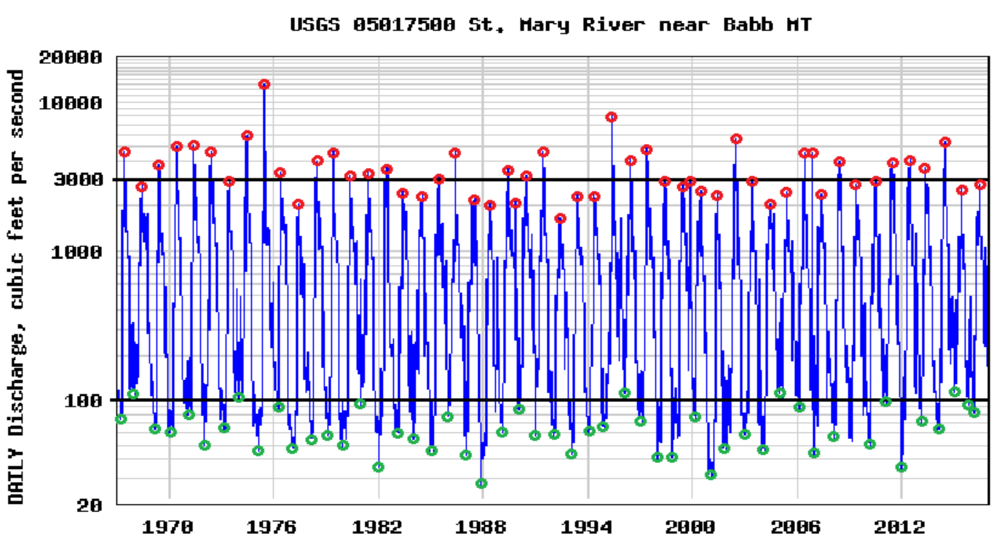

Figure 3. Daily discharge showing annual maximum (red dot) and minimum (green dot) flows over the past 50 years, 1976-2017, St. Mary River, St. Mary Diversion, MT (nwis.waterdata.usgs.gov). Measurements are taken upstream from the diversion and include Milk River Project allotment (up to 700 cfs for the time period shown) during periods of diversion (i.e. late-March to early-October).

High-Flow Concerns

The 1:12 scale replica model (Figure 2) of the proposed Rock Ramp was built at a 10% grade resulting in a 60-foot incline. The model possessed a homogenous boulder surface with little complexity and did not incorporate grouting or a low-flow "notch" or "channel" as specified in the design plans. Still, the simplified ramp provided important high-flow testing to assess the potential for creating a velocity barrier for upstream-moving fish during high flows. While conducting various realistic high-flow scenarios TSC engineers measured surface velocities on the model ramp (USBR 2017):

Modeled Flow		Surface Velocity
600 cfs	→	4.3 fps
3,600 cfs	→	6.5 fps
6,000 cfs	→	8 fps
10,000 cfs	→	10 fps

Initial results were encouraging. Under all test scenarios the resulting velocities fell below the threshold of a passage impediment as defined for salmonids (12 fps) by NMFS (2008) and should be, at least in theory, sufficiently low to allow Bull Trout and various other species to swim on the ramp during essentially all realistic flow levels.

The BRT, however, has concerns regarding the distance over which these velocities are maintained. Fish that are forced to swim with bursts or continuous cruising speeds for a long time or distance will succumb to fatigue and stress with repeated attempts. This is especially true on long uniform incline surfaces that offer no opportunities for rest. In general, if velocities on the ramp exceed the sustained swimming abilities of the target species for long distances, adequate resting habitat must be provided on the ramp surface (Katopodis 1991, NRCS 2007). Resting habitat allows fish to ascend the ramp at a slower pace, darting from one alcove to another, with less stress and fatigue. Specific velocity criteria would then be applied only to the max flow measured in the shortened connections (chutes) between the refuge areas and should not be greater than the burst swimming abilities of the target species.

The current Rock Ramp design incorporates a notched crest that will concentrate flow into a fully grouted, engineered, Low-Flow Fishway on the ramp surface (USBR 2016). This channel should possess numerous larger embedded boulders that are strategically situated in a way that best provides channel complexity and resting alcoves for upstream migrants. Smaller localized areas within the boulder field of the ramp may also provide refuge and reduced velocity passage routes for smaller and weaker-swimming non-target species, but measuring these localized velocities is nearly impossible and consequently, determining what species can ultimately pass upstream at various flows will be problematic.

Low-Flow Concerns

While high flows and their associated higher velocities only affect upstream passage, low-flow conditions have the potential to compromise both upstream and downstream passage on the Rock Ramp. Instream flow in early spring (before run-off conditions) and late summer (base-flow after diversion) is typically quite low (Figure 3). With 100 cfs or less often spilling over the entire length of weir, resultant water depths diminish to only inches or less at the dam crest. Conditions will be further exacerbated by the requirements of the proposed Canal Screen and Bypass system which calls for an additional 30-40 cfs to be temporarily diverted and returned downstream through the Bypass, significantly reducing the volume of spill that would otherwise be available for passage on the ramp. Lastly, though we do not have a clear understanding of interstitial flow through the highly porous Rock Ramp, any water lost to sub-flow through the structure will not be available for fish on its surface.

The BRT has two obvious concerns associated with low-flow conditions. First, will there be sufficient depth to allow swimming over the entire length (and width) of ramp surface? NFMS (2008) recommends minimum passage depths of 12 inches and considers depths less than 10 inches to be passage impediments (Table 2). Clearly, under typical annual low-flow conditions where only inches (or less) spill over the crest, adequate swimming depths will not be achieved if the spill is distributed across the entire width of the ramp. Secondly, will the loss of surface water to interstitial flow cause stranding or even impingement of fish on the ramp surface, especially those fish moving downstream over the crest?

The Rock Ramp design will incorporate a notched crest and an entirely-grouted, engineered Low-Flow Fishway that should concentrate flows and help considerably with maintaining adequate swimming depths (USBR 2017). Additional grouting of the upper portion (~ 1/3) of the remaining ramp surface should also help conserve surface flow on the ramp during periods of low-flow.

<u>Alternative Comparisons:</u>

The BRT finds that when accompanied by a NMFS-compliant Fish Screen and Bypass system that effectively returns entrained migrants to the lower river, both alternatives (Fish Ladder and Rock Ramp) will provide a safe and functional upstream and downstream passage corridor for ESA-protected Bull Trout and some other non-target species throughout the range of typical river discharges at the proposed St. Mary Diversion. Both alternatives will also meet the primary objectives of diverting water for irrigation and safely dissipating hydraulic energy downstream.

Fish Ladders are a well-studied technology and are relatively common on the landscape. Built of concrete, they are designed to withstand extreme environmental conditions and should function under normal annual river discharges at the St. Mary Diversion, from peak flows down to around 20 cfs (USBR 2017). Gated ladder inflow provides operational flexibility and control. From fish-trapping to PIT Tag detection systems, this option offers a variety of possibilities for monitoring fish movement within the regulated environment of the Ladder. It also provides a unique opportunity to conduct selective fish passage and invasive species control through trapping and/or design feature alterations (i.e., increases in velocities and step elevations). Fish Ladders are typically more expensive, however, and generally require more maintenance.

From a biological perspective, a Fish Ladder appears very unnatural and does not provide full-river passage. Instead, this option requires fish to locate the small Ladder Entrance that is situated in the Sluiceway and separated from the main flow by the opposite Sluiceway wall. The entrance (currently designed at 2 ft x 3 ft) does not meet NMFS criteria of at least 4 ft in width and FWS Ecological Services will only support designs that meet NMFS criteria. If the Ladder option is selected the entrance size will need to increases appropriately. Also, the maximum design flow capacity of the Ladder (~30-40 cfs) fails to meet NMFS attraction flow criteria of at least 5% of total flow at instream flows above 600-800 cfs. This will require routing additional attraction flow from the upstream impoundment to the Ladder Entrance during higher flows, either through a gated pipe or by incrementally raising the upstream Sluicegates. Presumably, finding the small entrance will become increasingly difficult during normal annual high-flow conditions (Figure 3).

If the Fish Ladder option is chosen, the BRT would prefer a structure capable of passing all species and a long term monitoring, trapping, and selective passage program to address concerns with Aquatic Invasive Species (introduced Walleye are present downstream in St. Mary Reservoir). Glacier Park and the Blackfeet Tribe would also prefer a Fish Screen and Bypass system that is capable of filtering the smallest fish feasible, preferably adhering to NMFS criteria for salmonid fry rather than fingerlings (NMFS 2008). Both have verbally stated their concerns and requests, and Glacier National Park has formally submitted comments to this regard twice during previous scoping periods.

Collectively, however, the BRT agrees that while monitoring and invasive species control is important, providing safe and effective two-way passage for Bull Trout and as many other native species as possible should remain our top priority. Although we agree that a traditional concrete Fish Ladder would suffice in passing fish and offer opportunities for monitoring and selective passage, we believe that an engineered surface of a Rock Ramp that delivers adequate swimming depths and offers resting habitat and fish-passage corridors through step-pool sequencing that mimics natural streambed configurations in the St. Mary watershed will provide better passage opportunities for Bull Trout and other fishes. Not only is the Rock Ramp a more natural and visually appealing option, but it is better at preventing scour and structural undermining, safer for the public, and should be more cost-effective (USBR 2017).

For fish, the Rock Ramp option provides a more natural environment that spans the full width of river. Fish are not required to find a small concrete opening, but instead have full channel passage during normal and higher flows. During periods of low-flow, adequate depths, velocities and refuge are ensured within the fully grouted Low-Flow Fishway that extends the full length of the ramp to the downstream thalweg of the river. Similarly, rather than a small opening at the exit and near the Canal Headworks, the full-channel width of the Rock Ramp should reduce the incidents of falling back and entrainment of ascending fish. Finally, the natural shape and composition of the Rock Ramp will provide additional benefits to numerous other species including river mammals, waterfowl, reptiles, amphibians, insects, mollusks, and crustaceans.

Compared to traditional ladders, providing passage via a roughened inclined surface of a Rock Ramp is a relatively new technology with evolving criteria (USBR 2007, NRCS 2007, Mesa et al. 2008, FSOC 2012). At low-head dams such as the St. Mary Diversion, however, these structures have been used for several years to successfully pass numerous species of fish, many of which are much less capable swimmers than Bull Trout. For Example, a Rock Ramp on the Red River of North Dakota (photos shown in Appendix Figures 2 and 3) provides upstream passage for a number of warm-water fishes, including Redhorse Sucker, Walleye, Northern Pike, and various other sucker and minnow species (NRCS 2007).

Specific BRT Recommendations for Alternative-B, the Rock Ramp:

Although NMFS does not provide specific guidance for Rock Ramps, several inferences can be made as to appropriate depths, gradients, velocities and habitat features based on observations of natural in-stream obstacles that local target-populations regularly contend with. If conditions on the Rock Ramp, and especially within the engineered Low-Flow Fishway, can be achieved that are similar to passage conditions in the natural stream, we should expect that the properly constructed roughened channel of a Rock Ramp will pass all life stages and species that arrive at the Diversion (NMFS 2008). Further, the constructed roughened surface is a particularly good option for fish passage in fluvial systems with cobble-boulder channel beds like the St.

Mary River, (NRCS 2007, NMFS 2008 and FSOC 2012). The use of rock substrates and natural bed materials will help emulate the natural cascades, riffles and step-pool sequences that local fish regularly negotiate. By replicating these natural habitat features, a broader diversity of species and life stages will be able to utilize the ramp's surface.

The BRT collectively agrees that Alternative-B (Rock Ramp) with its naturally roughened surface and the addition of larger strategically placed boulders, constructed resting alcoves and grouted surfaces in the engineered Low-Flow Fishway (Fishway) and across the remaining ramp where feasible, will provide the most effective upstream corridor for Bull Trout and other fishes at the St. Mary Diversion. With fewer concerns regarding attraction flows, finding the fishway entrance, and fallback and entrainment, the more-natural Alternative-B is the BRT's preferred alternative. Listed below are specific BRT recommendations regarding the design of the proposed St. Mary Diversion Rock Ramp, including Ramp gradient, Fishway location and habitat features, Crest Notch location and capacity, Grouting requirements, and additional modeling recommendations.

1) Ramp Gradient - Design and modelling should include ramp slopes more comparable to natural stream gradients encountered by the local population.

As discussed earlier, the TSC-modelled Rock Ramp has a gradient of 10% over the resultant 60 feet of total ramp length. Other than the previously mentioned swimming performance estimates that relate more to stream velocities than gradient and the general NMFS (2008) recommendations in Table 2, the BRT cannot find data-driven scientific support for passing Bull Trout over a consistent 10% incline of any length. Although resultant water velocities on the modelled ramp appear to be manageable at most flows, a 10% gradient seems excessive when compared to natural stream gradients encountered by Bull Trout during migrations from the lower river to the spawning area in upper Boulder Creek. Average stream gradients along this corridor vary from 0.2% in the relatively flat 1-mile stretch of river from the Diversion upstream to the mouth of Swiftcurrent Creek to 2.9% over the lower 4 miles of Boulder Creek (Table 3). Further, with the exception of the Diversion Dam itself, nowhere along the entire 20.1-mile corridor do fish encounter waterfalls, cascades or other vertical passage impediments with gradients greater than 4.0%. In other St. Mary drainages, however, Bull Trout regularly negotiate similar and even higher gradient impediments during annual spawning migrations (Figure 4). All of these obstacles, however, possess high channel complexity that provides passage through natural step-pool sequences formed by bedrock sills, large boulders, logs and/or debris – habitat features not currently incorporated in the design for the entire Rock Ramp surface.

The problem with excessive gradient is really the associated water velocities that impede upstream movement of fish, especially during high flows. However, simply reducing ramp gradient to accommodate the swimming capabilities of fish comes at the expense of a proportional increase in the total distance that fish must travel to ascend the ramp. Ultimately, if water velocities exceed the sustained swimming abilities of the target species for extended distances, adequate resting habitat must be provided or fallback will be an issue. Of course adding roughness and complexity will break up laminar flow and reduce local velocities but they too come at a price – increased cost and maintenance. The real challenge here is finding that unique combination of gradient, velocity, length and roughness that works best for fish moving upstream on the ramp surface during higher flows. The BRT would like to see resultant surface velocities from additional ramp modeling that includes reduced ramp gradients of 5-7%.

Table 3. Stream reaches and corresponding lengths and average gradients for various segments of Bull Trout migration corridor from the lower St. Mary River to the Boulder Creek spawning area.

Stream Reach	Reach Length	Average Stream Gradient
Lower St. Mary River (International Boundary to St. Mary Diversion)	9.0 miles	0.4 %
St. Mary Diversion to the mouth of Swiftcurrent Creek	1.0 miles	0.2 %
Lowermost Swiftcurrent Creek to Boulder Confluence	2.7 miles	1.3 %
Lowermost Boulder Creek	4.1 miles	2.9 %
Middle Boulder Creek	1.7 miles	1.7 %
Boulder Spawning Area	2.0 miles	0.8 %
Total Corridor	**20.1 miles**	**1.4%**

2) Low-Flow Fishway - Depths, Velocities and Habitat Features

The BRT remains concerned with diminishing instream flows during the latter period of adult upstream migration which can extend through August. To ensure passage throughout this period, the BRT strongly recommends a fully-grouted Low-Flow Fishway constructed on the ramp surface that extends from a Notch in the dam's crest to the toe of the ramp. The Fishway should be designed to convey all base flow (minimum instream flow) and maintain biologically adequate depths and velocity conditions throughout the period of operation.

NMFS (2008) recommends passage depths of at least 12-inches and defines a passage impediment as water depths less than 10-inches or flow velocity greater than 12 ft/s over 90% of the stream channel cross section. Based on our thorough observations of essentially all BLT migration corridor habitats within the St. Mary watershed, the BRT concurs with these criteria and supports maintaining a minimum depth of 12 inches throughout the Low-Flow Fishway, but strongly recommends considerably greater depths in constructed pool habitat (resting habitat).

The arrangement of Boulders and other bed materials within the grouted fishway should demonstrate channel complexity similar to the characteristics of the natural stream bed. The use of large rock with smaller fill materials should emulate the natural passage features (cascades, riffles and step-pool sequences) that fish are accustomed to moving through. Strategically placed boulders will provide sills and pool habitat sufficiently deep and slow to allow for recovery of fatigued fish. Under this configuration, specific velocity and head-differential criteria (NMFS 2008) would only apply to the short transitions (chutes) between resting habitat features. Accordingly, the BRT recommends average chute velocities of less than 5 fps and maximum head differentials of 6-12 inches. These criteria should allow a number of fish species and size-classes to ascend the ramp while moving at a slower pace, darting from one pool to another with less stress and fatigue.

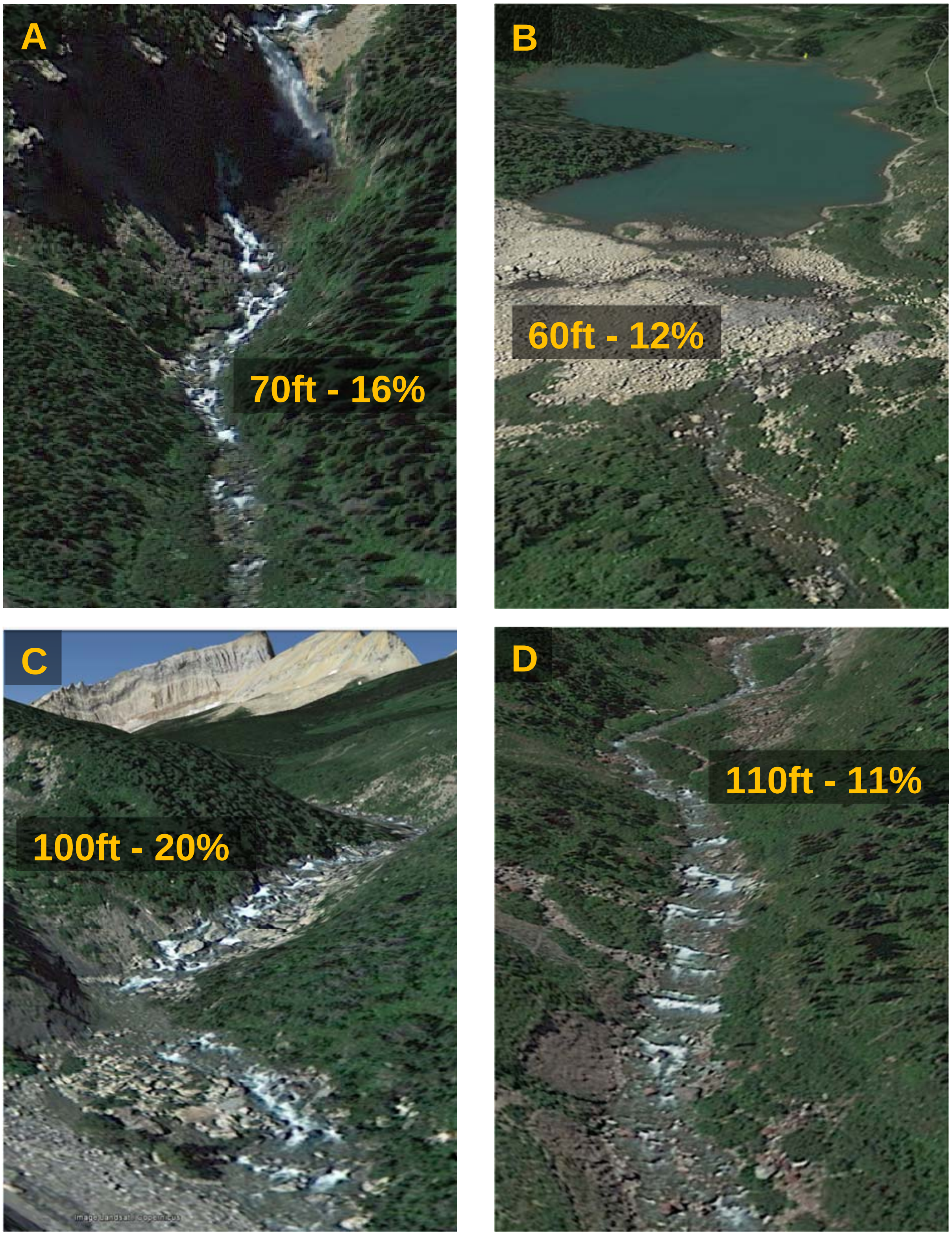

Figure 4. High-gradient (>10%) stream reaches that are regularly navigated by adult Bull Trout during upstream spawning migrations in (A) upper Otatso Creek just below Otatso Falls, (B) Otatso Creek at the outlet of Slide Lakes, (C), Otatso Creek at Park Line Falls, and (D) upper Canyon Creek downstream from Cracker Lake.

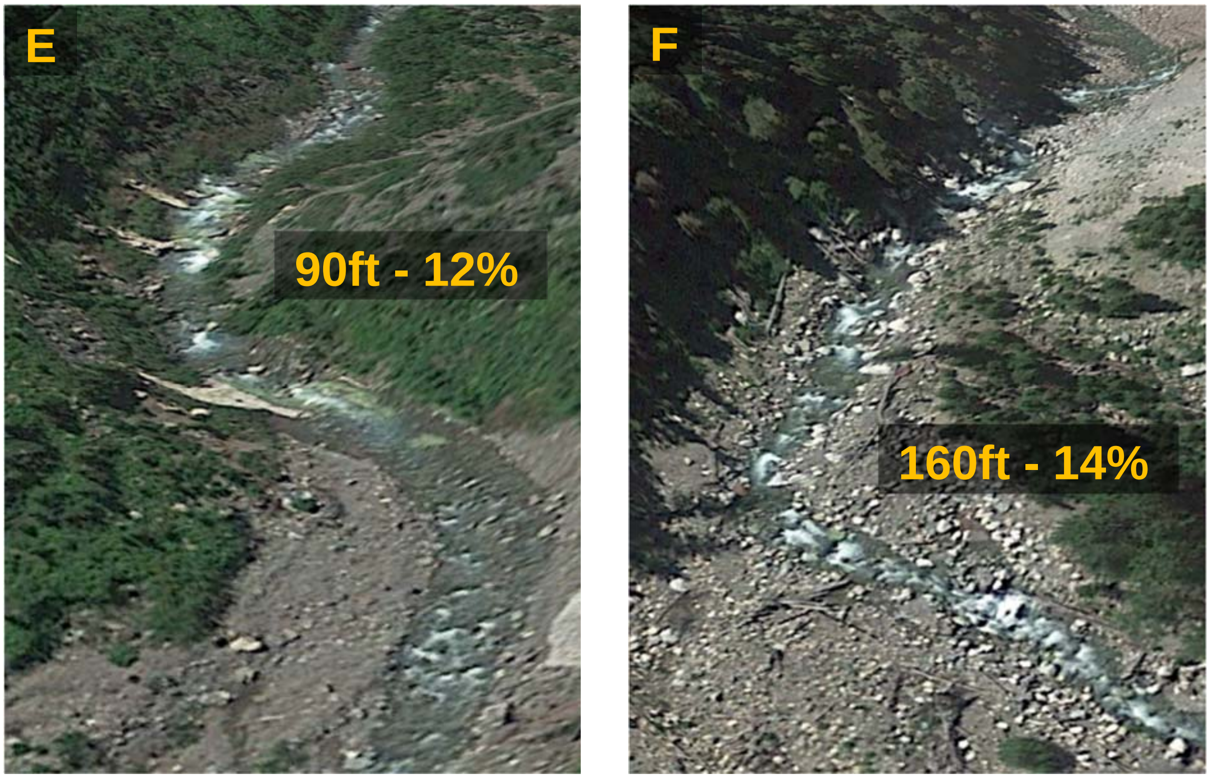

Figure 4 (cont.) High-gradient (>10%) stream reaches that are regularly navigated by adult Bull Trout during upstream spawning migrations in (E) middle Canyon Creek and (F) lower Canyon Creek.

3) Crest Notch Capacity - Capture all base flow up to 100 cfs

The BRT recommends that the Crest Notch be capable of capturing all available instream flow below a minimum of 100 cfs (i.e., the entirety of base flow; Figure 3), with the remainder of the Crest and Rock Ramp designed to withstand and safely pass remaining flows with minimal structural damage.

4) River-Left Location of Crest Notch and Low-Flow Fishway

The pull of the river-left Headworks will train the St. Mary River to pass the gates and allow diversion of Reclamation's water right. Similarly, operation of the river-left Sluiceway in conjunction with the Dam Crest that extends to the opposite (right) bank will result in scour and thalweg formation along the downstream river-left bank. The BRT recommends placing the Crest Notch and Low-Flow Fishway nearer to the left end of the Dam Crest. This location should increase overall functionality in a number of ways. First, it better aligns the Fishway with the downstream river channel and should assist with formation and maintenance of the downstream river-left thalweg. Secondly, a river-left location provides the best opportunity at capturing Boulder Creek water (i.e., the "smell" of natal spawning stream) at all flow stages, helping to alleviate concerns regarding attraction flow and mixing (or lack thereof) of Boulder Creek and Lower St. Mary Lake outflow. Lastly, directing the flow along the left river bank assures maximum river depth and flow immediately downstream at the river-left outlet of the Screen Bypass as specified by NMFS Bypass Outflow Criteria (Table 1; NMFS 2008).

5) Grouting Requirements and Bed Materials

The BRT agrees that the loss of surface water to interstitial flow would likely prevent maintenance of the recommended 12 inches or more of depth (NMFS 2008) and preclude full width passage on the ramp, at least during periods of low flow. To an effort to reduce this loss, we support the design plans to fully grout the entire Low-Flow Fishway channel and the upper portion (approximately the upper third) of the remaining ramp. The BRT also recommends that the Rock Ramp be composed of an appropriate mix of bed materials ranging from fines to boulder-sized substrates. The diversity of materials should help fill the voids between the larger substrates and substantially reduce interstitial flow. Uncertainty of interstitial flow capacity may require additional design and modelling.

6) Additional modelling recommendations.

To gain a better understanding of how various aspects of the proposed St. Mary Diversion facilities affect fish passage, the BRT recommends that TSC further model the following items.

- Additional ramp modeling that includes reduced ramp gradients of 5-7%. The BRT would like to see resultant surface velocities on the ramp.

- Entire Rock Ramp under average to base flow conditions. TSC has provided encouraging modeling results for moderate to high instream flows (600-10,000 cfs), but the BRT has equally important concerns regarding performance under average to low flow conditions. We are particularly interested in the conveyance ability of the ramp surface, water loss to sub flow, effectiveness of grouting and resultant water depths.

- The fully-grouted Low-Flow Fishway with the various habitat features under average to base flow conditions. We are especially interested in the velocities in pools (resting habitat) and their connections (chutes); the minimum depths in pools and their connections; and maximum head differential between pools when flows are limited.

- Crest notch effectiveness at concentrating discharge and capturing base flows under moderate to low-flow conditions.

- Sluiceway velocities during non-diversion period. Although we have no information on water velocities through the sluiceway, the BRT is concerned with upstream passage through the open Sluiceway, especially during periods of elevated flows (i.e. heavy rain and snow-melt events) occurring in the early spring and fall. Associated velocities are likely prohibitive for some smaller and less adapt swimmers. The BRT recommends we model the Sluiceway velocities under realistic base-flows down to about 50 cfs.

Future National Environmental Protection Act (NEPA) Considerations:

The NMFS salmonid fingerling screen is not a unified recommendation of the BRT as the NPS and Blackfeet Tribe have advocated for smaller screening criteria (NMFS fry) to better protect other species which migrate through the system at smaller sizes. This is an outstanding issue that will be discussed in depth in future NEPA documents. Selective passage is also preferred by the NPS and Blackfeet to keep aquatic invasive species, specifically non-native walleye, which reside downstream in the St. Mary Reservoir, Alberta.

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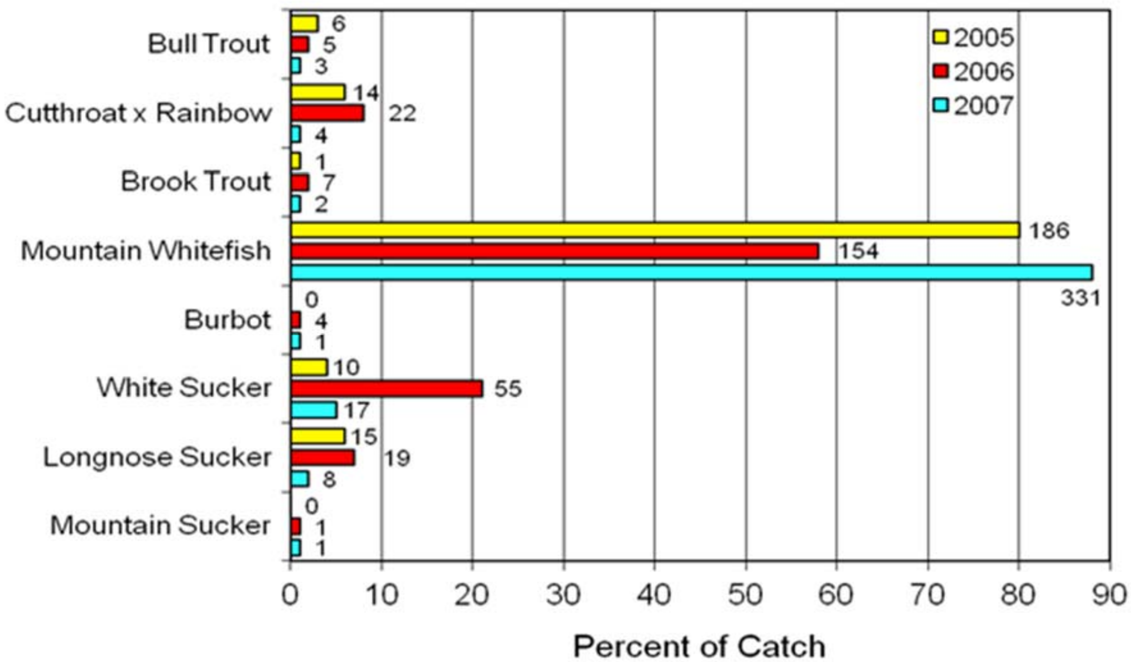
APPENDIX



Appendix Figure 1. Percent composition of total catch during summer electrofishing surveys in the St. Mary River, downstream from the St. Mary Diversion, Montana, 2005-2007.

Appendix Figure 2. North Dam on the Red River, ND (top two photos) before construction of Rock Ramp (bottom photo). Photos captured from Google Earth, 2017.

Appendix Figure 3. Rock Ramp at various river stages, Red River, ND.