Willwood Dam Operating Recommendations Summary
November 7, 2017

Fall Draw-Down, Spring Sluice, Irrigation Season

Activity	Dates	Fisheries/Willwood Irrigation District Objectives	Average Turbidity (NTUs)	24-Hour Maximum Turbidity (NTUs)
Fall Draw Down	Oct. 15th – Oct. 31st	Minimize impacts to adult fish/Lower pool to avoid ice damage to canal gates	180	1,000
Spring Sluice	Mar. 28th – Apr. 12th	Minimize impacts to juvenile and adult fish/Controlled release of accumulated sediment	180	1,000
Irrigation Season	Apr. 13th – Oct. 14th	Minimize impacts to juvenile and adult fish/Maintain high pool levels for irrigation diversion, make releases from sluice gates when possible	110% of Upstream	1,000

Exceptions: When the turbidity of the Shoshone River upstream of Willwood Dam is above the recommendations, turbidity downstream of the dam should not exceed more than 110% of the upstream value (i.e., if upstream turbidity is 400 NTUs, turbidity downstream should not be more than 440 NTUs).

Notifications: When downstream turbidity is greater than 180 NTUs for more than 3 days during the fall draw down or spring sluice or downstream turbidity is greater than 1,000 NTUs for more than 24-hours, or circumstances arise that warrant evaluation, Willwood Irrigation will notify DEQ, Game and Fish, and other partners and discuss potential options.

November 1st through March 27th

Date	Fisheries/Willwood Irrigation District Objectives	If Upstream Turbidity is <100 NTUs	If Upstream Turbidity is > 100 NTUs
Nov. 1st – Dec. 31st	Minimize releases of sediment to avoid disruptions to spawning and egg development/Maintain pool below canal gates to avoid ice damage	10 NTU Increase	10% Increase
Jan. 1st – Mar. 27th	Minimize impacts to juvenile and adult fish/Maintain pool below canal gates to avoid ice damage	10 NTU Increase	10% Increase

Exceptions: When it is not possible for the dam to operate within the recommendations and also maintain the pool elevation below the bottom of the canal gates, the Irrigation District will minimize the turbidity downstream to the best of their ability without raising the pool elevation above the bottom of the canal gates.

Notifications: When downstream turbidity is greater than a 10 NTU or 10% increase for more than one week, downstream turbidity is greater than 1000 NTUs for more than 24-hours, or circumstances arise that warrant evaluation, Willwood Irrigation District will notify the DEQ, Game and Fish, and other partners and discuss potential options.

Rationale for Operating Recommendations for Willwood Dam
to Protect Downstream Shoshone River Fishery

November 7, 2017 Draft

1.0 SUMMARY

The Wyoming Department of Environmental Quality/Water Quality Division (WDEQ/WQD), in cooperation with the Wyoming Game and Fish Department, Willwood Irrigation District, the United States Bureau of Reclamation, the State Engineers Office, the Wyoming Water Development Office, and other stakeholders has developed preliminary recommendations for the operation of Willwood Dam. The recommendations are intended to: allow Willwood Irrigation District to deliver water to its users; provide the Willwood Irrigation District with the necessary flexibility to operate the dam in a manner that will protect the existing infrastructure such as lowering the reservoir pool each fall to prevent ice damage to the canal gates; allow for gate maintenance when necessary; and minimize the accumulations of sediment behind Willwood Dam while also maintaining suspended sediment and/or turbidity concentrations in the Shoshone River at levels necessary to meet this water's designated use as a coldwater fishery. These recommendations are aimed at protecting the naturally reproducing Brown Tout and Mountain Whitefish fisheries downstream from the dam as they are more sensitive than stocked trout. The recommendations are based on readily available information and will be updated as new information becomes available. As a general recommendation, to the greatest extent possible, the Irrigation District should time the release of sediment to those periods when the Shoshone River is transporting increased amounts of sediment, most notably during spring and summer flows. Recommendations for suspended sediment and turbidity concentrations downstream of Willwood Dam are included in Table 1.

2.0 BACKGROUND

The Operating Criteria for the Willwood Dam was last revised in 2011. Prior to this revision, the Willwood Irrigation District was planning a number of maintenance projects for the dam, including increased functionality for the sluice gates. As such, the 2011 Operating Criteria identified that it would be in effect between January 1, 2012 and December 31, 2014, or until the first phase of the Willwood Dam rehabilitation project was completed. Since the first phase of the Willlwood Dam rehabilitation project was completed in October/November of 2016, the Wyoming Department of Environmental Quality, Willwood Irrigation District, Wyoming Game and Fish Department, United States Bureau of Reclamation, the State Engineers Office, the Wyoming Water Development Office, and other stakeholders have developed the following operating recommendations that will replace the previous operating criteria. The operating recommendations are being revisited to help minimize the build-up of sediment behind the dam and acknowledge that limiting the dam to a 10 NTU increase during the non-irrigation season may not be necessary to protect the downstream fishery. This document provides revised suspended sediment and turbidity recommendations as well as the rationale and information used to derive the recommendations. It is understood by all parties that the recommendations developed here are based on a limited amount of information and are to be reviewed and updated as more information becomes available.

Table 1. Recommended average and 24-hour maximum suspended sediment and turbidity for the Shoshone River downstream from Willwood Dam

Activity	Date	Flow conditions and suspended sediment releases	Mean Discharge of Shoshone River Below Buffalo Bill 2007-2016 (cfs)	Average Suspended Sediment Concentration (mg/L)	Average Turbidity (NTUs)	24-Hour Maximum Suspended Sediment (mg/L)	24-Hour Maximum Turbidity (NTUs)	Newcombe and Jensen (1996) Severity Index
Fall Draw-Down	Oct. 15th – Oct. 31st	Flows tapering to baseflow; minimize impacts to adult fish	480	325	180	3,000	1,000	<9
Spring Sluice	Mar. 28th – Apr. 12th	Flows starting to increase; minimize impacts to juvenile and adult fish	690	325	180	3,000	1,000	<9
Irrigation Season	Apr. 13th – Oct. 14th	Peak flows; minimize sediment accumulation and impacts to juvenile and adult fish	1990	110 % of the Upstream	110% of the Upstream	3,000	1,000	<9

Exceptions: When the suspended sediment and/or turbidity of the Shoshone River upstream of Willwood Dam is above the recommendations, turbidity downstream of the dam should not exceed 110% of the upstream value (i.e., if upstream turbidity is 400 NTUs, turbidity downstream should not be more than 440 NTUs).
Notifications: When downstream turbidity is greater than 180 NTUs for more than 3 days, downstream turbidity is greater than 1,000 NTUs for more than 24-hours, or circumstances arise that warrant evaluation, Willwood Irrigation District will notify WDEQ/WQD, WGFD, and other partners and discuss potential options.

Table 2. Recommended turbidity for the Shoshone River downstream from Willwood Dam between November 1st and March 27th.

Date	Description of flow conditions and suspended sediment releases	Mean Discharge of Shoshone River Below Buffalo Bill 2007-2016 (cfs)	If Upstream Turbidity (NTUs) is <100 NTUs	If Upstream Turbidity is > 100 NTUs
Nov. 1st – Dec. 31st	Baseflow conditions; minimize releases of sediment to avoid disruptions to spawning and egg development	390	10 NTU Increase	10% Increase
Jan. 1st – Mar. 27th	Baseflow conditions; minimize impacts to juvenile and adult fish	370	10 NTU Increase	10% Increase

Exceptions: When it is not possible for the dam to operate within the recommendations and also maintain the pool elevation below the bottom of the canal gates, the Irrigation District will minimize the turbidity downstream to the best of their ability without raising the pool elevation above the bottom of the canal gates.
Notifications: When downstream turbidity is greater than a 10 NTU or 10% increase for more than one week, downstream turbidity is greater than 1000 NTUs for more than 24-hours, or circumstances arise that warrant evaluation, Willwood Irrigation District will notify the WDEQ/WQD, WGFD, and other partners to discuss potential options.

2.1 Turbidity, Suspended Sediment, and Bedload

Turbidity is a measure of the transparency of a liquid and is an expression of the amount of light that is scattered by material in the water when a light is shined through the sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid includes clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and other microscopic organisms (USGS 2017). Wyoming's current turbidity criteria provide the following limits: a 10 NTU increase to Class 1 and 2 cold water fisheries and/or drinking water supplies and a 15 NTU increase to Class 1 and 2 warm water or nongame fisheries. The criteria do not include a duration or frequency and do not provide any additional details on how to determine increases.

Wyoming's surface water quality standards have always included turbidity criteria, dating back to 1968. The current 10 NTU and 15 NTU increase in turbidity were first adopted in 1979, with the 10 NTU increase applying to Class 1 and 2 waters and the 15 NTU increase applying to Class 3 waters. In 1990, the 10 NTU increase criteria were first applied to coldwater fisheries and the 15 NTU increase criteria were applied to Class 3 waters and warmwater fisheries. The exemption for the Guernsey silt run was also added in 1990. The turbidity criteria were not specifically applied to the drinking water designated use until 2001, when the classification system changed significantly. The ability of the Water Quality Division Administrator to grant an exemption was also added in 2001. Wyoming's current surface water quality standards also include narrative criteria for settleable solids (Chapter 1, Section 15) and floating and suspended solids (Chapter 1, Section 16), which were first included Wyoming's surface water quality standards in similar form in 1968.

Although Wyoming has historically adopted United States Environmental Protection Agency (USEPA) recommended water quality criteria to protect designated uses, Wyoming's turbidity criteria do not appear to be derived from USEPA's recommendations. USEPA first released recommendations for turbidity in the 1976 Quality Criteria for Water document, known as the Redbook, which were left unchanged in the 1986 Quality Criteria for Water document, known as the Gold Book. The criteria were intended to protect aquatic life and recommended that "settleable and suspended solids should not reduce the depth of compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life" (EPA 1986).

EPA's current recommendations for "solids suspended and turbidity" reference the 1986 Gold Book and thus updated national recommendations do not currently exist. In an effort to evaluate the current science associated with suspended and bedded sediments, in August 2003, EPA developed a draft document describing potential approaches to developing water quality criteria for suspended and bedded sediments (SABS; USEPA 2003). USEPA defines SABS as particulate organic and inorganic matter that suspend in or are carried by the water, and/or accumulate in a loose, unconsolidated form on the bottom of natural water bodies. SABS is intended to include clean sediment, suspended sediment, total suspended solids, bedload, turbidity, or in common terms, dirt, soils, or eroded materials (USEPA 2017).

USEPA (2003) identifies that SABS are a unique water quality problem compared to toxic chemicals in that suspended solids and bedded sediments (including the organic fraction) occur naturally in water bodies and are essential to the ecological function of a water body. Suspended solids and sediments transport nutrients, detritus, and other organic matter which are critical to the health of a water body. Suspended solids and sediment in natural quantities also replenish sediment bedloads and create valuable micro-habitats, such as pools and sand bars.

SABS in excessive amounts, however, constitute a major ecosystem stressor that can cause deleterious impacts to aquatic communities. Likewise, sediment starvation caused by dams is also a problem in some ecosystems and can also cause significant changes to aquatic communities. Changes to SABS can alter the structure and function of communities of aquatic plants, algae, benthic invertebrates, as well as fish. Impacts to biota may be directly from SABS acting on organisms or indirectly from SABS through alteration of physical habitat that then cause impacts to biota (USEPA 2003).

USEPA's 2003 review also summarizes other state's approaches to water quality criteria for SABS and notes that approaches vary considerably. Some states have turbidity criteria, some have total suspended solids criteria, some of these criteria are numeric, while other criteria are narrative. In addition, some states have no SABS criteria at all. The review evaluates ways to potentially develop recommended SABS water quality criteria and concludes that the severity of impacts to changes in SABS quantity and timing is a function of many factors that include sediment concentration, duration, particle size, life history stage, temperature, and physical and chemical characteristics of the particles, which are generally site-specific. As such, it can easily be concluded that criteria for SABS should likely be site-specific and that efforts to derive criteria that apply to divergent waterbodies will likely result in identifying impairments due to sediment where they do not exist or missing impairments that do exist due to the inaccuracies associated with the criteria.

Therefore, to avoid deleterious impacts to aquatic communities on the Shoshone River, management of suspended and bedded sediments should, to the greatest extent possible, maintain natural or background levels and timing of SABS that are unique to the Shoshone River. As such, recommendations for the operation of Willwood Dam should follow the natural sediment movement within the Shoshone River. To achieve this, it is recommended that the dam modify operation of the sluice gates based on the turbidity and suspended sediment concentrations of the Shoshone River and maximize the movement of sediment during higher flows that extend from approximately April 1st to August 1st (Figure 1).

The exception to this recommendation would be in circumstances where the dam must be actively managed to fulfill operating requirements such as when the pool elevation must be lowered and maintained below the canal gates in the fall and winter to prevent freezing and damage to infrastructure. During this period, the primary focus of management will be on allowing the dam to lower the pool elevation below the canal gates while minimizing deleterious effects to the downstream naturally reproducing Brown Trout and Mountain Whitefish fisheries. The naturally reproducing fishery is the primary focus because the early life stages of these fish species may be present in the Shoshone River and are likely to be more sensitive than stocked adult salmonids. In addition, the population trends for these species are not directly influenced by stocking and can therefore be used to evaluate the impacts of various management activities. That said, the Shoshone River fishery as a whole is important due to the heavy use of the Shoshone River by anglers. This water is classified by the Wyoming Game and Fish Department as a blue ribbon trout fishery; historically it supported a biomass of >600 pounds of trout per mile. As such, the proposed recommendations are also intended to be as protective of the fishery as a whole.

3.0 Recommendations to Protect Shoshone River Fisheries

Based on information provided by the Wyoming Game and Fish Department, Brown Trout and Mountain Whitefish naturally reproduce in the Shoshone River downstream of Willwood Dam, while Cutthroat Trout and Rainbow Trout are regularly stocked. To minimize the impacts of SABS to the brown and Mountain

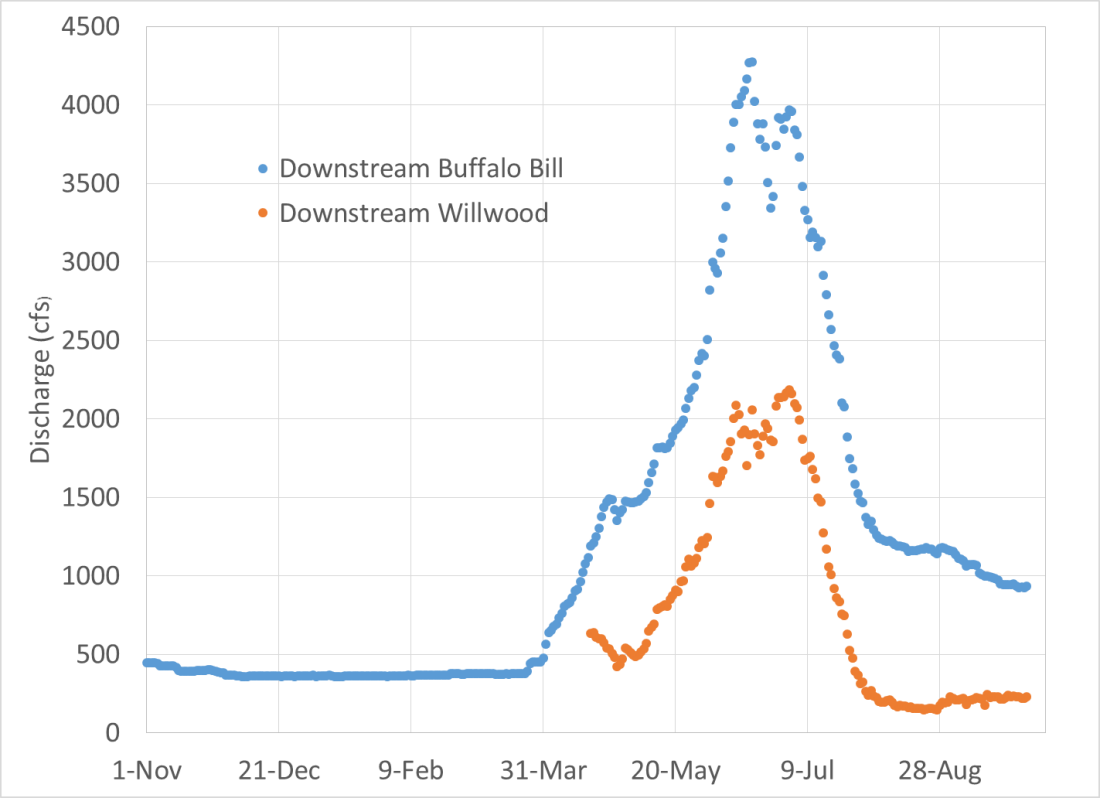

Figure 1. Mean daily discharge of the Shoshone River below Buffalo Bill Reservoir between September 2007 and February 2016 and over the crest of Willwood Dam between 2008 and 2017.

Whitefish fisheries, the non-irrigation season recommendations are intended to protect spawning, juvenile, and adult Brown Trout and Mountain Whitefish, depending on the life stages most likely to be present at a given time.

The main impacts of SABS to fish include behavioral effects, such as changes in the natural movements and migrations of fish; inability to see prey or feed normally that can reduce growth rates and reduce resistance to disease; physiological effects such as decreases in gill functioning or gill clogging. In addition, changes in the quantity and timing of SABS may lead to sediment deposition during critical periods that can result in the loss of spawning habitat, burial and suffocation of eggs and larvae. Severity of damage is related to the dose of exposure, the duration and exposure, as well as the size and angularity of the particles involved (USEPA 2003).

The following include the sensitive spawning and development periods for Brown Trout and Mountain Whitefish.

Approximate Spawning Period:	October 15-November 15th
Peak Spawning Period:	November 1st
Egg Development to Hatch:	October 15th - January 1st
Hatch to Juveniles:	January 1st -

3.1 Recommendations for Fall Pool Draw-Down (October 15th – October 31st)

During irrigation diversions, the reservoir pool elevation at Willwood Dam typically needs to be at or above the dam crest. Irrigation diversions normally conclude each fall around mid-October. Prior to winter and freezing temperatures, the pool elevation behind Willwood Dam must be lowered below the bottom of the canal gates to prevent ice damage to the gates. It is also critical in the winter that water not be allowed to flow over the top of the dam, as freezing may potentially damage the dam apron. The following recommendations are therefore intended to recognize these critical operational requirements for Willwood Dam while minimizing potential impacts to the downstream fishery.

Brown Trout and Mountain Whitefish use interstitial spaces at the bottom of streams to lay or broadcast their eggs. Even thin coverings of fine particles can lead to egg mortality or reduce successful egg hatch and emergence of larvae. As such, the reproductive success of these fish is dependent on limiting the deposition of sediment prior to spawning and also minimizing the deposition of sediment following spawning.

Since Brown Trout and Mountain Whitefish spawn between approximately October 15th and November 15th, it is recommended that the Willwood Irrigation District lower the water level below the canal gates prior to winter between October 15th and October 31st to minimize sediment deposition on potential spawning gravels and eggs during the latter half of the spawning period. During the October 15th to October 31st period, the primary objective would be to lower the pool elevation below the canal gates while also avoiding lethal effects to adult and juvenile Brown Trout and Mountain Whitefish by maintaining average suspended sediment concentrations below 325 mg/L and average turbidity levels below 180 NTUs. It is also recommended that the pool elevation be lowered over then entire 17-day period and any potential sediment released over the entire period, rather than one large pulse, so as to increase the likelihood that the sediment that is released remains in suspension and is not deposited on spawning habitat. In circumstances where the dam must release higher concentrations of suspended sediment than 325 mg/L and 180 NTUs while lowering the pool elevation, 24-hour average concentrations should be kept below 3,000 mg/L suspended sediment and 1,000 NTUs turbidity. Exceptions to these recommendations are circumstances where the upstream turbidity exceeds the recommendations; in such cases, the turbidity downstream should not exceed approximately 110% of the upstream concentration.

The 325 mg/L average suspended sediment threshold as well as the 3,000 mg/L 24-hour average suspended sediment thresholds were selected based on preventing lethal and paralethal effects (Table 2; severity index less than 9 during the 17-day period and 24-hour periods, respectively) to juvenile and adult salmonids (Model 1) in circumstances where particles sizes range from approximately 0.5 – 250 µm (Newcomb and Jensen 1996). Model 1 was selected because it is based on data from juvenile and adult salmonids and includes data from studies on Mountain Whitefish and Brown Trout (see Newcombe and Jensen 1996, Table 2). The equation below, from Newcomb and Jensen (1996), was used to derive the recommendations:

$$\text{Severity Index} = 1.0642 + 0.6068*(\ln(\text{Duration in hours})) + 0.7384*(\ln(\text{mg SS/L}))$$

Model 1 also seemed applicable based on the expected size of suspended sediment particles on the Shoshone River downstream of Willwood Dam. Suspended sediment particles are expected to be dominated by very fine sand or smaller (<250 µm), based on data collected during the October 2016

sediment release and analyzed by the University of Wyoming (McElroy 2017). McElroy (2017) stated that the October 2016 event at Willwood Dam liberated 96,000 cubic yards of very fine sand (62-125 µm in diameter) and silt (2.0 – 62 µm in diameter) from behind the Willwood Dam and that median grain sizes of deposited sediment were approximately 130 µm very fine sand near Willwood Dam and 30 µm coarse silt near Byron, NY.

The 180 NTU average and 1,000 NTU 24-hour turbidity thresholds are based on the relationship between total suspended solids and turbidity from 13 paired samples collected by WDEQ/WQD at a monitoring site immediately downstream from Willwood Dam (see Figure 2, below). Even though the data set is small, it is recommended that the relationship between total suspended solids and turbidity be used to derive turbidity recommendations for Willwood Dam because turbidity can be measured in real-time and can be used to make immediate changes to dam operations. Turbidity has been shown to have a moderate to strong relationship to suspended sediment concentrations at some sites (Ellison 2013). The correlation between turbidity and suspended sediment concentration is variable based on the particular suspended sediment characteristics of a stream (sediment size, shape, and refractive index all influence turbidity) and therefore the data has been limited to only those collected immediately downstream from Willwood Dam.

It is important to note that the Newcombe and Jensen (1996) relationships are based on suspended sediment concentration, not total suspended solids. That said, it is recommended that the relationship between total suspended solids and turbidity be used until paired suspended sediment concentration and turbidity data can be collected on the Shoshone River. Total suspended solids typically underrepresents the amount of suspended sediment, with suspended sediment concentrations as much as 2 times total suspended sediment concentrations (Ellison et al., 2013). It is also not recommended that a correction factor be applied to the suspended sediment concentrations from Newcombe and Jensen (1996) at this time since such correction factors should be derived using site-specific data and these data do not currently exist. In addition, the current turbidity recommendations are lower than the values would be if a correction factor were applied to the total suspended solids data; this can be considered a margin of safety for the current recommendations.

The suspended sediment and total suspended solids concentrations are likely to be similar in the data set used to develop the relationship because it is expected that the majority of the suspended sediment is comprised of fine material, rather than sand or larger particles that can increase differences between total suspended solids and suspended sediment concentrations. This is based, in part, on the fact that the dam was not likely to be sluicing and mobilizing larger particles at the low total suspended solids (maximum value 168 mg/L) and turbidity values (maximum value 134 NTUs) used to establish the relationship between total suspended solids and turbidity. As noted above, this relationship and the recommendations will be updated as more data becomes available.

There were also concerns about the possibility of the sediment that is released during the fall-draw down may settle into potential spawning habitat. To determine whether this is likely, the particles sizes that would likely to be mobilized at a given stream slope and depth was evaluated by calculating the critical shear stress and using the relationship between critical shear stress and grain diameter included in Rosgen (2006). Using the average stream slope for the Shoshone River identified by McElroy (2017), 0.003, mean depths between 0.5 ft. and 1.5 feet that would be expected during the October 15th to October 31st period in potential spawning habitat, and the unit weight of water, 62.4

Table 2. Severity index from Newcombe and Jensen (1996).

Effect Category	Severity	Description of effect
Nil	0	No behavior effects
Behavioral	1	Alarm reaction
	2	Abandonment of cover
	3	Avoidance response
Sublethal	4	Short-term reduction in feeding rates; short-term reduction in feeding success
	5	Minor physiological stress; increase in rate of coughing; increased respiration rate
	6	Moderate physiological stress
	7	Moderate habitat degradation; impaired homing
	8	Indications of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition
Lethal and paralethal	9	Reduced growth rate; delayed hatching; reduced fish density
	10	0-20% mortality; increased predation; moderate to severe habitat degradation
	11	>20-40% mortality
	12	>40-60% mortality
	13	>60-80% mortality
	14	>80-100% mortality

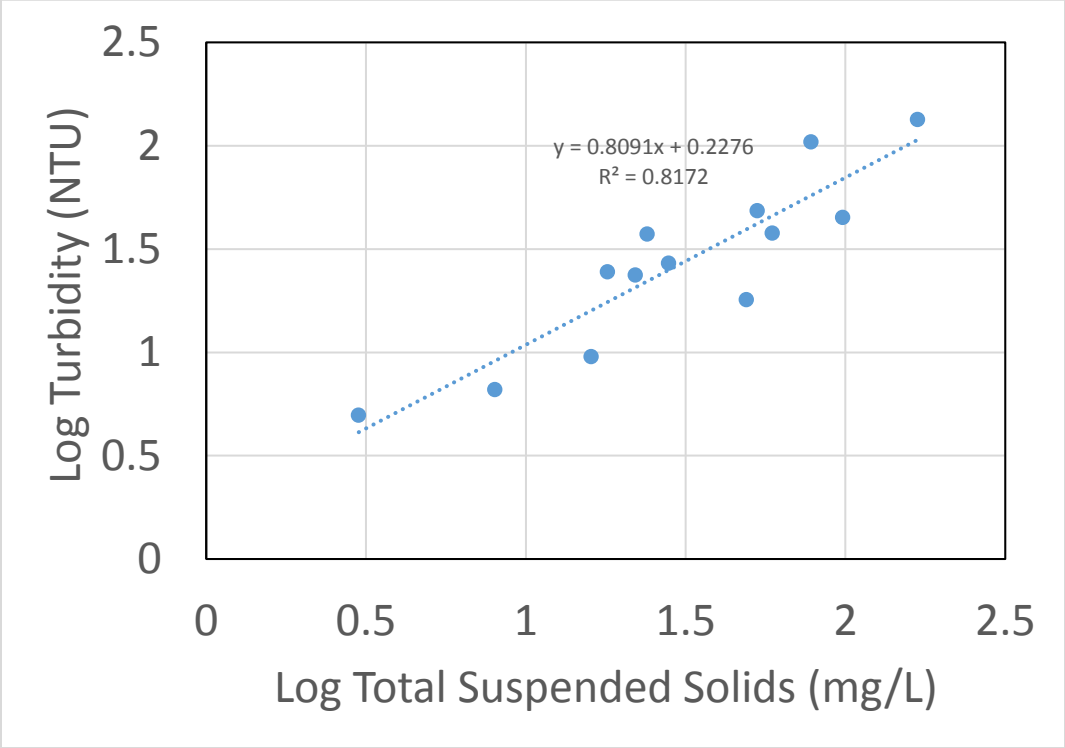

Figure 2. Relationship between total suspended solids and turbidity based on 13 paired samples collected downstream from Willwood Dam in 2008, 2009, 2016, and 2017.

lbs/ft^3, critical shear stress ranged from 0.09 to 0.28. Median grain size at these shear stress values were then calculated using the power trendline from Leopold, Wolman, and Miller (1964) that were included in Rosgen (2006). Grain diameter ranged from 6.6 mm at 0.5 feet depth to 20.8 mm at 1.5 feet deep, the smallest of which are gravels. Since the majority of sediment that is likely to be released from Willwood Dam is much, much smaller than gravel during the 17-day period, it is unlikely that this material will be deposited.

It is recognized that there may need to be exceptions to the recommendations in circumstances where the suspended sediment and/or turbidity of the Shoshone River upstream of Willwood Dam are above these thresholds. In these circumstances, the dam should be operated in a manner to maintain similar levels (within 10%) of suspended sediment and/or turbidity in the Shoshone River downstream of Willwood Dam. In such cases, measurements upstream of the dam can be multiplied by 1.1 to derive the recommended water quality downstream of the dam (e.g., 400 NTUs upstream of the dam x 1.1 = 440 NTUs downstream of the dam). It is recommended that the Willwood Irrigation District notify WDEQ/WQD, WGFD, and other partners when downstream turbidity is greater than 180 NTUs for more than 3 days, downstream turbidity is greater than 1,000 NTUs for more than 24-hours, or in other circumstances that warrant evaluation. Stakeholders will then discuss what potential actions could be taken by the dam to mitigate potential impacts to the downstream fishery while also protecting the infrastructure of the dam.

3.2 Recommendations for Spawning and Egg Development Period (November 1st – December 31st)

Once Willwood Dam has lowered the pool elevation between October 15th to October 31st to achieve the winter levels necessary to avoid damage to the dam and canal infrastructure during freezing conditions, the operation of the dam will focus on maintaining the pool elevation below the bottom of the canal gates.

To minimize potential impacts during this sensitive spawning period, it is recommended that the dam minimize the release of suspended sediment between November 1st and December 31st, as this time period represents the later part of the spawning period and the critical egg development period for Brown Trout and Mountain Whitefish. In addition, the November 1st to December 31st timeframe also occurs as the Shoshone River is approaching baseflow conditions, when flows from Buffalo Bill Reservoir are less than 450 cfs (Figure 1). During this period, the Shoshone River does not have the flows necessary to move substantial amounts of suspended sediment.

As such, the recommended suspended sediment and turbidity levels are intended to minimize the deposition of sediment in potential spawning gravels that may impede spawning, smother redds, or prevent eggs from developing and hatching normally. Therefore, in order to minimize potential impacts to spawning and reproduction and to recognize that the Shoshone River has minimal flows during this period to keep sediment suspended, it is recommended that turbidity not increase more than 10 NTUs below the dam when the turbidity upstream of the dam is less than 100 NTUs and that the turbidity not increase more than 10% when the turbidity upstream of the dam is greater than 100 NTUs. Exceptions to these recommendations are in circumstances where the dam would need to raise the pool level above the bottom of the canal gates in order to maintain the turbidity recommendations. In these cases, the dam should minimize the downstream turbidity to the greatest extent possible without raising the pool elevation above the bottom of the canal gates. It is recommended that Willwood Irrigation District notify WDEQ/WQD, WGFD, and other partners when turbidity is greater than the 10 NTU or 10% NTU increase

for more than one week, downstream turbidity is greater than 1,000 NTUs for more than 24-hours, or in other circumstances that warrant evaluation. In such cases, Willwood Irrigation District and partners will discuss whether it may be appropriate to raise the pool elevation above the bottom of the canal gates or what other actions may be taken that will best protect the dam as well as the fishery.

3.3 Recommendations for Hatch and Juvenile Fish Development (January 1st – March 27th)

During the January 1st to March 27th period, the Irrigation District should continue to maintain the pool elevation below the bottom of the canal gates. That said, during the end of this period, air temperatures may not be below freezing and there may be additional flexibility for the dam to raise the pool elevation above the bottom of the canal gates if it becomes too difficult to maintain the recommended turbidity levels downstream of the dam.

Brown Trout and Mountain Whitefish eggs will hatch on the Shoshone River around early January during baseflow conditions. Baseflow conditions continue until approximately March 31st, at which times flows begin to increase due to snowmelt runoff and increased flows from Buffalo Bill Reservoir. To minimize potential impacts to small, sensitive fish, it is recommended that the dam not increase turbidity more than 10 NTUs when the turbidity upstream of the dam is less than 100 NTUs and not more than 110% of the upstream turbidity when the turbidity upstream is greater than 100 NTUs. Exceptions to these recommendations are in circumstances where the dam would need to raise the pool level above the bottom of the canal gates in order to maintain the downstream turbidity recommendations. In these cases, the dam should minimize the downstream turbidity to the greatest extent possible without raising the pool elevation above the bottom of the canal gates. It is recommended that Willwood Irrigation District notify WDEQ/WQD, WGFD, and other partners when turbidity is greater than the 10 NTU or 10% NTU increase for more than one week, downstream turbidity is greater than 1,000 NTUs for more than 24-hours, or in other circumstances that warrant evaluation. In such cases, Willwood Irrigation District and partners will discuss whether it may be appropriate to raise the pool elevation above the bottom of the canal gates.

3.4 Recommendations for Spring Sluice (March 28th – April 12th)

To minimize sediment accumulation behind the dam and since it may not be possible for Willwood Dam to sluice the majority of their sediment during the irrigation season, it is recommended that the Irrigation District employ a 16-day spring sluice event prior to the start of the irrigation season to mobilize sediment from behind the dam. This period coincides with the rising limb of the hydrograph, as flows on the Shoshone River start to increase as a result of snowmelt and increased releases from Buffalo Bill Reservoir that should help to minimize deposition of sediment. This period also coincides with the period when flows start to increase below Willwood Dam (Figure 1). It is recommended that the dam maintain average suspended sediment concentrations of approximately 325 mg/L and turbidity of approximately 180 NTUs and that 24-hour maximum concentrations not exceed 3,000 mg/L suspended sediment and 1,000 NTUs. Exceptions to these recommendations are in circumstances where the upstream concentrations are higher than the recommendations. In such cases, the downstream concentrations should not exceed more than 110% of the upstream concentrations. It is recommended that the Willwood Irrigation District notify WDEQ/WQD, WGFD, and other partners when downstream turbidity is greater than 180 NTUs for more than 3 days, downstream turbidity is greater than 1,000 NTUs for more than 24-hours, or in other circumstances that warrant evaluation.

3.5 Recommendations for Irrigation Season (April 13th – October 15th)

The period of April 13 through October 15 generally has both the highest and lowest flows in the Shoshone River downstream of Willwood Dam. Depending on water supply conditions, spring releases from Buffalo Bill Reservoir often result in flows of more than 2,000 cfs passing Willwood Dam, with peak flows occurring between late May to early July (Figure 1). However, after runoff, between August and October 15, flows downstream of Willwood Dam typically range from 70 to 100 cfs.

The main goal for the Willwood Irrigation District during the irrigation season is to deliver water to its users. Typically the reservoir pool is maintained at or above the crest of Willwood Dam to provide the necessary depth for diversion of water through the canal gates and into the canal. However, whenever river flows are high enough to meet minimum gate opening requirements and pool elevations are high enough for desired canal diversions, the District can release flow through the sluice gates and potentially pass sediment. So although Willwood Irrigation District has not previously received operating recommendations during the irrigation season, it is recommended that the District try to pass sediment during this period. Movement of sediment during this period is important because: this period corresponds to the highest flows below Willwood Dam; this period is when the Shoshone River is likely to be transporting the most sediment due to higher flows; and it is unlikely that the Irrigation District will be able to mobilize the annual sediment load of the Shoshone River during the spring sluice alone. Even with this recommendation, it is recognized that having the sluice gates open while the reservoir pool is up will help keep the sediment immediately upstream of the gates moving, but will not likely pass the heavier sediments that settle far upstream where the river velocity decreases upon entering the reservoir pool. Due to the potential limitations of opportunistically sluicing during the irrigation season, it is also recommended that the Irrigation District evaluate their ability to mobilize sediment and determine whether mechanical suspension of sediment may help achieve the desired goal of mobilizing the annual sediment load.

Since potential impacts to the fishery will be minimized if suspended sediment concentrations downstream of the dam are similar to those concentrations upstream of the dam, it is recommended that the Irrigation District try to maintain turbidity levels downstream of the dam at levels similar to those upstream of the dam. This recommendation is dependent on sufficient flows within the Shoshone River downstream of Willwood Dam to maintain sediment in suspension. Turbidity downstream of the dam should not be more than 110% of the turbidity upstream from the dam. In addition, to minimize lethal effects to juvenile and adult fish, it is recommended that suspended sediment concentrations not exceed 3,000 mg/L and turbidity not exceed 1,000 NTUs for more than a 24-hour period, except in circumstances where the upstream concentrations exceed these recommendations. In such cases, the downstream concentrations should not exceed more than 110% of the upstream concentrations. It is recommended that the Willwood Irrigation District notify WDEQ/WQD, WGFD, USBOR, WWDC, and other partners when downstream turbidity is greater than 110% of upstream turbidity, downstream turbidity is greater than 1,000 NTUs for more than 24-hours, or in other circumstances that warrant evaluation.

3.5 Future Recommendations

WDEQ/WQD has contracted with USGS to obtain paired “real-time” suspended sediment concentration and turbidity data upstream and downstream of Willwood Dam beginning in the fall of 2017. These data should help to identify potential deficiencies in the existing total suspended solids and turbidity relationship used to derive the recommendations included above and to update these recommendations.

The Newcombe and Jensen (1996) severity index, particularly at low suspended sediment concentrations, has limitations. In addition, as noted by Newcombe and Jensen (1996), many gaps remain, particularly for the youngest age-classes (eggs through young juveniles). They go on to state that each developmental stage should be identified and treated separately for the purpose of developing uniquely age-specific and size-specific dose-response profiles, and thresholds for sublethal and lethal effects must be known more precisely. In addition, they noted that finding useable data was a challenge and that they rejected many studies because they were too vague about sediment concentration, duration of exposure, or the exact nature of the ill effect. Since Model 1, that was used to develop the recommendations above, does not include impacts to eggs, it is recommended that additional work be conducted to determine recommended suspended sediment concentrations to minimize negative impacts to eggs. Additional data on the impacts of suspended sediment concentrations to the Shoshone River fishery is warranted. This information could be used to evaluate the relationships presented by Newcombe and Jensen on the Shoshone River.

It would also be beneficial to identify Brown Trout and Mountain Whitefish spawning habitat in the Shoshone River so that these areas can be monitored for potential impacts from management recommendations. It would also be helpful to determine more specifically the timing and emergence of Brown Trout and Mountain Whitefish in the Shoshone River so that the fall-drawn down recommendations could be refined.

In addition, since the thresholds at which suspended sediment become deposited sediments is highly dependent on flow, additional work should be conducted to develop recommendations for the Shoshone River downstream of Willwood Dam that included a more detailed evaluation of the flow regime and its influence on SABS.

4.0 Works Cited

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