



Turbidity Changes During Culvert to Bridge Upgrades at Carmen Creek, Idaho

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Introduction

Forest Service, BLM, and state forest roads provide access for timber harvest and recreational use. Culverts used on these roads were historically designed to convey water under the road with little attention given to passage of aquatic organisms. In the past decade or so, driven largely by the Endangered Species Act listing of various salmonids in the Pacific Northwest, managers have designed and installed culverts to accommodate passage of aquatic species. Many existing culverts designed under the old criteria are impediments to passage and are replaced with culverts or bridges designed to accommodate aquatic species passage. Managers weigh the short-term negative impacts of sediment in the stream during culvert replacement against the positive long-term impacts of improved passage when considering which culverts to replace.

Regulatory agencies, such as National Marine Fisheries Service, are requiring improved quantification of the short- and long-term impacts. One frequently used metric for the short-term impacts is turbidity. Allowable turbidity standards for surface water quality are set individually by each state. Idaho State criteria for cold water aquatic habitat require that turbidity not exceed the background level by more than 50 NTU (nephelometric turbidity units) instantaneously or more than 25 NTU for more than 10 consecutive days (IDEQ 1994).

Jakober (2002) studied a culvert replacement in the Bitterroot National Forest in Montana and reported that 95 percent of the construction-related sediment occurred in the first 2 hours after diversion removal. He stated that sediment concentrations decreased to near pre-project levels within 24 hours.

Citation:

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Eleven culvert removals during road obliteration operations were monitored at three locations on national forest lands in Idaho and Washington (Foltz and others 2008). Two of the locations had stream flows of less than 0.021 cfs (0.6 L s^{-1}) while the remaining had a stream flow of approximately 0.35 cfs (10 L s^{-1}). The study measured sediment concentration and turbidity before, during, and up to two days after culvert removals at distances ranging from 65 ft (20 m) downstream from the culvert outlet to 330 ft (100 m) downstream. Each combination of stream flow, how long the excavation equipment was in the stream, and presence or absence of stream diversion resulted in 11 unique observations with no replication of similar conditions. In spite of these difficulties, several general conclusions were possible. Sediment concentrations and turbidity peaked when the culvert was removed, which allowed water to flow on the soil that had formerly supported the culvert. In-stream mitigation, such as straw bales or excavated sediment traps, reduced sediment concentrations while the culverts were being removed. However, the trapped sediment was later mobilized when the straw bales were removed. Sediment concentrations were an order of magnitude less 330 ft (100 m) downstream compared to the location 65 ft (20 m) downstream from the culvert outlet. At a distance of 0.5 miles (800 m) downstream, the instantaneous turbidity values were less than 50 NTU above the background. Excavation equipment moving in the stream bed always increased the sediment concentration and turbidity readings.

To answer the short-term impact questions on a culvert to bridge upgrade, the BLM, the State of Idaho, and the U.S. Forest Service partnered to conduct a study of two culvert-to-bridge upgrades on an anadromous fish-bearing stream in Idaho by measuring stream turbidity during the upgrade.

Carmen Creek (figure 1), a Rosgen B3 channel type, is a tributary of the Salmon River at river mile 253 (407 km). The average annual flow is 3 to 7 cfs (85 to

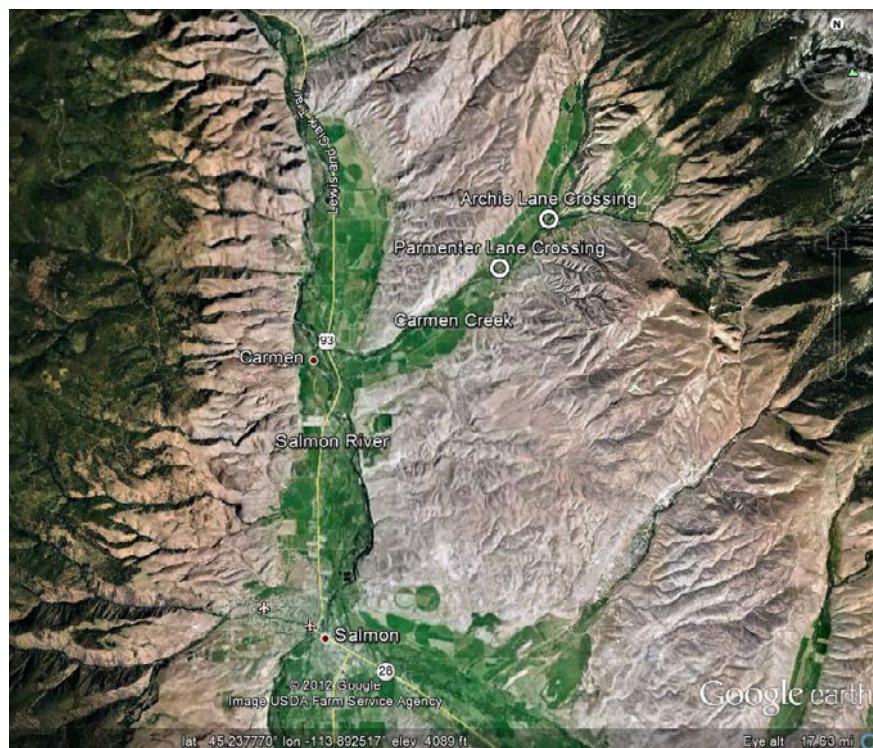


Figure 1 – Location of Carmen Creek and Salmon River north of Salmon, Idaho.

200 L s⁻¹) in the summer, fall, and winter, and it can peak as high as 150 cfs (4,200 L s⁻¹) during spring run-off and early summer. Carmen Creek elevation changes from approximately 5200 ft to 3840 ft (1600 m to 1170 m) at the confluence with the Salmon River, for an average gradient of 142 ft per mile (26.9 m km⁻¹) over approximately 9.5 miles (15 km) of stream with the majority of the elevation drop in the first 2 to 3 miles (3 to 5 km) of the creek. Substrate in Carmen Creek is 50 percent cobble, 40 percent gravel, and 10 percent sand. The riparian area consists of a mature cottonwood overstory that provides shade, cover, and large woody debris to the stream.

Endangered Species Act listed fish include Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*), Snake River steelhead (*Oncorhynchus mykiss*), and Bull trout (*Salvelinus confluentus*). In 2006 the Idaho Fish and Game Department found juvenile Chinook salmon below the proposed culvert to bridge upgrade project. Steelhead were sighted in 2007 in the lower reaches of Carmen Creek below the proposed work area (Warren 2007). Bull trout are found in the upper portion of the creek above the proposed work area (Warren 2007).

Culverts at some road crossings were barriers to fish migration, preventing fish passage above the culvert during low flows. During spring run-off, large woody debris was continually pinned against the culverts, allowing large amounts of debris to catch in the culvert and create a barrier for aquatic species. Parmenter Lane, figure 2, and Archie Lane, figure 3, were two of these fish barrier road-stream crossings.



Figure 2 – Parmenter Lane road crossing before and after culvert to bridge replacement.



Figure 3 – Archie Lane road crossing before and after culvert to bridge replacement.

Between September 14 and 27, 2011, the Parmenter Lane road crossing was upgraded from two 6 and 7 ft (180 and 210 cm) diameter CMP culverts to a pre-fabricated steel bridge 24 ft (7.3 m) wide and 50 ft (15 m) in length. Between October 4 and 13 the Archie Lane road crossing was upgraded from two 6 and 7 ft (180 and 210 cm) diameter CMP culverts to a pre-fabricated steel bridge, 16 ft (4.9 m) wide and 45 ft (14 m) in length. Before and after photographs are shown in figures 2 and 3.

Methods

The culvert upgrade procedure was similar at both locations. The first step was to install a 36 inch (91 cm) diameter plastic bypass pipe to accept the creek flow and divert it around the work area. Next, temporary dams above and below the road crossing were created using 4-ft (120 cm) diameter bags filled with gravel. These dams diverted the creek into the bypass pipe and kept water from flowing through the work area. A pump upstream of the upper temporary dam assisted in diverting the stream into the bypass. To allow vehicles to cross Carmen Creek during the construction, a temporary bypass road and pipe were installed between the two temporary dams (figure 4). Once the stream was flowing in the bypass, any fish trapped between the dams were caught and relocated out of the work area. Removal of the old culverts

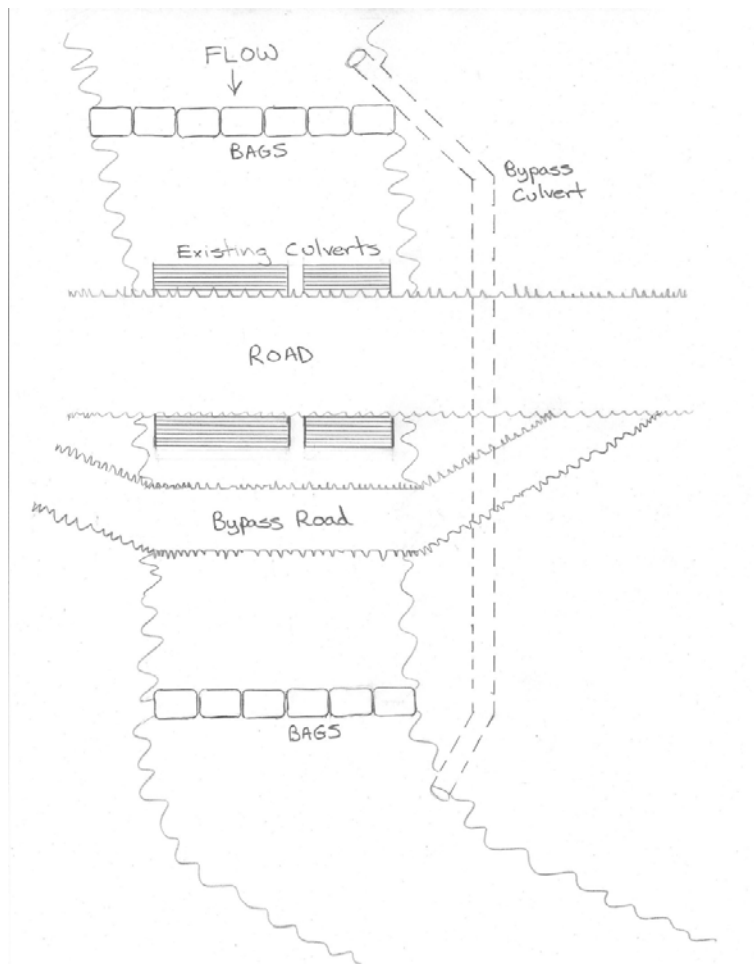


Figure 4 – Sketch of sediment mitigation techniques used at Parmenter Lane. Similar ones were used at Archie Lane.

was accomplished in a single day with installation of the new bridge requiring 10 to 12 additional days. In-stream activity by excavators or other machinery was minimized. Upon completion of the bridge installation, the bypass road was removed; the upstream and downstream dams and the bypass pipe were removed over a four hour time period to gradually allow the stream to flow beneath the new bridge.

Turbidity measurements were made using two HANNA HI 93703 Turbidity Meters. Both meters were calibrated with zero and 10 NTU standard solutions. A turbidity sample was taken above the upper temporary diversion dam at the beginning and again at the end of each work day to establish the background turbidity. A second sampling point was located 30 ft (10 m) downstream of the bypass pipe outlet. This point was representative of the maximum turbidity immediately downstream of the construction activity. A third sampling point was located 330 ft (100 m) downstream of the bypass pipe outlet. This point was chosen with the expectation that it was near the end of the mixing zone. Inspection of the sediment plume during construction activities verified that it satisfied the “end of mixing zone” requirement. Location of the three sampling points is indicated in figure 5 for Parmenter Lane and figure 6 for Archie Lane. Samples were taken in 10 ml cuvetts at a depth of 6 inches (15 cm) in the center of the channel. Turbidity readings were taken immediately after sampling.

Sampling criteria for the Parmenter Lane location was every 15 minutes or when the turbidity visually increased. When the turbidity was visually high, a sample was taken



Figure 5 – Sampling locations at Parmenter Lane.



Figure 6 – Sampling locations at Archie Lane.

at least every 5 minutes until the stream cleared up. The individual sampling at the upper point recorded a description of the construction activity.

Based on the results of the Parmenter Lane sampling, the Archie Lane sampling criteria were modified to a sample every 30 minutes or when the turbidity visually increased. Construction activity was again recorded.

Results

Parmenter Lane

Flow in Carmen Creek during the Parmenter Lane work was 0.70 cfs (20 L s^{-1}) on September 14 and 15, 0.72 cfs (20 L s^{-1}) on September 26, and 0.46 cfs (13 L s^{-1}) on September 27 with water velocities of approximately 1.25 ft s^{-1} (0.38 m s^{-1}) and water depths of 12 to 14 inches (30 to 36 cm). The background turbidity at the Parmenter Lane location varied between 0.8 and 1.5 NTU for each of the four days measurements were taken.

Turbidity at end of mixing zone

At the end of the mixing zone (the 330 ft [100 m] downstream sampling location), none of the measurements exceeded the Idaho State turbidity regulations of 50 NTU above the background turbidity (figure 7). The maximum turbidity at the end of the mixing zone was 51 NTU on September 14 at 13:37 when the excavator was in the stream preparing to install the upper temporary dam and the bypass pipe (figure 8, point a). Five minutes before the high reading the turbidity was 8.9 NTU and five minutes after the high reading the turbidity was 8.5 NTU. When the excavator was in the stream digging a hole for the bypass pump (figure 8, point b) and again when flow was diverted into the bypass pipe (figure 8, point c), turbidity readings reached 31 NTU and remained elevated for 45 minutes.

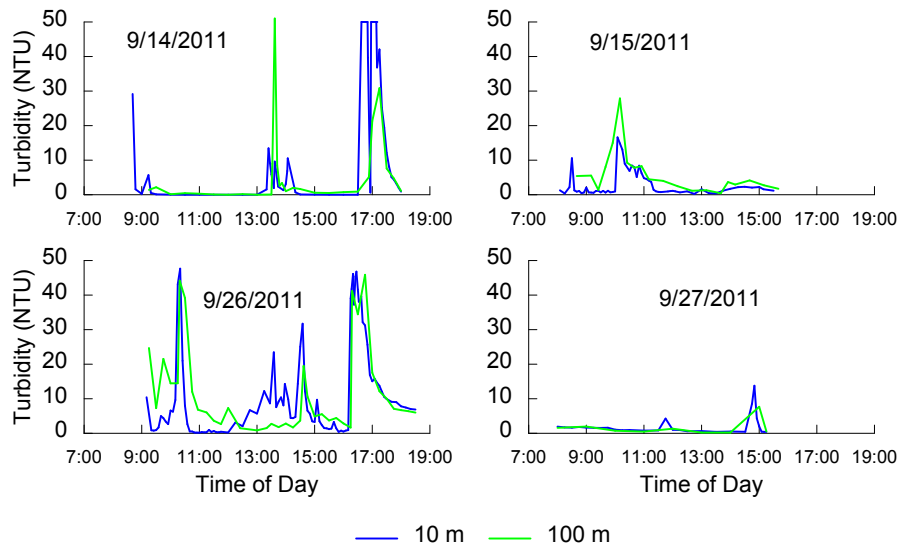


Figure 7 – Turbidity for Parmenter Lane location. Each graph scaled to 50 NTU maximum. Note that 9/14/2011 has truncated peaks where the readings exceeded 50 NTU at the 10 m downstream sampling point.

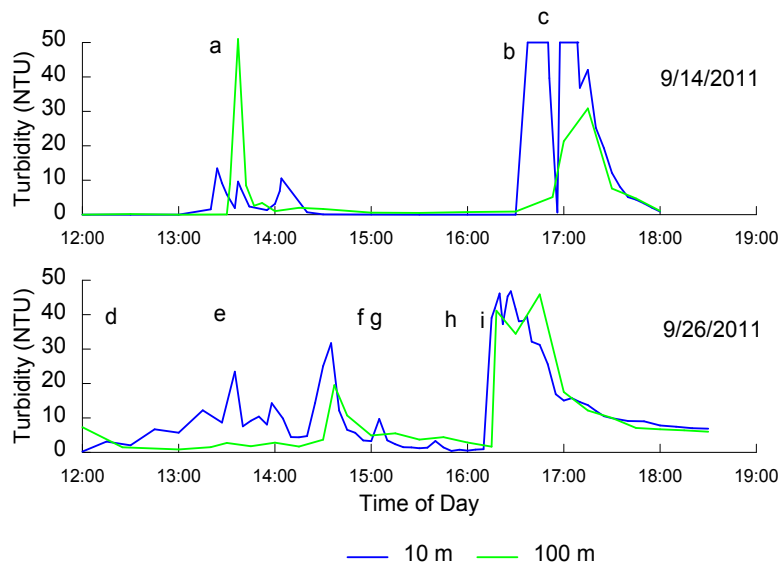


Figure 8 – Turbidity for Parmenter Lane location. Letters correspond to activity causing elevated turbidity readings. a and b – excavator in stream for less than 5 minutes. c – began pumping through bypass culvert. d – began breaching upper dam. e – began breaching lower dam. f – upper dam removal complete. g – began removing bypass culvert. h – bypass culvert removal complete. i – removal of lower dam complete.

When the last portions of the upper and lower temporary dams and the bypass culvert were removed on September 26 at 16:35 (figure 8, point i), the maximum turbidity was 46 NTU. An hour passed before the turbidity dropped below 10 NTU with another 45 minutes required before reaching 5 NTU. Removal of the temporary dams and the bypass pipe allowed the stream to flow across the freshly disturbed stream bed where the culverts had been and across the bypass road where most, but not all, of the loose sediment had been removed by the excavator and dump trucks.

Turbidity immediately adjacent to lower temporary dam

At this sampling location turbidity plumes had not mixed, which caused turbid and less-turbid zones in the stream. Samples were always taken in the most turbid portion of the stream. On September 14 the turbidity measurement 30 ft (10 m) downstream from the lower temporary dam peaked at 125 NTU when the excavator was physically in the stream digging a hole for the bypass suction pump. The turbidity dropped below 50 NTU above background after the excavator moved out of the stream. During the 15 minutes that the turbidity was elevated at the point adjacent to the downstream dam, the maximum turbidity 330 ft (100 m) downstream was 31 NTU.

All of the turbidity peaks occurred when one of the following activities occurred:

- Excavator physically in the creek
- Excavator out of the creek but moving rocks in the creek
- Excavator out of the creek but placing vegetation immediately adjacent to the creek
- Final remnants of the lower temporary dam being removed.

A visual illustration of the range of turbidity readings from 1 to 40 NTU in Carmen Creek is shown in figure 9. The pictures were taken at the 330 ft (100 m) downstream of the sampling location at the Parmenter Lane location.

Archie Lane

Flow in Carmen Creek during the Archie Lane work was 0.35 cfs (10 L s^{-1}) on October 4 and 1.6 cfs (45 L s^{-1}) on October 13 with water velocities of approximately 1.25 ft s^{-1} (0.38 m s^{-1}) and water depths of 12 to 18 inches (30 to 46 cm). The background turbidity at the Archie Lane location varied between 0.7 and 1.8 NTU for each of the two days measurements were taken.

Turbidity at end of mixing zone

The Archie Lane location did not exceed 50 NTU above background at the end of the mixing zone (figure 10). The maximum turbidity measured at the end of the mixing zone was 50 NTU when the lower temporary dam was removed.

Turbidity immediately adjacent to lower temporary dam

At this sampling location, turbidity plumes had not mixed, which caused turbid and less-turbid zones in the stream. Samples were always taken in the most turbid portion of the stream. On October 13, the turbidity measurement 30 ft (10 m) downstream

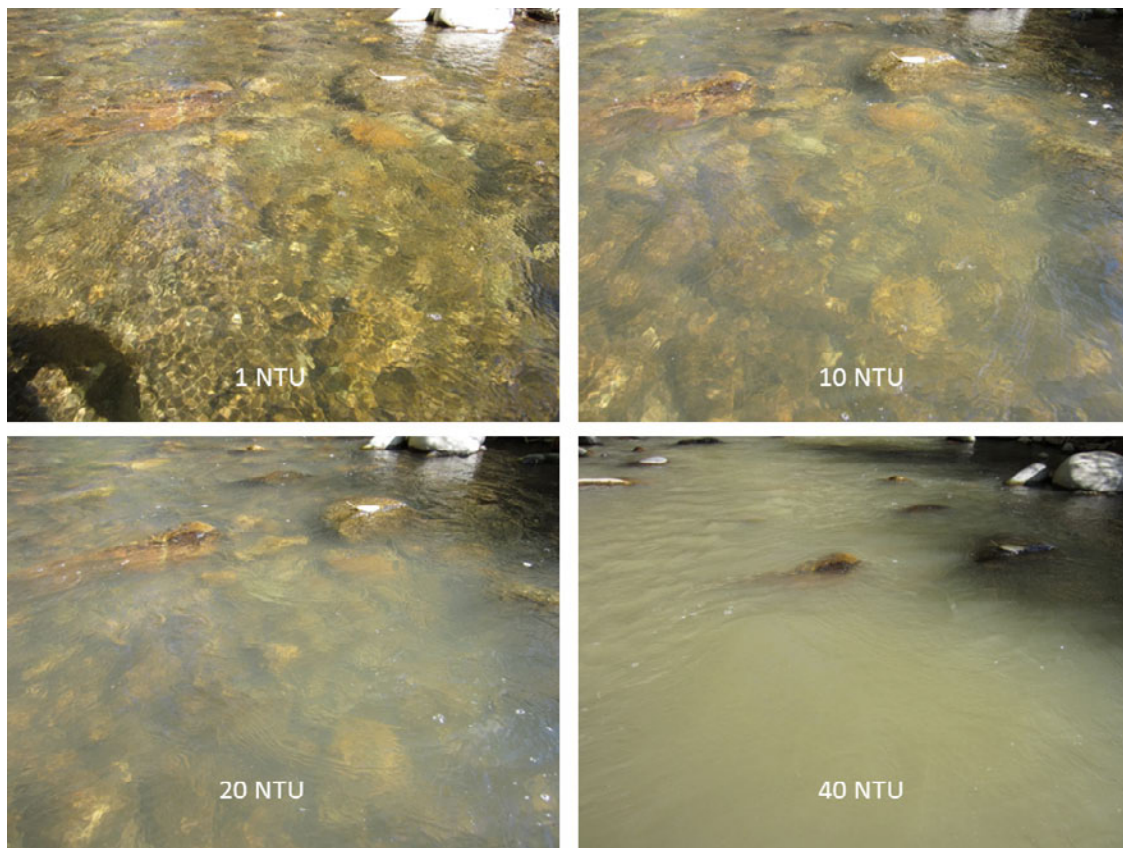


Figure 9 – Turbidity levels in Carmen Creek during Parmenter Lane culvert upgrade.

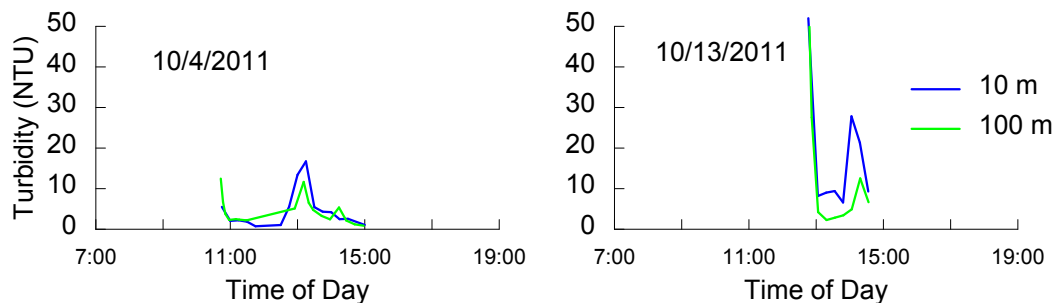


Figure 10 – Turbidity readings for Archie Lane location. Each graph scaled to 50 NTU

from the lower temporary dam peaked at 52 NTU near the end of the surge of water caused by removal of the temporary dams and flushing of the bypass pipe. Within 15 minutes the turbidity had decreased to 8 NTU.

Similar to the Parmenter Lane location, all of the peaks occurred when one of the following activities occurred:

- Work on installing the bypass dams
- Releasing water from bypass dams after completion of bridge installation.

Discussion

This study was not conducted in an experimental framework, but as an observational study. Skill, attitude, and technique of the equipment operators; stream flow; and weather conditions are a few of the factors that can have an impact on the stream turbidity during similar culvert to bridge conversions. Further, we were not able to directly compare one technique to another, such as various degrees of mitigation or alternative temporary dam materials. Nevertheless, the study has utility because it provides a concrete example of measured turbidity values rather than speculation of what turbidity values might be. Each culvert upgrade is unique due to the various physical settings of the culvert such as slope, depth of fill, and stream flow. The mechanisms that cause elevated sediment concentrations and turbidity are, however, similar from one location to another.

There appear to have been three major mechanisms that resulted in elevated turbidity readings: equipment in the stream, stream flow over loose sediment, and disturbance of the stream banks. Most of the instances of equipment in the stream were kept to less than five minutes resulting in elevated turbidity readings of 15 minutes or less. The excavator activity caused fresh sediment to be suspended in the stream. When the excavator left the stream, the generation of sediment stopped, and the stream flow flushed the suspended sediment downstream. Minimizing the amount of in-stream time was an important technique to both keep the turbidity values low and to keep the duration of elevated turbidity readings short. Proper minimization of equipment activity in the stream results in reduced turbidity impacts.

A second mechanism causing elevated turbidity readings was when stream flow occurred over loose soil between the temporary dams. When the stream flow occurred over sediment between the temporary dams left over from either the bedding material for the original culverts or the sediment from the bypass road that could not be removed, the time required to flush the loose sediment was between 60 and 105 minutes.

The third mechanism causing elevated turbidity readings was activities that disturbed the stream banks. Placement of rip-rap rock and transplanting vegetation to the stream banks were the primary activities that occurred in this study. Each of them resulted in short-term (less than 10 minutes) minor (less than 10 NTU) increases in turbidity.

The mitigation practices employed in this study appeared to have done a good job of keeping the turbidity values within the State of Idaho regulatory requirements. Specifically, these practices involved installing the temporary in-stream dams above and below the culvert to bridge location, using the pipe to bypass the stream around the construction site, and slowly removing the temporary dams. We think the slow removal of the upper and lower dams over a period of four hours, rather than as quickly as possible, resulted in lower turbidity values. Further, we think the use of a bypass pipe, rather than the use of an excavated bypass channel, resulted in lower turbidity values. These methods may be adopted as standard practice.

The results of the Carmen Creek study were similar to both Jakober (2002) and Foltz and others (2008). All three studies observed that the majority of sediment concentrations or turbidity occurred shortly after removal of the stream diversion. Both Foltz

and others and the present study confirmed that turbidity was reduced to regulatory acceptable levels at the end of the mixing zone, 330 ft (100 m), downstream from the culvert replacement work site. Finally, both Foltz and others and the Carmen Creek study observed that equipment moving in the stream bed always caused increased sediment concentration and turbidity readings.

Conclusions

While each culvert upgrade is unique, the mechanisms that contribute to increased sedimentation and elevated turbidity are similar. Carmen Creek upgrades provided an example of those mechanisms and methods to reduce their impacts. The Carmen Creek road crossing upgrades from large diameter CMP culverts to bridges were completed without exceeding the Idaho turbidity requirement of 50 NTU above background measured at the end of the mixing zone. All of the peak values occurred when the excavator was physically in the creek, when the temporary dams were removed, or when the excavator was moving stream bed rocks or placing vegetation on the creek banks. Elevated turbidity readings persisted as long as the excavator was in the stream plus 5 to 10 minutes after exiting the stream. The slow removal of the temporary dams and bypass culvert over a period of four hours caused small, less than 10 NTU, increases that persisted for a short duration, less than 10 minutes. When the temporary dams were completely removed, the elevated turbidity readings less than 50 NTU persisted for up to 105 minutes. The placement of rip-rap rock and transplanting of vegetation resulted in turbidity increases of less than 10 NTU for less than 10 minutes.

We have no measurements of what the turbidity values would have been without the use of upstream and downstream temporary dams, the diversion of the stream into a culvert, or the slow removal of the temporary dams and bypass pipe employed at the two Carmen Creek locations. However, the measured values resulting from these practices strongly suggest that this combination was successful in reducing the short-term impacts of the culvert to bridge upgrades. We recommend their continued use for culvert upgrade projects.

Acknowledgments

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