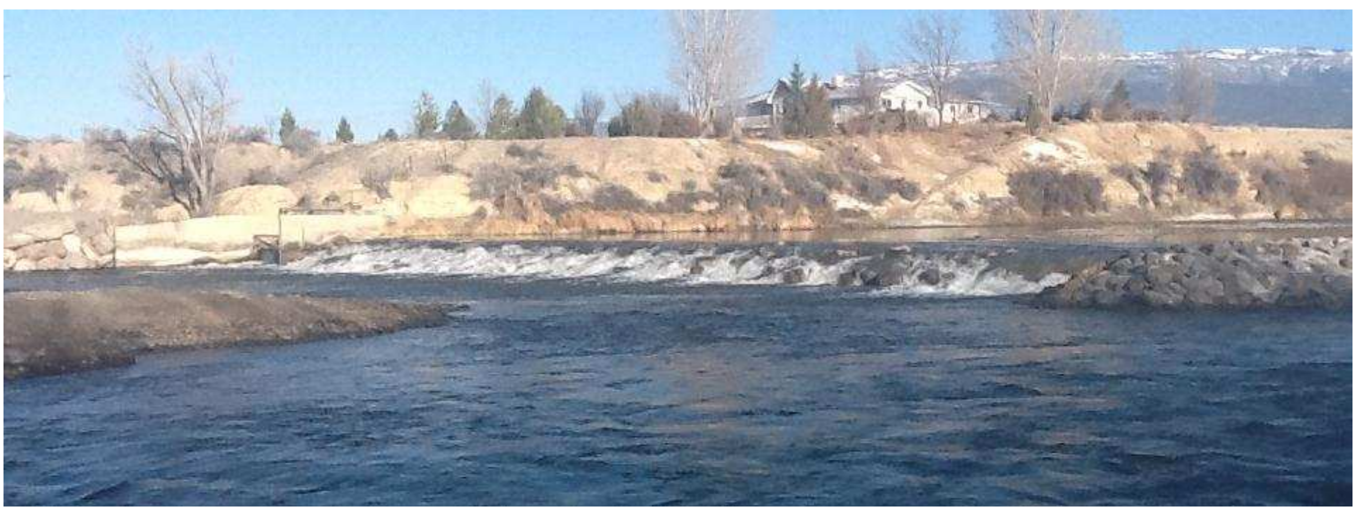
Hartland Diversion Dam
Fish Passage

Final Report



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Introduction

Hartland Diversion Dam is located on the Gunnison River 3.6 miles upstream of the Uncompahgre River confluence near Delta, Colorado. The 6 foot high structure restricted upstream movement of fish during most flow stages. The Hartland Diversion Dam was construction in 1881 for agricultural irrigation and stock watering purposes. Hartland Irrigation Company diverts 41-43 cfs through their headgate on the north side of the river between March and November. The dam spanned the entire river, approximately 300 feet. The dam was constructed of railroad iron driven vertically into the river and reinforced with steel and rip-rap and was repaired and upgraded in 1942. The Hartland Irrigation Company owns the diversion dam and operates and maintains the headgate and irrigation canal. The structure was unsafe and not passable by river enthusiast. The predominant native fishes include bluehead sucker (Catostomus discobolus), flannelmout sucker (C. latipinnis). And roundtail chub (Gila robusta). Hartland Diversion Dam and Fish Passage construction began September 1, 2011 and was completed on March 6, 2012. The benefits of providing fish passage at the Hartland Diversion Dam include extending the upstream range and re-establishment of endangered Colorado native fishes and increasing the number of bottomland sites and opportunities for habitat restoration and enhancement to assist the recovery of endangered fish. This would allow fish to utilize habitat to spawn and increase the larvae drifting downstream to utilize additional flooded bottomlands. The passage has allowed for approximately 15 miles of habitat for native and endangered fish. The construction of boat passage along with modifications to the dam to reduce hazard on the north side of the river has allowed for low hazard passage by boating enthusiasts.

Project Construction

Project Statistics:

Location:	Legal Description to be added
County:	Delta
Water Division:	50 cfs
Project Length:	350 feet
Adjacent Property Owners	2
Construction Contractor	Kissner General Contractors, Cedaredge, CO
Began Construction	September 1, 2011
End Construction	March 6, 2012

Project Cost:

Engineering Support	
Construction	
Rock	
Construction Management	
Trout Unlimited – Monitoring & Maintenance for 2012/2013	$ 20,000.00

Project Funding Sources:

US Fish and Wildlife Service	$1,394,194
Colorado Water Conservation Board	$ 560,000
Walton Family Foundation	$ 250,000
National Fish & Wildlife Foundation	$ 110,001

Colorado River District	$ 98,875
Gunnison Basin Roundtable	$ 53,100

Project Design

Background:
McLaughlin Water Engineers (MWE) was retained to complete final design in April of 2010 based on the conceptual design completed by Tetra Tech in December 2009. After the conceptual design was completed, additional design requirements had been added to the project, including 100-year stability, a narrower range of fish passage flows, and limiting the project impact on the existing floodplain. As a result, MWE developed a revised design that reduced the project footprint and costs while meeting the following project objectives:

- Provide fish passage around the diversion dam
- Provide boat passage connecting upstream and downstream river reaches
- Maintain diversion operations including improved stability of the diversion dam structure
- No negative impact to the regulatory floodplain.

Design Criteria:
The following is a summary of the final criteria for design:
- Maintain upstream pool elevation for diversion operations to a low river flow of +/-350cfs
- Structure stability up to the 100-yr flood event
- Low hazard boat passage
- 12" maximum hydraulic drops
- 3:1 or flatter bank slopes
- Fish Passage- Max. Velocity = 4 feet per second ("Fish's Eye" Location), Depth = 2' min.
- Fish Passage River Flow Design Range: Low = 750 cfs; High = +/-3000 cfs (Not specifically defined by USFWS)

Hydrology
Seasonal and annual fluctuations in flow on the Gunnison River were important to the design. A detailed hydrology analysis was conducted by Tetra Tech as part of the Conceptual Design Report dated December 2009. The analysis was based on gauge records (Gunnison River at Delta, CO, USGS 09144250) for 1976 to 1999. Of primary interest were typical flows during irrigation season and throughout the year for fish passage and migration and higher flows for structural design. Historic low river flows were also important for design to maintain the upstream pool for diversion. The following is a summary of hydrology results from Tetra Tech's analysis:

- 90% Exceedence in August = 350 cfs
- Average Lowest Daily Flow (1976-1999) = 650 cfs
- Average Daily Flow August = 1,200 cfs
- Average Daily Flow May = 4,800 cfs
- Peak Flow in May (based on DEIS for Aspinall Unit) = 7,400 cfs (projected)
- 5-yr Return Period = 11,600 cfs
- 100-yr Return Period = 21,200 cfs

Summary of Design Layout & Concept

The design combines a center boat passage and two fish passages along each bank into one hydraulically connected channel. The boat passage is a drop-pool design that utilizes concentrated hydraulic drops between upstream and downstream pools. Fish passages include two "roughened passages", one with Confined Loose Boulder (CLB) and the other with concrete cylinders placed in a chevron pattern both to create different types of fish passage hydraulics. The boat and fish passages are hydraulically connected at the pools, in other words, the water level is equal in the three passages at each pool location. Divider islands adjacent to boat passage drops separates flow until it converges at the pools. A grouted boulder divider wall running parallel adjacent to the new structure separates flow over the dam and to the boat/fish passages. A counter-weir downstream of the last drop-pool is included to protect the structure from tailwater degradation and help orient flows away from the left bank. Upstream of the chevron fish passage a jetty was designed to reduce local bank erosion, reduce debris and entrance velocities to the chevron fish passage, and direct river users to the center boat passage channel. Figure 1 shows an overall layout of the project.

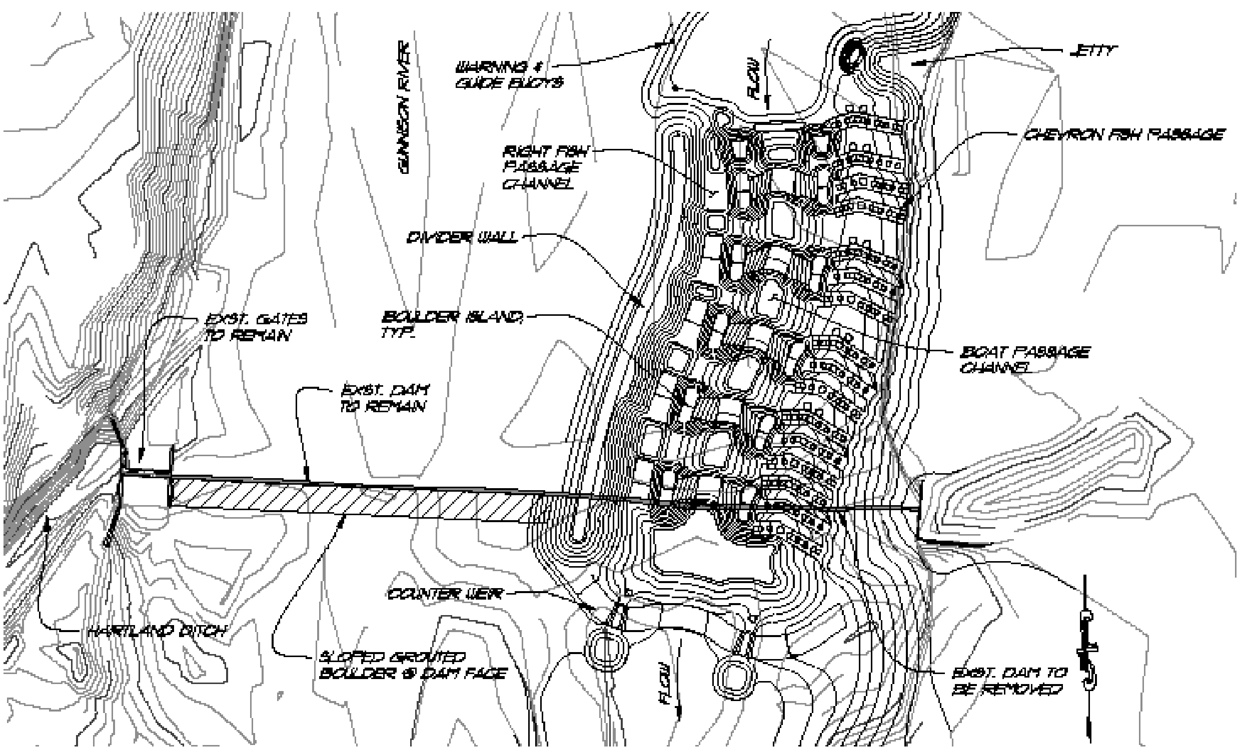

Figure 1 – Hartland Dam Fish and Boat Passage Final Design Layout

Figure 2 – Hartland Dam Fish and Boat Passage

Fish Passage

Three threatened fish species the Bluehead Sucker, Flannelmouth Sucker, Roundtail Chub were identified as the "target species" for fish passage. However the swimming capabilities and movement preferences of these species are not well known. Therefore the United States Fish and Wildlife Service (USFWS) opted to use fish passage guidelines from the more studied and better understood Razorback Sucker, which is believed to be a weaker swimming fish than most native species including the three identified target species. Fish passage criteria were developed based on research and monitoring of the Razorback Sucker conducted by the United States Bureau of Reclamation and (USBR) and USFWS.

Two fish passage channels were designed for this project to provide flow variation and multiple options for fish movement. A Confined Loose Boulder (CLB) roughened fish passage concept was designed for the "Right Fish Passage" (river right of the boat passage). This concept utilizes large boulders (36"+) placed randomly in the channel to provide highly roughened flow and interstitial spaces between boulders for fish movement. Smaller boulders are used to fill voids at the surface between larger boulders to reduce foot/hand entrapment hazards. Adjacent banks are roughened with large grouted boulders extending into the flow for additional passage. Figure 3 illustrates the Right Fish Passage. The "Chevron Fish Passage" channel utilizes concrete cylinders placed in a controlled chevron pattern to provide fish passage along the river-left bank. The concept creates long narrow eddies behind cylinders that assists fish in orientating upstream and through the structure. Three rows of chevrons at each drop structure create headlosses that maintain the 12-inch water surface elevation difference between pools (hydraulic drop). Chevrons have been designed to distribute the headlosses between each row and to maintain low velocities. The chevron boulder pattern/slots are based upon research performed by B. W. Mefford at the United States Bureau of Reclamation for passing non-salmonid species (Ref: "USBR Experience with Multiple-Slot-Baffled Fishways", B.W. Mefford, 2009). MWE adapted the USBR design to reduce the hazard to river users and provide "skimming flow" over the concrete cylinders to reduce debris accumulation (See Figure 4).

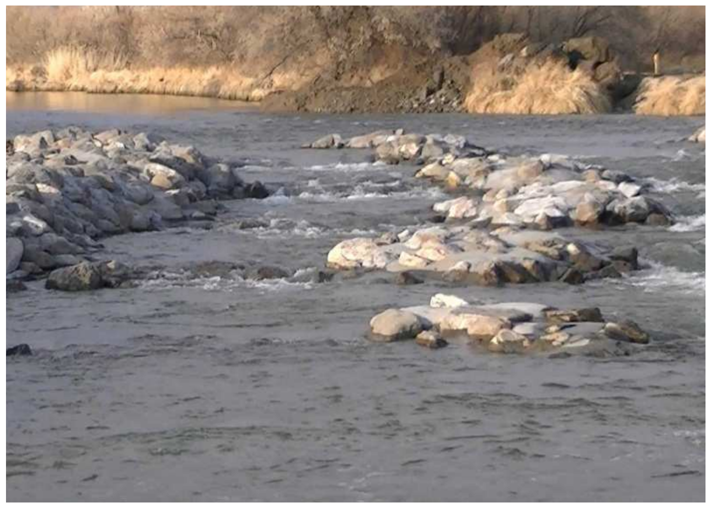

Figure 3 – Right Fish Passage

Figure 4 – Chevron Fish Passage

The center boat passage channel improves fish passage. Center drop structures are abrupt drops with intermediate pools along the centerline to create resting areas for fish and provide cross passage for fish between channels. Fish moving upstream use the strength of current or "attraction flow" to guide movement. The center channel increases attraction flows to the overall bypass structure.

Hydraulic Modeling

One- and two- dimensional hydraulic models were used for the design of the project. HEC-RAS v4.0 developed by the U.S. Army Corp of Engineers was used for fish/boat passage design, flood conveyance, diversion hydraulics, and ditch capacity analysis. 1D models provide coarse hydraulic results based on average hydraulic properties, such as velocity and depth, at cross section perpendicular to the flow in the river. In order to evaluate more localized hydraulic conditions necessary for fish and boat passage design, a two-dimensional model was developed. 2D models divide a project area into group of small boxes or a "mesh" that allows average hydraulic results for the individual boxes within the model. Unlike 1D models, 2D models provide direction of flow. The hydraulic modeling software used for this 2D modeling was **TUFLOW**.

Diversion Hydraulics

A HEC-RAS hydraulic model was developed to determine the required headwater elevation at the dam to maintain the required diversion flow in the Hartland Ditch. The model was developed using on-site survey information and was calibrated using field measurements of the ditch water surface during operation. Orifice and weir calculations were performed for various flow levels and regimes at the existing headgate structure to determine diversion capacity to the ditch. A removable stop log system was designed at the entrance of the center boat passage channel to allow diversion during low river flows (+/-350 CFS).

Flood Conveyance

MWE obtained the Federal Emergency Management Agency (FEMA) hydraulic model results that define the Federal Insurance Rate Map (FIRM) for the Gunnison River. This model is in HEC-2 format, which was converted to HEC-RAS as the 'Duplicate Effective" model. An "Existing Conditions" model was created using recent site survey information and cross sections from the Duplicate Effective model in areas outside of the survey limits. Lastly, a "Revised Conditions" model was developed based on the fish passage design.

A comparison of the Existing Conditions model and Revised Conditions model results for the final design was performed and indicated that the final design does not negatively impact the floodplain. MWE provided a summary of the analysis to the Delta County Floodplain Administrator for approval prior to construction. MWE will perform the same flood conveyance analysis for the "as-built" project based on a field survey of the constructed structure and submit to Delta County for final approval. The final design and as-built flood conveyance analyzes submitted to Delta County are included in Appendix B (MWE is not finished with the as-built flood conveyance analysis at this time. Submittal forthcoming.)

2D Modeling

Detailed hydraulic analysis and design of the fish and boat passages was performed using a 2D hydraulic model. Two flows were modeled, one at the low fish passage river flow (+/-750 cfs) and another at a higher river flow (+/-3000 cfs) to determine if fish passage and boat passage criteria were satisfied. Hydraulic results for velocity, depth, unit flow, flow direction and water surface elevations (hydraulic grade line) were used to evaluate and design the structure. Multiple design and model iterations were completed to develop the final design of the passages. The following is a summary of the 2D modeling results used for design:

- Flow direction- location of eddies for fish and boat passage, bank conditions, cross flow at pools between channels, entrance/exit conditions
- Distribution of flow between three channels
- Velocity and depth in fish passages
- Super elevation of flow at bends
- Distribution of hydraulic drop (profile) in channels
- Location and form of hydraulic jumps in boat passage

The velocity results from 2D models are “average depth velocities”. The average depth velocity in a river, as indicated by its name, is an average of the variable velocities between the river bottom and water surface. It is equivalent to the velocity at 6/10’s the total depth.

When fish move upstream they seek the path of least resistant or minimum velocity, therefore fish tend to move along the river bottom and other slow moving areas. The velocity along this path illustrates the concept of “fish’s eye” velocity. In other words, the velocity the fish experiences or “sees” during movement with a reach of river. Shear stresses created by the roughness of the river bed result in much slower velocities near the river bottom than at the surface. It is reasonable to define the “fish’s eye” velocity as the water velocity at 8/10’s the total depth. From empirical data developed by Chow (1959), the velocity at 8/10’s depth is approximately 0.75 times the average depth velocity. Additionally, McLaughlin Water Engineers has recently completed 3-dimensional hydraulic modeling for another fish passage project using the chevron boulder concept. The results indicate a velocity reduction of approximately 0.6, which closely agrees with the theoretical velocity depth profile presented by Chow. Therefore, an adjustment factor of 0.75 was applied to the average depth velocity results from the two-dimensional modeling to reflect the actual velocity performance of the fish passage structure.

Results of the final design model at both flow conditions indicate that the design meets fish passage depth (2’ min.) and velocity (less than 4 feet per second) criteria at the “fish’s eye” locality. A sample of the 2D modeling results output is shown in Figure 5.

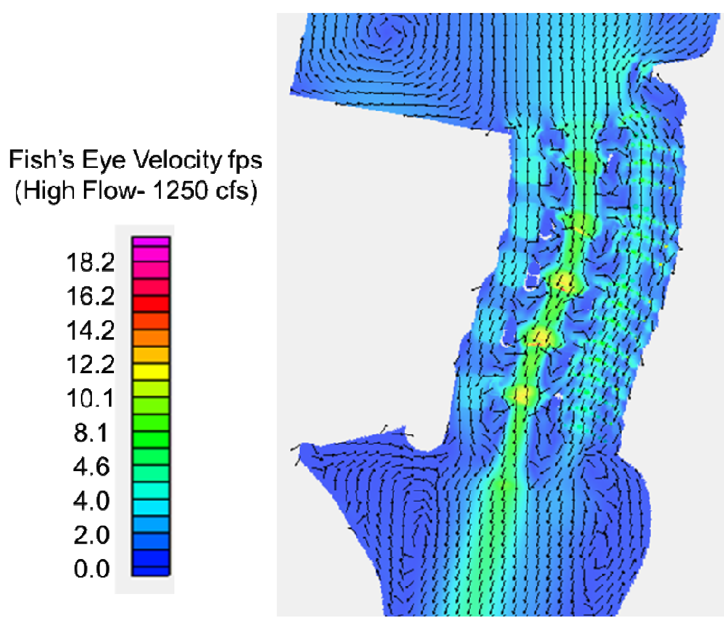

Figure 5 – 2D Modeling Output Example

Structural Stability

An analysis for stability of the structure up to a 100-year flood event was performed. One- and two-dimensional hydraulic modeling results were used for the analysis. Lane’s Weighted Creep Method was used to determine required cut offs to reduce uplift, seepage, and piping under the structure. Boulder sizes were calculated using design criteria for sloped grouted boulder drops as developed by McLaughlin Water Engineers, 1986 (later incorporated into the “Drainage Criteria Manual”, by Urban Drainage and Flood Control District.) Criteria included tractive force concepts such as shear stress, impact/drag forces, uplift/buoyancy, and bed friction. Scour depths were evaluated at the toe of the counter-weir and jetties using applicable empirical equations presented in “Guidelines for Computing Degradation and Local Scour”, by Pemberton and Lara (Technical Guideline for Bureau of Reclamation, 1982).

A grouted boulder mat of rounded locally available materials was used as the primary armoring type for most of the structure. The mats have various thicknesses and cementations grout is kept as low as structurally prudent. Calculation of riprap size and lack of locally available angular rock (quarry produced) led to this armoring approach. This is reflective of other river projects on the Western Slope. Boulder diameters range from 18” up to 48” - depending on where they are placed in the grouted boulder mat, and their projection above the river bottom.

Figure 6 – Grouted Boulders

The design utilizes buried loose riprap on the left bank with buried grouted boulder containment rows placed at approximately 20’ intervals perpendicular to flow. Inclusion of the containment rows allows the use of locally available round stones. Top soil was placed over the riprap and boulder containment rows during construction. The adjacent property owner is planning on planting willows and other vegetation along this bank for further stabilization. Riprap was sized using the Federal Highway Administration and Urban Drainage and Flood Control District design criteria.

Armoring in the chevron fish passage channel consists of loose boulders between concrete walls perpendicular to the channel. The walls provide grade control at each row of chevrons and containment of boulders. Existing river cobble was mixed with locally available round rock to create a well graded subgrade material with a mean diameter of 24-inch. Boulders were placed at the bottom of the channel to provide roughness and resistance to scour. River cobble was used to fill voids between boulders at the surface.

A sloped grouted boulder cutoff was constructed at the upstream edge, downstream edge, and along the divider wall. Shallow (4’ deep) grouted boulder cut offs were installed at the each drop structure. “Self-launching” riprap was used for toe scour protection along the upstream jetty and downstream of the counter-weir.

Dam Modifications

The remaining section of the existing Hartland Dam, approximately 150’, was modified to improve the structural stability and reduce the hazard to river users. A roughened grouted boulder slope was constructed extending from the face of the existing dam downstream approximately 20’. Painted Sky and Hartland Irrigation Company worked directly with Kissner General Contractors to develop the dam modifications. MWE did not provide the design, engineering or construction observation for the dam modifications.

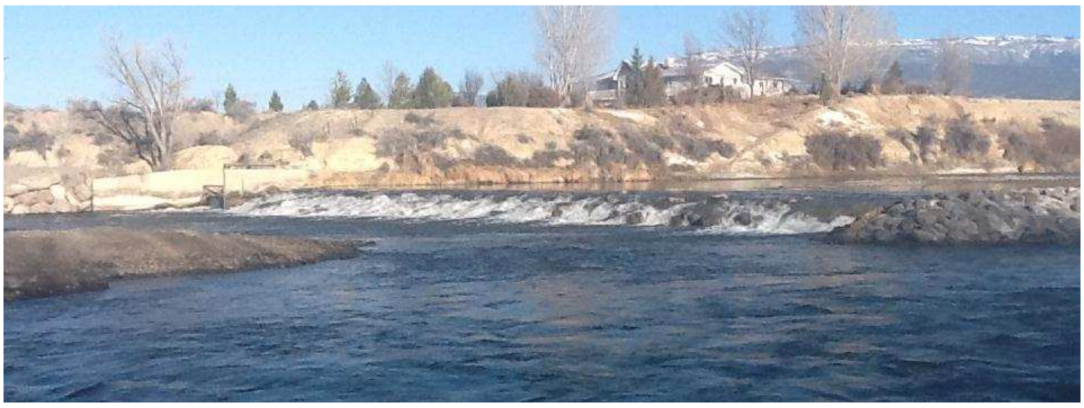

Figure 7 – Dam Modifications

Project Monitoring & Tuning

Due to governmental budget cuts, the resource and conservation development program (RC&D) was defunded in March, 2011. This resulted in Painted Sky losing their partnership with Natural Resource Conservation Service that provided office space and a coordinator to assist with the RC&D program. Due to this, Painted Sky has elected to begin dissolving. As part of this decision, Painted Sky along with the Walton Family Foundation transferred the monitoring phase and funds received for that portion of this project to Trout Unlimited. Future monitoring and tuning will be done and reports provided by Cary Denison, Gunnison Basin Project Coordinator.

Several areas within the project reach will need to be monitored and possibly adjusted or “tuned” post construction:

- Bank and channel stability
- Boat passage hydraulics & safety
- Dam modification hydraulics & safety
- Fish passage performance
- Debris in boat & fish passages

Stabilization problems have existed downstream of the existing Hartland Dam on the river left bank owned by the Hutchins for some time. A power pole has been relocated several times due to the erosion of a steep bank approximately 800 feet downstream of the dam. Four (4) boulder structures (jetties) have been constructed along this bank to prevent further erosion.

Modification of the dam for the boat and fish passage structure will affect the flow regime downstream by concentrating more flow along the left side of the river, which could cause de-stabilization of the banks. Prior to construction of the fish and boat passage structure, Painted Sky had been working with the Hutchins and the NRCS to do a comprehensive bank stabilization project for their property utilizing Environmental Quality Incentives Program (EQIP) funds and cost matching. Painted Sky was seeking funds to assist the Hutchins with their portion of the cost matching. The NRCS was planning on evaluating the reach after the dam modification, boat and fish passages were complete and develop stabilization measure to be implemented. As a result several stabilization measures in the original design including blanketing and revegetation, a boulder jetty downstream of the structure, and removal and replacement of bed material would be evaluated and implemented as part of the NRCS project. For initial bank stabilization at the request of the Hutchins, Painted Sky and Kissner GC installed four boulder jetty structures along the east bank downstream of the dam and upstream of the existing boulder jetties. Stabilization of the channel and banks along and downstream of the new structure is an integral component of the overall project that needs to be pursued and completed based on monitoring of the reach. With the dissolution of Painted Sky this spring, Trout Unlimited will become the lead on monitoring of channel and bank stability and stabilization improvements.

Protocols for monitoring are currently under development. Periodic site inspection of the structure and project reach will be conducted to monitor and evaluated performance and conditions over a range of river flows. Fish passage monitoring will include measurements of velocity and depth and inspections for debris. Hydraulic conditions are to be observed in the boat passage particularly for conditions that pose safety risks, such as, debris accumulation, “keeper” waves, and flow alignment. Observations of the sloped grouted boulder dam modifications (west side) for similar safety risks will be conducted including inspections for the presence of a reverse roller keeper hydraulic at the toe of the dam. Debris accumulated on the dam or boat and fish passages will be removed immediately due safety concerns and negative performance implications.

Hydraulically, this project is complicated. The structure must pass slow swimming fish and boaters, while maintaining the Hartland Irrigation Companies diversion capabilities. Computer modeling was completed as part of the design to reduce the level of uncertainty. A three-dimensional computer or physical modeling effort was initially recommended to further reduce this uncertainty, however funding was not available. As a result, adjustments to in river features or “tuning” will likely be required after construction and initial startup and observation. This will involve the modification of the structure to optimize the performance to meet the project objectives. Tuning modifications will be developed based on evaluations and conclusions from monitoring. Typical tuning of similar structures includes adding or eliminating loose boulders in fish passages, removing chevron faux rocks, and structural modifications to grouted boulders, control crests, and dam modifications.

Cory Williams, US Geological……I will add a paragraph about his monitoring and data as well….

Future Work

The extent and scope of future work is not clearly defined at this time and will evolve over time based on going monitoring. However, several areas and tasks for future work are anticipated at this time. Bank and channel stabilization improvements adjacent to and downstream of the new structure may be required. The fish and boat passage structure will likely require tuning and some routine maintenance to function properly over the long term. The Gunnison River moves significant amounts of debris and sediment some of which will most likely be deposited in or accumulate on the new structure. Debris and possibly sediment will need to be removed periodically for low hazard boat passage and proper function of the fish passage channels.

Appendix

I will add several photos here….

Appendix A – As Recorded Project Drawings

Appendix B – Copy of Flood Analysis and Letter to Delta County As-built Condition