Stream Habitat Investigations and Assistance

Federal Aid Project F-161-R22

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Federal Aid in Fish and Wildlife Restoration

Performance Report

Colorado Parks & Wildlife

Aquatic Research Section

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STATE OF COLORADO

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The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Colorado Parks & Wildlife policy by the Director or the Wildlife Commission.

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PERFORMANCE REPORT

State:	**Colorado**
Project Number:	**F-161-R-22**
Project Title:	**Stream Habitat Investigations and Assistance**
Period Covered:	**July 1, 2015 through June 30, 2016**
Principal Investigators:	**Matt C. Kondratieff** **Eric E. Richer**

Project Objectives:

Job 1: Stream Restoration and Habitat Enhancement Studies

Need

Rivers and streams in Colorado have experienced substantial anthropogenic changes over the past 200 years. These changes were largely due to historic land use activities and water development, such as beaver trapping, placer and gravel mining, flow regulation, timber harvest and tie drives, and construction of roads and railroads (Wohl, 2011). Many streams have been channelized in an attempt to convey floods, protect infrastructure, and maximize crop production. Grazing of livestock in riparian areas has also led to bank erosion, loss of riparian vegetation, and impaired aquatic habitat. These impacts have led to the degradation of aquatic habitat and stream functions at both the watershed and reach scale. Fortunately, stream restoration efforts show promise as a means to aid species recovery, improve water quality, and create new areas for wildlife habitat and recreational activities (Bernhardt et al., 2005). However, additional research on restoration methods and outcomes is needed to understand which techniques are most effective and sustainable.

Objectives

1. Survey and quantify salmonid populations at three project sites by June 30, 2016.
2. Survey salmonid habitat at three project sites by June 30, 2016.

Approach

Action #1:

- Level 1 Action Category: Data Collection and Analysis
- Level 2 Action Strategy: Research, survey or monitoring – fish and wildlife populations
- Level 3 Action Activities: Abundance determination; Age, size, and sex structure

Utilize Before-After Control-Treatment (BACT) study designs to monitor and evaluate stream restoration and habitat enhancement projects. During summer and fall months, we will conduct

electrofishing sampling to determine salmonid biomass, densities and individual fish lengths and weights in control and treatment sites. Fisheries data will be collected from select pre- and post-treatment stream reaches with assistance from aquatic biologists and researchers. Project sites include the (1) Yampa River tail water below Stagecoach Reservoir, (2) Twin Tunnels on Clear Creek, (3) Upper Arkansas River, (4) Middle Fork South Platte River, and (5) Gunnison SWA on the Gunnison River.

Action #1 Accomplishments:

Fish inventory surveys were conducted at three of the five sites listed above, including the Yampa River below Stagecoach Reservoir, Twin Tunnels on Clear Creek, the Upper Arkansas River, and the Gunnison SWA on the Gunnison River. Surveys were not completed on the Middle Fork of the South Platte River due to scheduling conflicts with the area fisheries biologist. During summer and fall months, we conducted electrofishing sampling to determine salmonid biomass, densities and individual fish lengths and weights in control and treatment sites.

Yampa River

The Yampa River downstream of Stagecoach Reservoir is one of the most popular tail water trout fishing destinations in the Nation with some of the highest trout densities and biomass anywhere in Colorado. Bank failure due to trampling from angler use, loss of stabilizing vegetation, and non-functional, in-channel boulder check dam features were the primary causes of habitat degradation and loss of trout productivity over time. Limiting factors to trout populations included: spawning habitat (exceedingly shallow depths or high concentrations of fine sediment), cover for adults (few undercut banks, deep pools, over-hanging bank vegetation and large wood), and limited in-channel habitat complexity (in-channel structure to create resting areas and increase habitat complexity). A habitat enhancement project was implemented and completed in 2013 on 0.6 miles of the tail water reach of the Yampa River below Stagecoach Reservoir. Primary species include rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*). Fourteen years of fish sampling were conducted prior to habitat enhancement and serves as a baseline data for comparison. The first year of post-construction fish sampling was conducted in fall 2015. Monitoring of fish populations, length/frequency, and species composition will continue for the next five years. Since this is a unique tail water reach, no suitable control site was located for comparison purposes. Therefore, habitat and fisheries response will be monitored as a before/after comparison only.

Clear Creek

Physical habitat characteristics of Clear Creek near Idaho Springs, Colorado, have been highly modified from historic conditions. Most of the stream runs parallel with a major Interstate highway (I-70) on one side and a historic railway grade on the other. Most of Clear Creek has been channelized and armored with rip-rap. There are very few locations remaining that include a functional floodplain. The Twin Tunnels construction project was initiated by the Colorado Department of Transportation (CDOT). Once construction of the new tunnels was completed, a temporary frontage road was removed, providing a unique opportunity for riparian restoration within the I-70 corridor. The riparian restoration and in-stream habitat project was completed in April 2015. Primary project goals were to address limiting habitat factors to brown trout,

improve conditions for anglers, and restore stream functions. Specific goals included: improving floodplain connectivity, establishing riparian vegetation, enhancing in-channel habitat features (such as establishing spawning gravel substrate within enhanced glides), and excavating deep lateral scour pools. Pre-construction baseline fish population data were collected during fall 2012, 2013, and 2014 from the proposed treatment site and an adjacent downstream control site. This established three years of baseline data prior to construction activities. The first year of post-construction fish sampling was conducted in fall 2015. Monitoring of fish populations, length/frequency, and species composition will continue for the next four years to evaluate habitat and fisheries response.

Upper Arkansas River

The Upper Arkansas River NRDA Habitat Enhancement Project was developed to address degraded fish habitat in the Upper Arkansas River. Historic mining activities severely degraded water quality within the watershed and were responsible for limiting trout population abundance and individual trout growth rates. Since water quality treatment measures have been implemented, fish populations have recovered to a degree. Fisheries biologists have determined the next steps in recovering trout populations will come from addressing fish habitat limitations. A total of six fish monitoring sites (including three untreated control sites) were established to measure the effectiveness of fish habitat enhancement treatments for the entire project reach. This project is unique in that some fish sampling sites have more than 16 years of baseline data collected prior to implementing the habitat enhancement project. These data provide baseline information for comparison with fish population data now that the project has been implemented. The first year of post-construction fish sampling was conducted immediately concluding project construction in 2014. The second year of fish sampling occurred in August 2015. Monitoring of fish populations, length/frequency, and species composition will continue for the next three years to evaluate habitat and fisheries response.

South Platte River

This long-term BACT study evaluating the effects of different habitat enhancement approaches for trout (i.e., boulder versus large wood treatments) was not sampled in 2015 due to scheduling conflicts with the area biologist. Four long-term fish population monitoring sites have been established on the Middle Fork of South Platte and South Platte Rivers in South Park, Colorado. Data have been collected at the boulder-dominated and control site over a period of 26 years. The four sites include an upstream reference reach site (Tomahawk SWA), toe-wood and large wood-dominated treatment site (Badger Basin SWA), boulder-dominated treatment site (Badger Basin SWA), and a downstream impaired control site (Badger Basin SWA). These four sites are scheduled to be sampled during fall 2016.

Gunnison River

The Gunnison River and Riparian Rehabilitation Project on the Gunnison River SWA is scheduled for construction during fall 2016. Primary goals of this project include enhancing fish habitat by treating eroding banks, developing in-stream structures, and replacing temporary push-up dams with boulder diversion structures on a 2.5 mile reach of the Gunnison River. Fish sampling data were collected on two separate stream reaches (control and treatment) using raft electrofishing and mark/recapture techniques on the Gunnison River during the summer of 2013 and 2015 to establish baseline fisheries data. The Almont site was used for the control reach and

the Van Tuyl site will serve as the treatment reach. Data collected included fish population estimates, fish size by relative abundance, and fish species composition. Fish biomass and density data collected from these sites will provide baseline data for later comparisons once the project is completed. Fish sampling surveys will be repeated again during fall 2016 for a total of three years of baseline fish population data prior to project implementation.

Action #2:

- Level 1 Action Category: Data Collection and Analysis
- Level 2 Action Strategy: Research, survey or monitoring – habitat
- Level 3 Action Activities: Baseline inventory; Monitoring

Topographic and sediment surveys will be used to evaluate changes in longitudinal profile, cross-sections, sediment size, and habitat suitability. BACT studies will be conducted at select site locations to evaluate changes in channel morphology following habitat treatments. For select sites, an Acoustic Doppler Current Profiler (ADCP) will be use to evaluate hydraulic conditions and habitat suitability. Project sites include (1) Wason and LaGarita Ranches on the Rio Grande River, (2) Twin Tunnels on Clear Creek, (3) Upper Arkansas River, (4) Middle Fork South Platte River, (5) Charlie Meyer SWA on the South Platte River, and (6) Gunnison River SWA on the Gunnison River.

Action #2 Accomplishments:

Topographic and sediment surveys were successfully conducted at three of the sites listed above: the Wason and LaGarita Ranches on the Rio Grande River, Upper Arkansas River, and Gunnison River SWA.

Rio Grande River

Topographic and bathymetric surveys were conducted at the Wason and LaGarita Ranches on the Rio Grande River for three representative reaches representing heavily treated, lightly treated, and control reaches. Each reach was approximately 1.2 miles long, for a total survey length of 3.6 river miles. Survey data were used to configure and calibrate HEC-RAS models for each reach to evaluate habitat diversity and conditions (e.g., width, depth, velocity, and slope) across a range of flows. Data analysis and reporting is ongoing.

Upper Arkansas River

Annual longitudinal and cross-section surveys were completed for the Upper Arkansas River habitat restoration project during fall 2015. The total reach length for the project is approximately five river miles. Preliminary monitoring results were presented at the Rocky Mountain Stream Restoration Conference in July 2015 (Richer, 2015). As-built drawings and monitoring results are being synthesized into a monitoring report (Richer and Herdrich, *in preparation*) that should be published in 2016. Survey data is also being used to configure and calibrate 2D habitat models for fish monitoring sites to evaluate changes in habitat suitability between pre-project and post-project conditions. Spatial sediment surveys were conducted at six fish monitoring sites in 2015 to support habitat modeling and evaluation.

Richer, E.E. 2015. Effectiveness of in-stream habitat restoration on the upper Arkansas River. Rocky Mountain Stream Restoration Conference, Breckenridge, Colorado. July 22, 2015.

Richer, E.E. and A.T. Herdrich. *In preparation*. Upper Arkansas River Habitat Enhancement Project: 2015 Monitoring Report. Colorado Parks and Wildlife, Aquatic Research Section, Fort Collins, Colorado.

Gunnison River

Topographic surveys were successfully completed for the Gunnsion River and Riparian Rehabilitation Project on the Gunnison River SWA. Survey data were used to develop a preliminary design, configure HEC-RAS models, and conduct floodplain analysis for three separate project reaches. Results from the floodplain analysis are detailed in Richer (2016) and included in Appendix A. Project construction is currently scheduled for the fall of 2016 and is likely to continue in 2017.

Richer, E.E. 2016. Gunnison River and Riparian Restoration Project: Floodplain Analysis and Preliminary Design Report. Colorado Parks and Wildlife, Aquatic Research Section, Fort Collins, Colorado. 42 pp.

Clear Creek

Topographic surveys for the Twin Tunnel habitat project on Clear Creek were not conducted during this reporting period. Survey work was cancelled due to weather conditions on two separate occasions. The as-built survey for the Twin Tunnels project is currently scheduled for the fall of 2016.

South Platte River

Additional topographic surveys were not conducted at sites on Middle Fork South Platte River, as survey work for this project was successfully completed during the previous reporting period. However, water temperature monitoring is ongoing within select study reaches.

In-stream construction was completed at the Charlie Meyers SWA on the South Platte River during this reporting period. As-built surveys to support before/after habitat evaluation at the Charlie Meyers SWA are currently scheduled for the fall of 2016.

Expected Results and Benefits

Research findings will elucidate how stream restoration and habitat treatments improve fishery resources, as well as channel form and function. Study results will help refine techniques and maximize the benefit of habitat restoration on stream functions and trout fisheries. Results and analysis will be collated from multiple existing habitat improvement project sites to provide guidance for future sportfish habitat improvement projects (multi-year analysis).

Job 2: Fish Passage Studies

Need

Upstream migration is a vital component of the salmonid life cycle. Trout are known to migrate upstream to find ideal spawning habitat and then move back downstream to over-winter in warmer, lower-velocity, and more productive waters. Connectivity between spawning, rearing, and adult habitat is an essential component of a trout fishery. Vertical obstacles in streams and rivers, such as waterfalls, culverts, and water-diversion structures, can impact fisheries by fragmenting migratory ranges. Therefore, it is important that fisheries managers identify and evaluate the impact of in-stream structures on fish populations.

Objectives

1. Monitor fish movement over one diversion structure with RFID technology by June 30, 2016.
2. Provide guidance and technical assistance for one fish passage feasibility study by June 30, 2016.

Approach

Action #1:

- Level 1 Action Category: Data Collection and Analysis
- Level 2 Action Strategy: Research, survey or monitoring – fish and wildlife populations
- Level 3 Action Activities: Movement

Passive Integrated Transponder (PIT) tags will be used to monitor upstream and downstream movement of trout over the Watson Hatchery diversion structure on the Cache la Poudre River. This site has been identified a potential site for a pilot fish passage project in the basin. Two antennae systems will deployed at the site, one upstream and one downstream of the diversion. Movement data will be used to determine if the Watson diversion structure is in fact a barrier to upstream migration and establish baseline movement patterns within the study reach.

Action #1 Accomplishments:

Infrastructure associated with the Watson Diversion structure was damaged during flooding in September 2013. Major construction including pipeline replacement was conducted at the Watson Diversion during 2016. Due to these construction activities, all RFID equipment had to be removed from the site during this reporting period. Although the Watson Diversion study was suspended due to ongoing construction, we were able to provide design guidance for implementation of a fish passage structure at another water diversion on the Cache la Poudre River, the Fossil Creek Reservoir Inlet Diversion (FCRID), utilizing swim performance and fishway design criteria developed in Ficke (2015). Construction of the fishway at the FCRID was successfully completed in 2016 and featured in the *Colorado Outdoors, 2016 Fishing Guide* (Young, 2016). Depths and velocities were measured within the FCRID fishway at two different

flows. Preliminary results suggest that the fishway is meeting design criteria for passage of trout and native forage species.

Ficke, A.D. 2015. Mitigation measures for barriers to Great Plains fish migration. PhD Dissertation, Department of Fish, Wildlife, and Conservation Biology, Colorado State University. 194 pp.

Young, M.T. 2016. The Cache la Poudre River fishway: a way around. *Colorado Outdoors, 2016 Fishing Guide*. 38-40.

Action #2:

- Level 1 Action Category: Technical Assistance
- Level 2 Action Strategy: Technical Assistance
- Level 3 Action Activities: With individuals and groups involved in resource management decision making

Implementing fish passage at diversion structures in Colorado is a challenging process, due to design, funding, permitting, and legal constraints. Given these challenges, feasibility studies have been identified by project stakeholders as a means to evaluate conceptual alternatives for fish passage and build support among stakeholders. We will provide technical assistance for at least one of the following feasibility studies: (1) the Whitney and BH Eaton Fish Passage Project on the Cache la Poudre River and (2) the St. Vrain Creek Fish Passage Project. The objective of these projects is to provide fish passage for all species present in the project reaches, including rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and various forage species.

Action #2 Accomplishments:

We provided technical assistance for both of the feasibility studies listed above. The Whitney and BH Eaton Fish Passage Feasibility Study should be finalized during 2016. Implementing fish passage at both diversion structures would reconnect 13.1 miles of fish habitat within the Cache la Poudre River. The feasibility study will provide 30% designs for implementing fish passage at both structures. CPW has provided funding assistance, fish passage criteria, baseline fisheries survey data, and technical guidance for the feasibility study. The designs selected from the feasibility study will be used to source funding for project implementation.

The St. Vrain Creek Fish Passage Project has focused on developing 65% designs for fish passage at two diversion structures, the Niwot Ditch and South Flat Ditch. The US Fish and Wildlife Service (USFWS) is responsible for developing design documents for the project. CPW has provided technical assistance to support project coordination, design, permitting, and funding assistance. Implementing fish passage at both diversion structures will reconnect 2.6 miles of critical fish habitat in St. Vrain Creek.

Expected Results and Benefits

Most rivers in the Colorado are fragmented by numerous diversion structures that prevent upstream migration of sportfish, adversely affect sediment transport, increase whirling disease

infection risk, entrain downstream migrating fish in irrigation ditches, and sporadically dry up river segments during periods of drought or baseflow. The loss of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) from fragmentation and entrainment is economically costly and represents a loss of public recreation opportunity as fish are unavailable for capture and/or harvest. Fish passage research is focused on evaluating the effectiveness of fish passage structures and the impact of diversion structures on aquatic habitat, as well as the development of species-specific design criteria to improve connectivity in Colorado rivers. Our research efforts utilize not only field measurements to validate fish passage criteria but also use PIT tagged individuals to validate movement on completed projects and provide evidence of success.

Job 3: Whitewater Park Studies

Need

With more whitewater parks than any other state, Colorado has become the epicenter for whitewater park design and construction. Whitewater parks contribute to local communities by providing revenue from tourism, promoting public interest in rivers, and creating recreational opportunities. However, whitewater parks can create hydraulic conditions that impair upstream migration of fish (Stephens et al., 2015; Fox et al., 2016) and create unfavorable habitat conditions for fish (Kolden et al., 2015). As a variety of whitewater park designs are being used throughout Colorado, CPW will build upon previous research by studying different types of structures and their effects on trout and habitat.

Objectives

1. Survey and quantify salmonid populations at two whitewater parks sites to evaluate impacts on fish passage and habitat by June 30, 2016.
2. Survey channel morphology and hydraulics at two whitewater parks sites to evaluate impacts on fish passage and habitat by June 30, 2016.
3. Results and analysis will be collated from multiple studies with the goal of producing management tools for development of fish-friendly whitewater parks (multi-year analysis).

Approach

Action #1:

- Level 1 Action Category: Data Collection and Analysis
- Level 2 Action Strategy: Research, survey or monitoring – fish and wildlife populations
- Level 3 Action Activities: Abundance determination; Age, size, and sex structure

Conduct Before-After studies on two new whitewater parks. Study sites are the Montrose Whitewater Park on the Uncompahgre River and the Gore Canyon Whitewater Park at Pumphouse on the Colorado River. Fish populations will be monitored with the assistance of biologists and researchers before and after construction of the whitewater parks to evaluate their impact on the trout fisheries. This physical habitat and fish passage work is complementary to

ongoing biological assessment work on invertebrates and sculpin at these sites also being conducted by CPW personnel.

Action #1 Accomplishments:

The Uncompahgre River whitewater park consists of a total of six channel-spanning structures. Each channel-spanning structure consists of a pre-cast concrete block located within the center of the channel with boulder wing walls extending laterally to each bank. A fish passage chute was designed within a portion of one of the boulder wing walls (each structure has a total of two wing walls, one located on river-left and one on river-right). The project was completed during the winter of 2015. Fish sampling sites were established downstream, within, and upstream of the Uncompahgre River whitewater park. Sites located downstream and upstream of the whitewater park were not treated (serving as "control" sites) to serve as a comparison against the whitewater park reach. One year of "before" monitoring data was collected as baseline data for comparison with the post-project controls and whitewater park. We collected our first year of post-construction fish sampling in November 2015 at all three fish sampling locations. Monitoring data will be used to determine if the whitewater park structure might result in an alteration of fish populations up or downstream of the structure, degradation of fish habitat in the pool located below the structure and provide evidence if the structure might be inhibiting upstream fish passage. Post-construction monitoring will continue for a minimum of two years.

The Gore Canyon Whitewater Park at Pumphouse consists of a single channel-spanning structure that is split into two chutes: one chute to accommodate fish and non-whitewater related recreation (i.e. drift boat passage) and one to accommodate whitewater-related recreation (i.e. play boaters and kayakers). The project was constructed and completed during the spring of 2015. Pre-project fish sampling was conducted in the vicinity of the project reach during the fall of 2014 for one year of pre-project baseline data. The first year of post-project fish sampling surveying was completed in November 2015. Monitoring data will be used to determine if the whitewater park structure has impacted fish populations, aquatic habitat, and upstream fish passage. Post-construction monitoring will continue for a minimum of two years.

Action #2:

- Level 1 Action Category: Data Collection and Analysis
- Level 2 Action Strategy: Research, survey or monitoring – habitat
- Level 3 Action Activities: Baseline inventory; Monitoring

Impacts to habitat quality and fish passage will be assessed by surveying water depth and velocity with an ADCP before and after project construction. In addition, topographic surveys will be conducted before and after construction to evaluate changes in channel morphology. Survey data will also be used to configure 2D models for assessing changes in habitat suitability across a range of flows. Results for ADCP measurements and 2D modeling will be combined to elucidate if whitewater construction has impacted fish passage at these study sites.

Action #2 Accomplishments:

Survey data from the Montrose Whitewater Park on the Uncompahgre River were used to configure and calibrate HEC-RAS models for both pre-project and post-project conditions. Results from HEC-RAS models will be used to evaluate changes in channel morphology and hydraulics, as well as inform boundary conditions for 2D habitat models. Configuration and calibration of 2D models is currently ongoing. Results from HEC-RAS and 2D modeling will be used to evaluate the impact of whitewater park implementation on habitat suitability and fish passage.

Multiple surveys were conducted at the Gore Canyon Whitewater Park at Pumphouse on the Colorado River during this reporting period. Topographic and bathymetric surveys were conducted to document post-project channel morphology. An ADCP was used to measure water depths and velocities throughout the project reach to provide calibration and validation data for hydraulic and habitat models. Survey data will be used to configure HEC-RAS and 2D models for the project reach and support evaluation of whitewater park implementation on habitat suitability and fish passage. Data processing, analysis, and model configuration is ongoing.

Action #3:

- Level 1 Action Category: Technical Assistance
- Level 2 Action Strategy: Technical Assistance
- Level 3 Action Activities: With individuals and groups involved in resource management and decision making

As research scientists, part of our job is disseminating research results to promote science-based resource management decisions to whitewater park designers, water management agencies, and aquatic resource management agencies.

Action #3 Accomplishments:

Three peer-reviewed publications and four theses were completed to provide the foundation for scientifically defensible management tools for development of fish-friendly whitewater parks. These publications provide inside into potential impacts on fish passage, fish habitat, and methods for assessing fish passage using 2-D and 3-D hydraulic modeling methods.

Expected Results and Benefits

Information from this study is being used to determine the impact of whitewater park construction on rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) populations, habitat, and movement. In addition, results will be used to develop design guidelines for whitewater parks that optimize both recreational and ecological benefits.

Job 4: Development and Evaluation of a Radio Frequency Identification (RFID) and GPS System

Need

Portable radio-frequency identification (RFID) systems that detect passive integrated transponder (PIT) tags can be used to analyze survival of aquatic species, fish movement patterns, and habitat utilization (Fetherman et al., 2014). RFID systems have been used in small, wadeable rivers to detect fish using both stationary and mobile designs (Fetherman et al., 2014). Incorporating mobility and GPS technology into RFID systems can link the spatial distribution of fish to individual characteristics, such as species, length, and weight. Combining individual characteristics with spatial data has a vast range of research possibilities, including season patterns in fish migrations, the effects of in-stream barriers on fish migration, habitat utilization by species and age-class, mark-recapture population estimates, the response of aquatic organisms to climate change, as well as the impact of land use on aquatic species.

Objectives

1. Conduct one study that utilizes the RFID-GPS system to evaluate seasonal movement patterns for rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) by June 30, 2016.

Approach

Action #1:

- Level 1 Action Category: Data Collection and Analysis
- Level 2 Action Strategy: Research, survey or monitoring – fish and wildlife populations
- Level 3 Action Activities: Movement

The RFID-GPS system will be deployed on the Middle Fork South Platte River near Hartsel, Colorado. One pass with will be conducted through study reaches at select times to evaluate seasonal movement patterns and reach-scale habitat utilization for trout.

Action #1 Accomplishments:

The RFID-GPS system was deployed within project reaches during July 2015, September 2015, and October 2015. Detection data from the RFID-GPS system will be combined with detection data from four fixed antenna sites to evaluate trout movement patterns. Preliminary results suggest that some brown trout (*Salmo trutta*) are migrating at least 25 river miles to access spawning habitat, whereas some rainbow trout (*Oncorhynchus mykiss*) are migrating at least 21 river miles to access spawning habitat. These finding are critically important for evaluating the importance of longitudinal connectivity in Colorado rivers where the prevalence of diversion structures and other barriers have severely fragmented aquatic habitats. The RFID-GPS system has also proven useful for evaluating issues with PIT-tag retention in salmonids. A preliminary evaluation of PIT-tag retention issues was presented by Richer et al. (2016) and a peer-reviewed publication focused on development of the RFID-GPS system is currently in preparation (Richer

et al., *in preparation*). Data collection for this project is still ongoing but is currently scheduled for completion in November 2016.

Richer, E.E., M.C. Kondratieff, and E.R. Fetherman. 2016. RFID-GPS system development and issues with PIT tag retention. Plains Fish Research Meeting, Fort Collins, Colorado. January 5, 2016.

Richer, E.E., E.R. Fetherman, M.C. Kondratieff, and T.A. Barnes. *In preparation*. Development of a mobile radio frequency identification (RFID) system that incorporates GPS to detect PIT-tagged fish in stream. North American Journal of Fisheries Management.

Expected Results and Benefits

This study will help identify the strength and limitations of the RFID-GPS system for detecting PIT-tagged fish in natural river systems. In addition, detection data should elucidate seasonal migration patterns for rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*). These data will used to evaluate migration patterns and reach-scale habitat utilization by species and size class.

Job 5: Technical Assistance

Need

CPW and other state and federal personnel are frequently in need of technical assistance related to stream habitat restoration, fish passage, and post-flood recovery. Technical assistance related to stream habitat restoration project identification, selection, design, evaluation, and permitting for CPW, and other state and federal personnel will be provided. Technical assistance includes review of stream restoration project designs for aquatic biologists and district wildlife managers (DWMs), site visits to proposed stream restoration locations, consultations with various agencies on stream restoration opportunities associated with highway and bridge improvement projects, project management of aquatic habitat treatment construction during highway bridge replacements or Fishing Is Fun (FIF) projects, consultations and technical support related to stream mitigation work for 404 permit violations, technical assistance related to fish passage design and construction, and teaching at various technical training sessions for CPW and other state and federal personnel.

Objectives

1. Provide at least 10 technical assistance reviews to CPW personnel, NGOs, and Federal Agency Personnel as requested by June 30, 2016.

Approach

Action #1:

- Level 1 Action Category: Technical Assistance
- Level 2 Action Strategy: Environmental Review

- Level 3 Action Activities: Review of proposed projects

Review proposed stream habitat restoration and fish passage projects, including design, contractor selection, and permitting for CPW and other state and federal personnel as requested. Review proposed designs for post-flood road reconstruction and stream restoration for the Colorado Department of Transportation (CDOT) as requested. Provide training to CPW and other state and federal personnel on stream restoration techniques and fish passage design criteria, including guidance for permitting.

Action #1 Accomplishments:

We provided technical assistance for the following stream habitat restoration and fish passage projects:

1) Recreation In-channel Diversion (RICD) application for the Glenwood Springs Whitewater Park on the Colorado River
2) Highland Ditch fish screening and passage project on the White River
3) Homestake Diversion rehabilitation project on the Arkansas River
4) Durango Whitewater Park on the Animas River
5) Lester-Attebury Diversion on the Arkansas River
6) Flushing flow recommendations for the Cache la Poudre River
7) FACStream Stream Mitigation Crediting Protocol for Colorado
8) Senate Bill 40 (SB40) certification for CR54 bridge on the Big Thompson River
9) Fish passage structure at Ware & Hinds Diversion on Elk Creek
10) Dickens Whitewater Park on St. Vrain Creek
11) Big Thompson River Public Accessible Lands River Restoration Project
12) Highway 34 reconstruction along the Big Thompson River (CDOT)
13) Windy Gap Bypass on the Colorado River
14) Upper Colorado Wild and Scenic Stakeholder Group
15) James Creek Conceptual Stream Restoration Plan
16) Upper Lone Pine Creek Habitat Enhancement Project on the Tombras Ranch
17) Lyons Whitewater Park reconstruction on St. Vrain Creek
18) Bohn Park Habitat Restoration Project on St. Vrain Creek
19) Fish Creek Habitat Enhancement/Passage Project on Fish Creek, Estes Park
20) Green Creek Fish Habitat Enhancement Project on Yampa River Tributary
21) Craig Station Water Intake Channel Improvement Project, Yampa River
22) Eagle River Stream Restoration and Whitewater Park Project, Eagle River
23) Grape Creek Habitat Improvement Assessment, Grape Creek
24) Consultations with Dave Graf, CPW Water Unit, Dolores River, San Miguel River and Devil Creek
25) River Bluffs Open Space-Poudre River Restoration Project, Poudre River
26) Master Plan for Cache la Poudre River through Fort Collins

Expected Results and Benefits

As research scientists, part of our job is disseminating research results to promote science-based resource management decisions to CPW internal management staff, resource users, and other outside management agencies. Our participation in technical review and project development supports the incorporation of our research findings into project designs, which hopefully leads to better quality projects that maximize benefits for sportfish populations and habitat, while minimizing unintended detrimental impacts.

References

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Appendix A

Gunnison River and Riparian Rehabilitation Project: Floodplain Analysis and Preliminary Design Report

Gunnison River and Riparian Rehabilitation Project: Floodplain Analysis and Preliminary Design Report

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Summary

The objective of this report is develop preliminary designs and evaluate floodplain impacts for three water diversion structures located within the Gunnison River State Wildlife Area (SWA). Pushup dams are currently used to divert water into the irrigation ditches. The construction and maintenance of pushup dams and irrigation ditches has impacted aquatic and riparian habitats. Replacing the pushup dams with cross-vane diversion structures should reduce maintenance needs while improving stream functions and aquatic habitat. Preliminary designs are presented as proposed conditions in Appendices A-C. Floodplain impacts were evaluated by comparing existing and proposed conditions in accordance with Colorado Water Conservation Board (CWCB) rules for regulatory floodplains. As none of the proposed designs create a vertical rise in excess of 0.3 ft, the proposed structures should not require a Letter of Map Revision (LOMR).

Introduction

The Gunnison River and Riparian Rehabilitation Project was funded by the Gunnison Basin Roundtable and CWCB in March 2014, and received the official Notice to Proceed on September 24, 2014. The goals of the project include:

- Increase wild brown and rainbow trout biomass and densities;
- Improve conditions for quality-sized adult trout;
- Improve fishing access with a trail system;
- Assist water right holders in improving and/or relocating existing water diversion structures to improve habitat, stability and channel alignment;
- Create in-channel deep pools to provide lower velocity holding areas;
- Explore the potential to reconnect the floodplain with the existing channel to improve river function, flood storage, and aquifer recharge;
- Assess aggradation and degradation near the bridges;
- Maintain the existing river planform to maintain property boundaries;
- Incorporate in-channel habitat improvement structures while not raising flood stage;
- Improve riparian habitat for wildlife and improve the river functions by planting native woody vegetation; and,
- Improve and manage boater access.

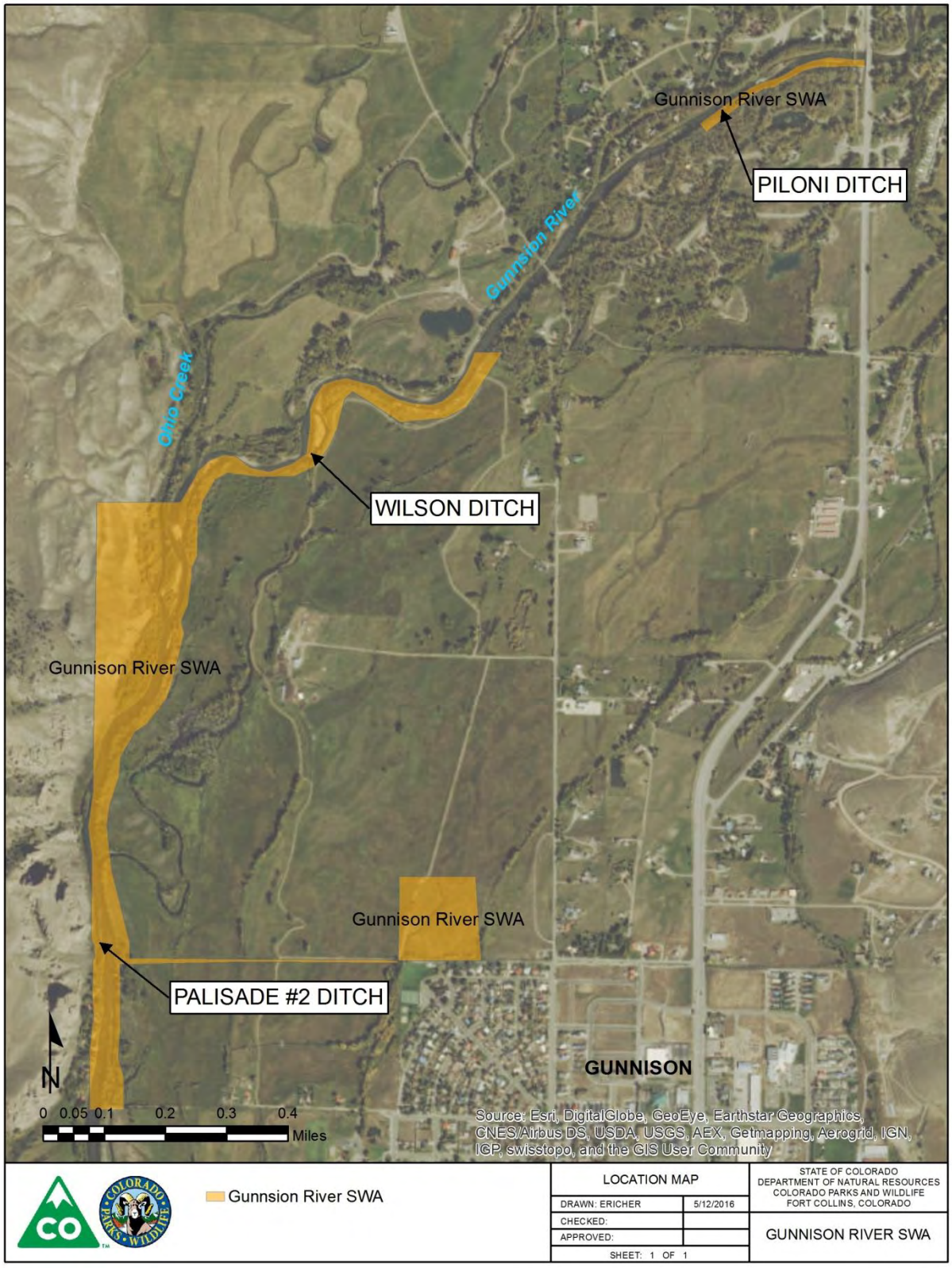


Figure 1. Location map for the Piloni Ditch, Wilson Ditch, and Palisade #2 Ditch near Gunnison, Colorado.

The objective of this report is to provide preliminary designs and floodplain analyses for three water diversion structures: the Piloni Ditch, Wilson Ditch, and Palisade #2 Ditch. All of the structures are located within the Gunnison River SWA near Gunnison, Colorado (Figure 1). The existing structures require frequent maintenance including re-construction of instream pushup dams and excavating ditch inlets. Replacing the existing pushup dams with boulder cross-vane structures (Rosgen, 2006) will reduce the need for maintenance while improving aquatic habitat and channel stability. Standard rules and regulations were used to evaluate the impact of the proposed structures on regulatory floodplains in accordance with CWCB (2010). These rules state that a LOMR is needed whenever a stream alteration activity is suspected to increase or decrease the base flood elevation in excess of 0.3 vertical feet. All design alternatives that resulted in a rise in excess of 0.3 ft were eliminated from consideration. The preferred alternatives for the Piloni Ditch, Wilson Ditch, and Palisade #2 Ditch are presented as proposed conditions in Appendices A, B, and C, respectively.

Site Description

The Gunnison River within the project reach has been impacted by channelization and construction of pushup dams to divert water into irrigation ditches. These activities have impaired floodplain connectivity and channel morphology, impacting riparian conditions and aquatic habitat. Floodplain analyses were focused on the reaches immediately upstream and downstream of the water diversions structures. Site characteristics for each location are unique and will be discussed independently.

Piloni Ditch — The Piloni diversion structure is located in the upstream section of the Gunnison River SWA below HW 135 (Figure 1). The Piloni diversion structure consists of a pushup dam that extended approximately 210 ft upstream from the head gate when surveyed in April 2015. Historical photos show that the pushup dam can extend an additional 60 ft upstream following construction. It appears that the upper 60 ft of the structure is often washed out during runoff. The Piloni Ditch has a decreed water right of 40 cfs (City of Gunnison, personal communication). However, flow records obtained from the Colorado Division of Water Resources (DWR) show that flows in the Piloni Ditch are typically much lower than 40 cfs (Table 1). It appears that flows in the Piloni Ditch over the past ten years have decreased compared to historical values due to conditions at the Piloni head gate. During surveys in April 2015, the head gate culvert was clogged with sediment and provided only 0.3 ft of free board between the invert of the ditch and top of the culvert (Figure 2). The issues with sediment accumulation below the Piloni head gate highlight the need for a new head gate structure that includes a sediment sluice. Sedimentation has also impaired flows through the ditch system and some ditch maintenance will likely be needed to optimize water delivery. Furthermore, there is a road culvert in the ditch approximately 23 ft downstream of the head gate. This culvert had a surveyed diameter of 2.13-2.32 ft, which is not sufficient capacity to accommodate 40 cfs. Existing conditions for the Piloni Ditch are depicted in Appendix A-1.

Table 1. Summary statistics for diverted flows into the Piloni Ditch, 1975-2015.

	Diverted Flow (cfs)				
Time Period	**Maximum**	**Average**	**Median**	**Minimum**	**Standard Deviation**
1975-2015	38.9	5.5	3.3	0.0	6.9
2006-2015	10.6	3.8	3.3	0.0	2.7

Figure 2. Outlet of the head gate culvert showing accumulation of sediment with adverse impacts on flows into the Piloni Ditch.

Wilson Ditch — The Wilson Ditch is located approximately 0.3 miles above the confluence with Ohio Creek (Figure 1). The inlet to the Wilson Ditch requires frequent maintenance due to issues with sediment aggradation. Maintenance activities at the Wilson Ditch have impacted channel morphology, sediment transport, riparian vegetation, and floodplain connectivity. To improve conditions at the Wilson Ditch, a boulder cross-vane diversion structure will be installed to provide grade control, improve sediment transport, and deliver water to the irrigation ditch. The Wilson Ditch does not have a decreed water right and is being designed to divert 15 cfs under "free river" conditions. Currently, there is no structure at the Wilson Ditch to divert flows from the Gunnison River. The current point of diversion is located on the downstream end of point bar, an area typically associated with sediment aggradation. Sediment deposition in the Wilson Ditch requires frequent maintenance that entails excavating ditch and piling sediment in the riparian area between the ditch and the Gunnison River (Figure 3). These maintenance activities have been ongoing for a number of years, impacting both channel morphology and riparian conditions. The river channel is notably wide at the point of diversion, which is exasperating issues with sediment aggradation. Existing conditions for the Wilson Ditch are shown in Appendix B-1.

Figure 3. Inlet to the Wilson Ditch showing large pile of sediment that has been removed from the ditch and placed between the ditch and the Gunnison River.

Palisade #2 Ditch — The Palisade #2 Ditch is located approximately 0.7 miles below the confluence with Ohio Creek (Figure 1). The existing diversion structure is a pushup dam that requires frequent maintenance. The DWR database shows that the Palisade Ditch #2 (WDID #5900647) has a decreed water right of 5 cfs. The Palisade #2 diversion structure consists of a pushup dam that extends approximately 350 ft upstream of the ditch inlet (Figure 4). Construction and maintenance of the pushup dam has widened the river channel, impacting channel morphology and aquatic habitat. Sedimentation at the ditch inlet also requires maintenance to optimize flows into the ditch. The existing head gate does not include a sediment sluice, which limits the ability to manage sediment in the vicinity of the ditch inlet and head works. The channel is bounded by a narrow vegetated bank on river right and a high, eroding bank on river left. Bank erosion near the terminus of the pushup dam on river left has undermined a number of cottonwood trees, exposed their root systems and compromising their stability (Figure 4). While recruitment of large wood to the river channel would benefit aquatic habitat, these are large trees that could accumulate at bridges and damage important infrastructure. Existing conditions for the Palisade #2 Ditch are shown in Appendix C-1.

Figure 4. Looking upstream at the Palisade #2 pushup dam, note the vegetated bank on river right and the exposed cottonwood roots on river left.

Preliminary Designs

Piloni Ditch Design — The proposed design for the Piloni diversion replaces the existing pushup dam with a boulder vane arm (Appendix A-2). To minimize floodplain impacts, the vane arm was set at the same elevations as the existing pushup dam. Based on historical photos and survey data, the vane arm was extended an additional 60 ft upstream to replicate the extent of the existing pushup dam prior to runoff. To provide additional stability at the terminus of the boulder vane arm, an optional boulder sill is shown on the proposed design layout. This sill would be set at the elevation of the existing stream bed and extend across the channel. The proposed structure may require maintenance following ice flows or floods, but can be repaired in the wet when flows are sufficiently low to accommodate equipment access.

Sediment issues at head gates and within irrigation ditches can increase maintenance needs for water users. Sediment sluice or bypass structures can be used to improve water and sediment management near head works. The head gate for the Piloni Ditch is constructed of landscape timbers that could be damaged during installation of a sediment sluice. Installing a new head gate and sediment sluice at the ditch inlet would improve water delivery and reduce sedimentation. Increasing culvert capacity within the irrigation ditch system would also improve water delivery. These design options should be evaluated by project stakeholders prior to developing the final design package.

Wilson Ditch Design — The objectives of the proposed design are to improve aquatic and riparian habitat by providing a stable water diversion structure that can deliver 15 cfs to the Wilson Ditch. Currently, there is not a water diversion structure at the inlet to the Wilson Ditch. The proposed design will use a boulder, cross-vane diversion structure (Figure 5; Rosgen, 2006) that will tied directly into the head works to divert flows into the Wilson Ditch. The elevation of two culvert inverts at the Wilson head gate structure were used inform design elevations for the cross-vane diversion structure. The invert of these culverts was surveyed at 7723.78 ft and the crest of the new cross-vane diversion structure was set 0.78 ft higher at 7724.50 ft. This design elevation should provide sufficient hydraulic head to deliver water to the Wilson head gate. Two steps were incorporated into the diversion structure design to provide additional grade control and to protect the upstream crest from scour. The vertical drop between each step was set to 1.0 ft. Proposed conditions for the Wilson Ditch are presented in Appendix B-2.

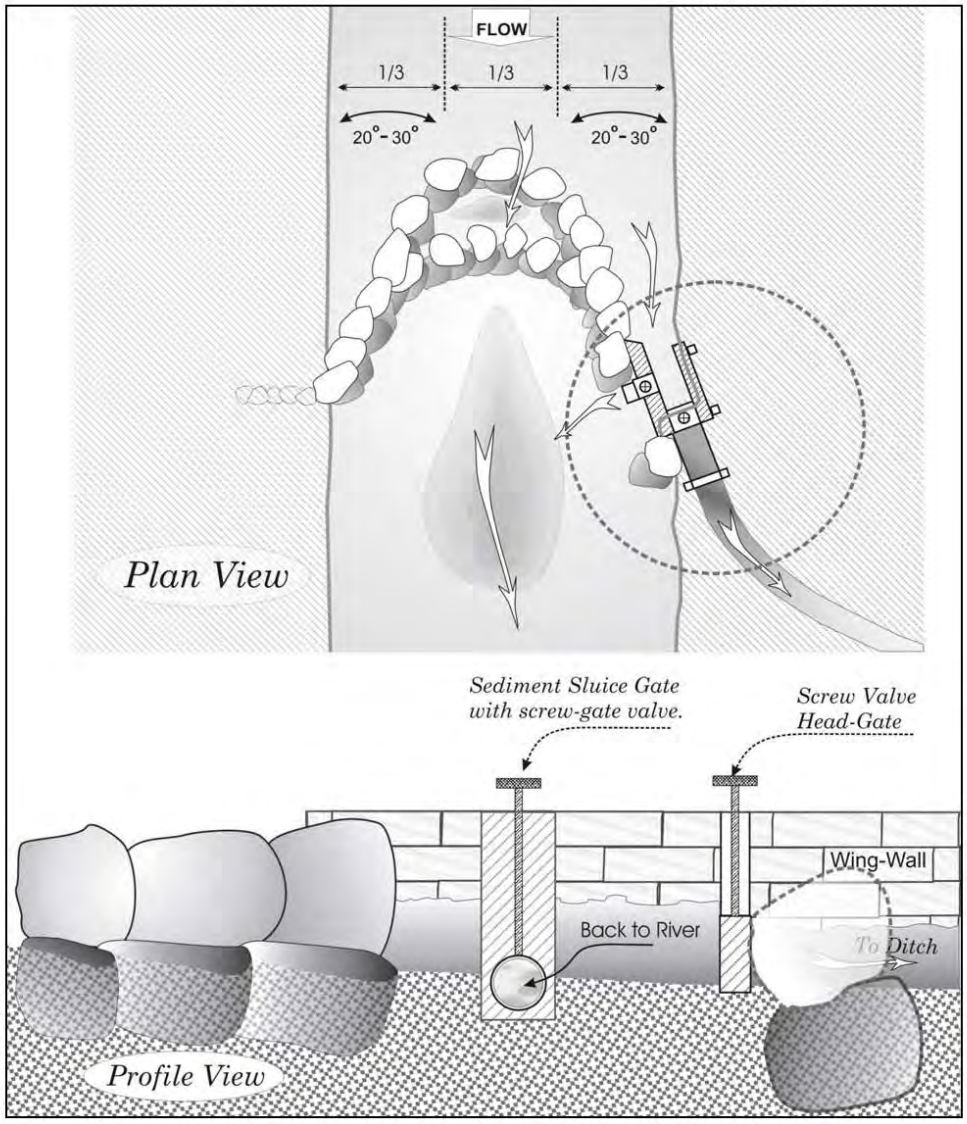


Figure 5. Example of a cross-vane diversion structure with irrigation head gate and sediment sluice (Rosgen, 2006).

Sedimentation at the ditch inlet, within the ditch itself, and at the head gate is a major issue at the Wilson Ditch under existing conditions. Relocating the ditch inlet to an area that is not prone to sedimentation should reduce issues with sediment aggradation. Furthermore, incorporating a sediment sluice into the head works should reduce maintenance needs and improve operations. Sediment that was previously excavated from the ditch will be graded into a multi-stage channel design that includes a low-flow channel, bankfull riparian bench, and terrace features. New streambanks will be stabilized with a boulder and cobble matrix and backfilled with native material. Willows, trees, and sod mats will be transplanted to riparian benches and terrace features to initiate revegetation, followed by seeding and planting with native riparian and upland species as specified on final construction documents. Concrete rubble previously used for bank stabilization will be removed from the left streambank downstream of the diversion structure. The new streambank will be stabilized with a combination of boulders and large wood that will also enhance aquatic habitat. The opposite point bar will be shaped to increase the radius of curvature around bend and reduce shear stress on the outside bank.

Palisade #2 Ditch Design — The existing pushup dam at the Palisade #2 diversion will be removed and replaced with a cross-vane diversion structure with a single step (Appendix C-2). The proposed design should reduce the need for maintenance, including re-construction of the pushup dam and removal of sediment from the ditch inlet. The crest of the cross-vane diversion structure was set at an elevation of 7696.90 ft, which is 0.5 ft higher than the invert of the culvert at the head gate (i.e., 7696.40 ft). The proposed structure should provide sufficient hydraulic head to deliver water the Palisade #2 Ditch. Bank erosion near the terminus of the existing pushup dam has undermined a number of cottonwood trees by exposing their root systems. Stabilizing the bank on river left would protect the cottonwoods from further erosion while improving channel morphology, sediment transport, and aquatic habitat. Bank stabilization around these cottonwood trees was not included in the preliminary design due to uncertainty regarding constructability and cost. The need for bank stabilization should be discussed with project stakeholders prior to developing the final design package.

Hydraulic Modeling and Floodplain Analysis

The 100-year flood is used to determine the regulatory floodplain in Colorado (CWCB, 2010). Any activity that increases the 100-year flood elevation in excess of 0.3 ft will require a LOMR. Existing and proposed conditions were modeled in HEC-RAS using the same cross-section locations, roughness values, and boundary conditions. This approach should determine if the proposed changes in channel morphology will impact the 100-year flood elevation. The preliminary designs presented in this report were developed with goal of minimizing floodplain impacts by limiting any rise in the 100-year flood to less than 0.3 ft, thereby preventing the need for a LOMR.

Site Survey — Existing conditions were surveyed with a Trimble GNSS surveying system to support assessment, design, and floodplain analysis. All survey data were corrected to the base station using an OPUS solution (Table 2) and checked against two NGS control points (i.e., JL0212 and JL0248). In some locations, floodplain elevations were supplemented with elevation data from a 30 meter Digital Elevation Model (DEM). All surveyed and supplemental points used to analyze existing conditions and inform

proposed conditions are shown in Appendices A-C. The initial site survey was conducted during April 2013. Additional surveys were conducted at the Piloni Ditch during April 2015 and at the Wilson Ditch and Palisade #2 Ditch during November 2015.

Table 2. NGS OPUS Solution for base point used to correct all survey data.

Description	Latitude	Longitude	Elevation (ft)
Base Station	38.564908	-106.921515	7834.17

Hydrologic Analysis — Flows for hydraulic analysis were identified using discharge records for two gauging stations, USGS 09114500 Gunnison River Near Gunnison, CO and USGS 09113980 Ohio Creek Above Mouth Near Gunnison, CO. To estimate the stream flow that corresponds to the surveyed WSE at the Piloni and Wilson diversions, instantaneous discharge records from Ohio Creek were subtracted from the Gunnison River records and averaged over the times when surveying took place. Discharge records for the Gunnison River Near Gunnison, CO were used evaluate flows at the Palisade #2 diversion. Daily summary statistics for Gunnison River above Ohio Creek were analyzed for WY 1999-2015 to evaluate typical flow conditions at the Piloni and Wilson diversions and select design discharge values (Figure 6). Daily summary statistics for Gunnison River near Gunnison were analyzed for WY 1999-2015 to evaluate typical flow conditions and select design discharge values for the Palisade #2 diversion (Figure 7).

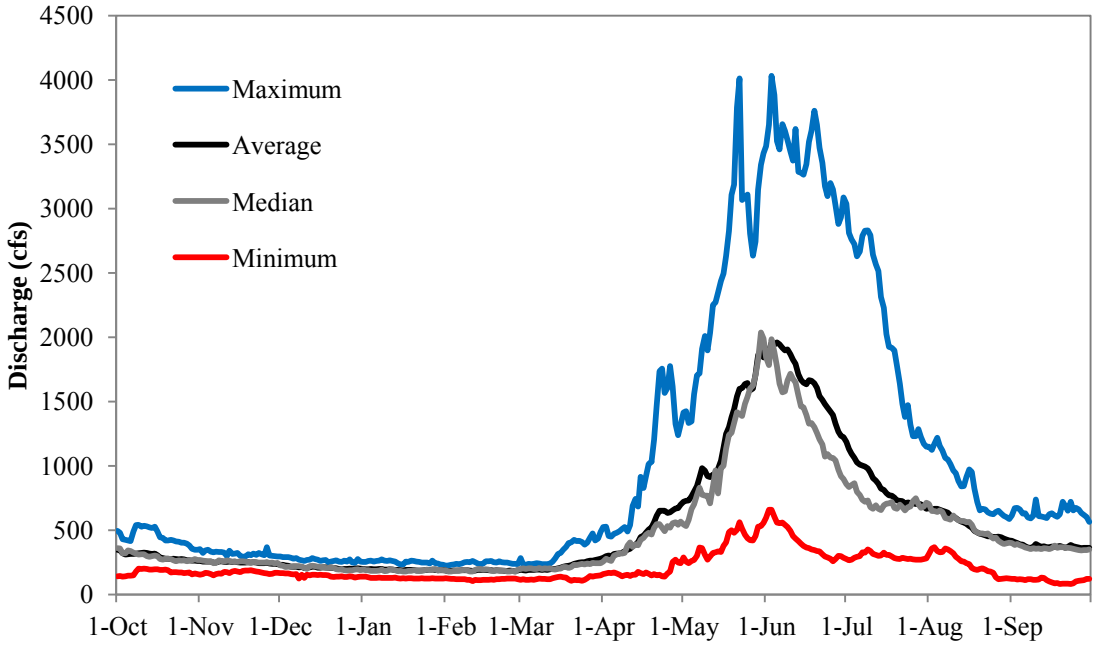


Figure 6. Average daily discharge statistics for Gunnison River above Ohio Creek, 1999-2015.

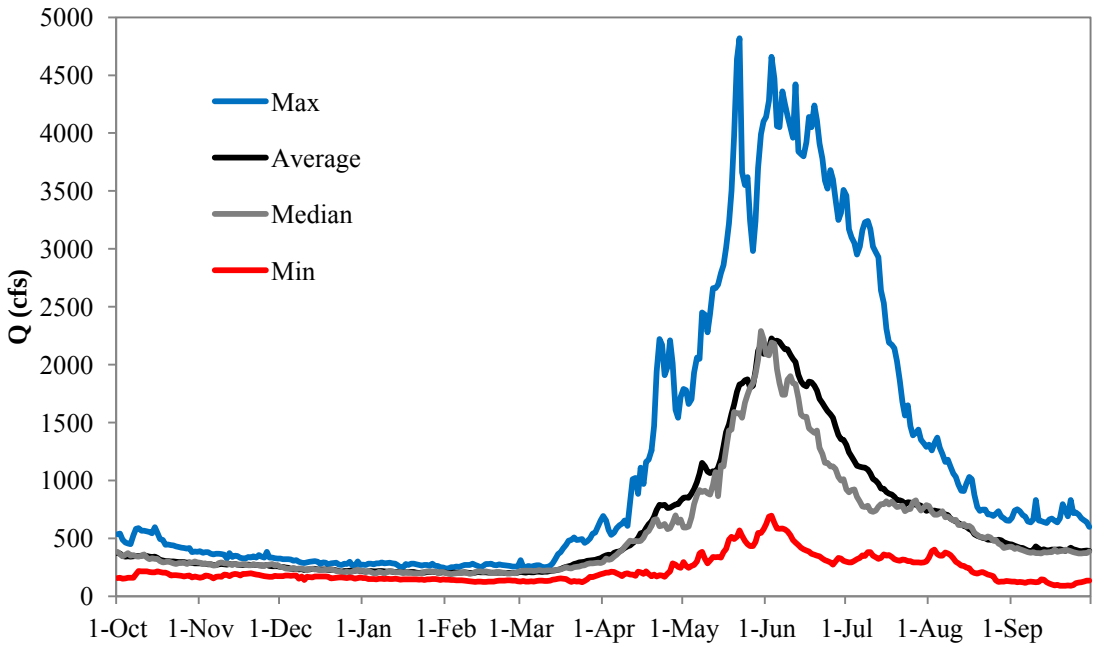


Figure 7. Average daily discharge statistics for Gunnison River near Gunnison, 1999-2015.

Peak flow statistics for the Gunnison gauge were obtained from the USGS StreamStats application. The Gunnison River gauge is located below Ohio Creek near the town of Gunnison. As the Piloni and Wilson ditches are located upstream of the Ohio Creek confluence, flow contributions from Ohio Creek were removed from peak flow estimates for the Gunnison gauge. To estimate flows for the reaches above Ohio Creek, peak flow data for Ohio Creek were subtracted from Gunnison River peak flow records for 1999-2014. These data were then used to develop a regression equation for estimating peak flows in the Gunnison River upstream of the Ohio Creek confluence. All flow profiles used to evaluate the proposed designs for the three diversion structures are presented in Table 3.

Table 3. Flow data (Q) used for the floodplain and design analysis at the Piloni, Wilson, and Palisade #2 diversion structures.

Flow Profile	Piloni Q (cfs)	Wilson Q (cfs)	Palisade #2 Q (cfs)	Description and Data Source
Cal	445	275	280	Calibration flow; Instantaneous discharge records
Design1	NA	500	500	Design flow; Average daily discharge records
Design2	1000	1000	1130	Design flow; Average daily discharge records
Design3	2000	2000	2260	Design flow; Average daily discharge records
Q2	3030	3030	3640	2-year flood; USGS StreamStats
Q5	4440	4440	5330	5-year flood; USGS StreamStats
Q100	8160	8160	9810	100-year flood; USGS StreamStats

Hydraulic Analysis — Flood elevations for existing and proposed conditions were modeled using HEC-RAS (USACE, 2010). The locations of cross section lines used in model configuration are depicted in Appendices A-C. The primary objective of hydraulic analysis was to evaluate the floodplain impacts for

the 100-year flood. To calibrate the models for existing conditions, Manning's n was varied between 0.035-0.055 to minimize the difference between surveyed and observed water surface elevations (WSE) across all cross-sections. Model calibration resulted in Manning's n values that varied between 0.039 and 0.055 depending on the site and amount of flow in the river (Table 5). The values presented in Table 4 were applied for all in-channel areas, and are typical for mountain streams with steep banks and bed material consisting of gravel, cobbles, and a few boulders (Chow, 1959; USACE, 2010). Manning's n for all over-bank areas was assumed to be 0.075, which is representative of floodplains with heavy brush. As Manning's n is known to decreased as stage increases (Chow, 1959), USGS field measurements for the Gunnison River Near Gunnison stream gauge and topographic survey data were used to evaluate the change in Manning's n across a range of flows (Figure 8) and estimate in-channel n-values for each flow profile (Table 4). Known WSE surveyed at upstream and downstream cross-sections were used for boundary conditions during model calibration. Following calibration, all other flow profiles were modeled using normal depth with site-specific bed slopes for the downstream boundary conditions.

Table 4. In-channel Manning's n-values for each flow profile used in hydraulic analysis.

Flow	Piloni Ditch		Wilson Ditch		Palisade #2 Ditch	
Profile	Q (cfs)	Manning's n	Q (cfs)	Manning's n	Q (cfs)	Manning's n
Cal	445	0.039	275	0.047	280	0.055
Design1	NA	NA	500	0.040	500	0.052
Design2	1000	0.039	1000	0.040	1130	0.043
Design3	2000	0.038	2000	0.039	2260	0.041
Q2	3030	0.038	3030	0.038	3640	
Q5	4440	0.037	4440	0.037	5330	0.037
Q100	8160	0.035	8160	0.035	9810	0.035

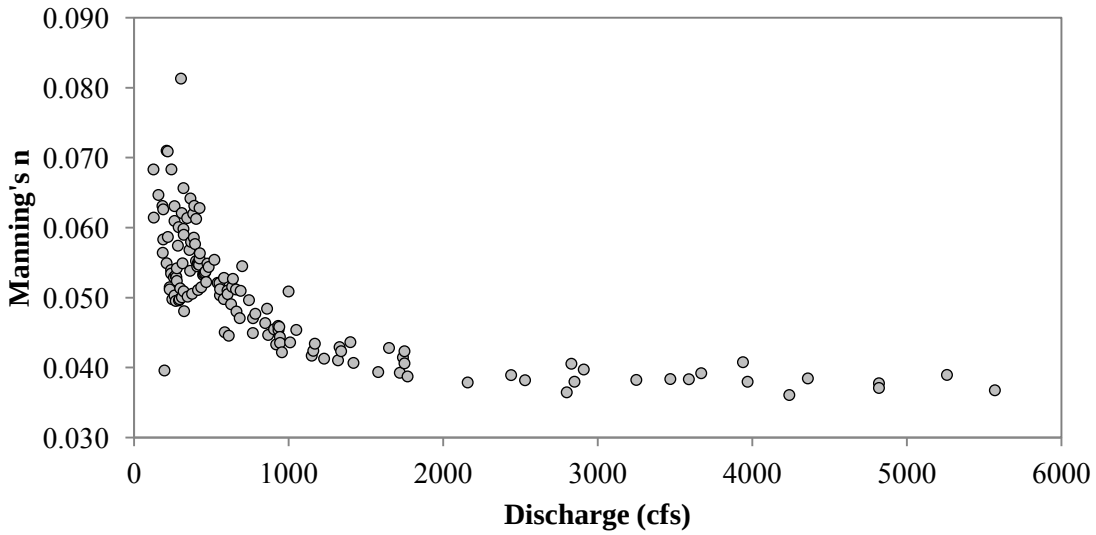


Figure 8. Manning's n values calculated from flow measurements at the USGS Gunnison River Near Gunnison, CO stream gauge.

Floodplain Analysis Results —Modeled WSE were compared between existing and proposed conditions to evaluate if the proposed designs will cause a rise in WSE for the 100-year flood. Results from the floodplain analysis for proposed designs are summarized in Table 6. The maximum change in water surface elevation (WSE) represents the maximum change in WSE at an individual cross section within a given reach. The average change in WSE describes the average change in WSE across all cross sections within a given reach, and provides a more general characterization of floodplain impacts for the reach in question. The maximum and average changes in water surface elevation for the 100-year flood at the Piloni Ditch were 0.01 ft and -0.01 ft, respectively (Table 5). This indicates the proposed design for the Piloni Ditch will not cause a rise. The maximum and average changes in water surface elevation (WSE) for the 100-year flood at the Wilson Ditch were 0.17 ft and -0.19 ft, respectively (Table 5). This indicates the proposed design for the Wilson Ditch will not cause a rise greater than 0.3 ft at any cross-section. The reach-average change in WSE indicates the proposed design for the Wilson Ditch will actually lower flood stage for the Wilson reach. These results indicate that a LOMR will not be required for the proposed design at the Wilson Ditch. The maximum and average changes in water surface elevation (WSE) for the 100-year flood at the Palisade #2 Ditch were 0.24 ft and 0.06 ft, respectively (Table 5). This indicates the proposed design for the Palisade #2 Ditch will not cause a rise greater than 0.3 ft at any cross-section. Based on these results, a LOMR will not be required for the proposed design at the Palisade #2 Ditch. Detailed graphic and tabular modeling results from floodplain analyses are presented in Appendices A-C.

Table 5. Results from floodplain analysis for each diversion structure showing the difference between modeled water surfaces for proposed and existing conditions across all cross-sections for the 100-year flood. WSE = Water Surface Elevation.

Site	Return Interval (years)	Q (cfs)	Difference between Proposed and Existing WSE			
			Maximum (ft)	Average (ft)	Median (ft)	Minimum (ft)
Piloni Ditch	100	8160	0.01	-0.01	0.00	-0.11
Wilson Ditch	100	8160	0.17	-0.19	-0.01	-1.13
Palisade #2 Ditch	100	9810	0.24	0.06	0.01	-0.07

Diverted Flow Analysis

HEC-RAS models were not configured to evaluate split-flow conditions into the irrigation ditches because the primary objective of hydraulic modeling was to evaluate the impact of proposed activities on the regulatory floodplain. However, the resultant WSE are indicative of the hydraulic head available in the vicinity of the head gate structure and were used to estimate potential flows into the irrigation ditches. It should be noted that the WSE estimated through hydraulic analysis are conservative. The standard-step backwater procedure works from downstream to upstream and fails to capture the true nature of split-flow conditions at the crest of the existing or proposed diversion structures. The influence of split-flow becomes less pronounced as flow increases and the diversion structures are submerged. Low flow conditions would be more accurately represented with split-flow or two-dimensional models. For low flows when the structures are not fully submerged, the modeled WSE will underestimate hydraulic head in the vicinity of the head gates.

Diverted Flow Analysis for the Piloni Ditch — To evaluate flows into the Piloni Ditch, modeled WSE at cross section 371.8 were compared to the invert elevation of existing Piloni head gate (i.e., 7752.5 ft). As the proposed design did not alter channel morphology at or below cross section 371.8, there was no difference in modeled WSE between the existing and proposed conditions at or below cross section 371.8. This issue highlights a limitation of the standard-step backwater approach used in HEC-RAS. For this analysis, flows into the Piloni Ditch were calculated with the assumption that the existing head gate structure would be replaced. The following specifications were used for the proposed head gate design: bottom width = 5.0 ft, side slopes = 0.0 H/V, Manning's n = 0.015, and a bottom slope = 0.001. Diverted flow estimates for the Piloni Ditch show that the ability to divert the full decree should occur around flows at and above 2000 cfs (Table 6). To help place modeling results into context, the surveyed water surface elevation corresponding to 445 cfs was also included in analysis of hydraulic head at the Piloni head gate. The proposed design should provide WSE at the Piloni head gate similar to or higher than existing conditions. Furthermore, replacing the existing head gate with a new concrete structure would improve flows into the ditch while reducing maintenance needs.

Table 6. Diverted flow estimates into the Piloni Ditch. WSE = Water Surface Elevation

Data Source	Cross Section	Discharge (cfs)	WSE (ft)	Hydraulic Head (ft)	Diverted Flow (cfs)
Survey	371.8	445	7753.82	1.32	18.8
HEC-RAS	371.8	445	7752.56	0.06	0.14
HEC-RAS	371.8	1000	7753.65	1.15	15.4
HEC-RAS	371.8	2000	7754.97	2.47	44.7
HEC-RAS	371.8	3030	7756.04	3.54	71.5
HEC-RAS	371.8	4440	7757.18	4.68	101
HEC-RAS	371.8	8160	7759.36	6.86	161

Diverted Flow Analysis for the Wilson Ditch — To evaluate flows into the Wilson Ditch, modeled WSE at cross section 357.5 were compared to the invert elevation of the existing Wilson head gate (i.e., 7723.78 ft). The City of Gunnison provided design criteria illustrating the WSE needed at the Wilson head gate to achieve the design discharge of 15 cfs into the Wilson Ditch (Figure 9). Based on these criteria, 1.8 ft of water depth is needed above the invert of Wilson head gate to achieve 15 cfs of discharge into the Wilson Ditch. As previously mentioned, modeled WSE will underestimate actual WSE near the head gate during low flows when the diversion structure is not fully submerged. Given this limitation, flow estimates into the Wilson Ditch are not assumed to represent actual conditions. Regardless, modeling results indicate there should be sufficient head to divert 15 cfs when flow in the Gunnison River is somewhere between 1000-2000 cfs (Table 7). In actuality, more water will be delivered to the Wilson Ditch head gate at low flows (e.g., <1000 cfs) than is indicated in Table 7 because the crest of the new diversion structure will be set 0.72 ft above the invert of the head gate culverts. For example, modeling results suggest there will be little to no water at the head gate when flows are 500 cfs in the Gunnison River. However, the proposed structure should be able to deliver some flow to the Wilson Ditch when the river is flowing 500 cfs. The model simply fails to capture the true nature of split-flow conditions created by the proposed structure. Therefore, the proposed design should deliver 15 cfs to the Wilson Ditch at flows lower than those indicated in Table 7.

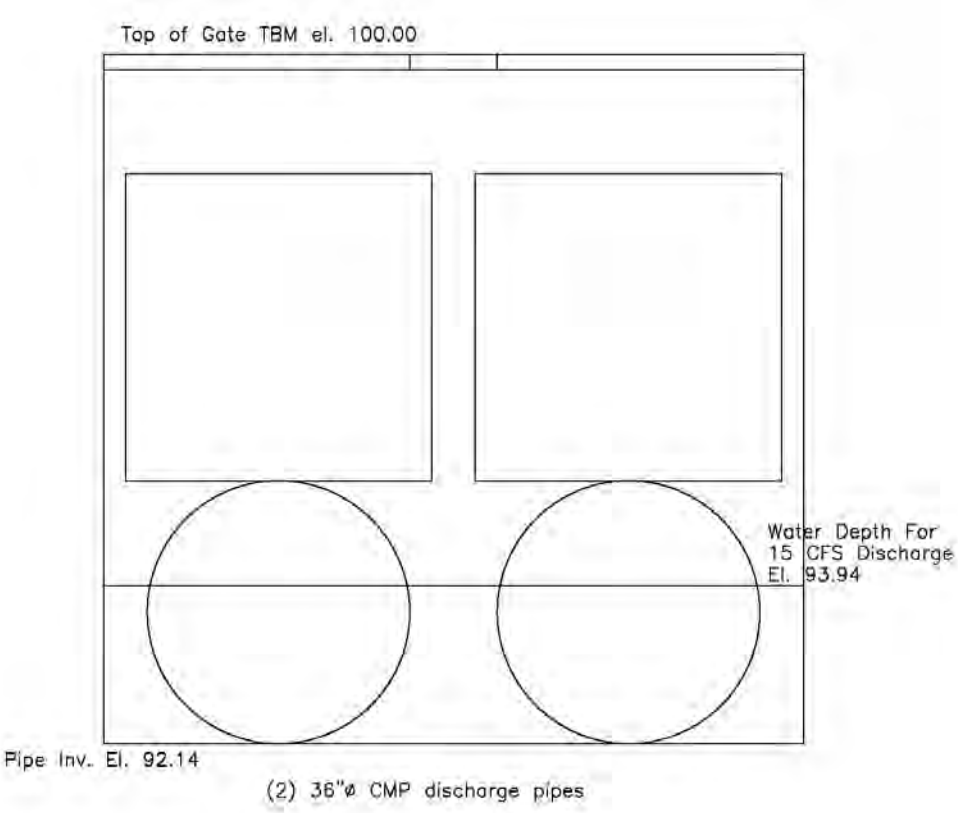


Figure 9. Wilson Ditch head gate schematic used to evaluate flows into the Wilson Ditch (not to scale).

Table 7. Diverted flow estimates into the Wilson Ditch. Hydraulic head needs to be greater than 1.80 ft to achieve 15 cfs of diverted flow. WSE = Water Surface Elevation.

Flow Profile	Cross Section	Discharge (cfs)	WSE (ft)	Hydraulic Head (ft)	Diverted Flow ≥ 15 cfs
Cal	357.5	275	7723.40	0.00	No
Design1	357.5	500	7723.79	0.01	No
Design2	357.5	1000	7724.80	1.02	No
Design3	357.5	2000	7726.30	2.52	Yes
Q2	357.5	3030	7726.94	3.16	Yes
Q5	357.5	4440	7727.14	3.36	Yes
Q100	357.5	8160	7727.72	3.94	Yes

Diverted Flow Analysis for the Palisade #2 Ditch — The proposed design for the Palisade #2 diversion structure should deliver the full decreed water right of 5 cfs to the Palisade Ditch. However, the model configuration used to evaluate floodplain impacts is inadequate for evaluating flows into the Palisade #2 Ditch. Limitations associated with 1-D hydraulic modeling were previously discussed and apply to the Palisade #2 Ditch. Regardless, diverted flows into the Palisade #2 Ditch were evaluated by using WSE at cross section 323.7, which is directly upstream of the ditch inlet. Hydraulic head at the ditch inlet was calculated by comparing modeled WSE to the invert of the ditch (i.e., 7697.0 ft). Flows into the Palisade #2 Ditch were then estimated using Manning's equation for a trapezoidal channel with the following

assumptions: bottom width = 7.8 ft, side slopes = 1.0 H/V, Manning's n = 0.025, and slope = 0.001. The selected slope of 0.001 was based on the assumption that deposited sediment below the ditch inlet will be excavated to optimize flows into the ditch.

To help place modeling results into context, the surveyed WSE corresponding to 280 cfs was also included in analysis of hydraulic head at the ditch inlet. Estimated flows into the Palisade #2 Ditch are presented in Table 8. Modeled WSE will underestimate water depths at the ditch inlet during low flows, as previously discussed. As the crest of proposed cross-vane diversion structure is set 0.5 ft higher than the ditch head gate, the proposed design should provide WSE at the ditch inlet that are similar to or higher than existing conditions. During the November 2015 survey, water was not flowing into the ditch due to sedimentation below the ditch inlet. However, diverted flow estimates suggest that water would have been flowing into the ditch if the area of sediment accumulation below the ditch inlet was excavated. This evidence suggests that the diverted flow estimates for 280-1130 cfs should be greater than 0 cfs, and that the 1-D hydraulic model fails to capture the true nature of split-flow conditions created by the water diversion structure during lower flows. Higher flow estimates suggest that there will be sufficient head to divert the full decree of 5 cfs when river flows are between 1130-2260 cfs (Table 8). In reality, the full decree should be diverted at flows lower than 1130 cfs. More detailed analyses with a split-flow or 2-D hydraulic model would be needed to improve diverted flow estimates. Estimates for diverted flow at higher discharges (e.g., 5330 cfs) suggest that substantial amounts of water could be diverted into the Palisade #2 Ditch during floods, which highlight the need for a sediment sluice near the head works to return sediment and excess water to the river during floods.

Table 8. Diverted flow estimates into the Palisade #2 Ditch. WSE = Water Surface Elevation

Data Source	Cross Section	Discharge (cfs)	WSE (ft)	Hydraulic Head (ft)	Diverted Flow (cfs)
Survey	323.7	280	7697.48	0.48	4.3
HEC-RAS	323.7	280	7695.33	0.00	0.0
HEC-RAS	323.7	500	7695.80	0.00	0.0
HEC-RAS	323.7	1130	7696.59	0.00	0.0
HEC-RAS	323.7	2260	7697.83	0.83	10.7
HEC-RAS	323.7	3640	7699.01	2.01	47.7
HEC-RAS	323.7	5330	7699.87	2.87	89.0
HEC-RAS	323.7	9810	7701.17	4.17	175

Conclusions

The proposed designs for the Piloni Ditch, Wilson Ditch, and Palisade #2 Ditch should be able to the deliver the full decreed water right to each ditch. In addition, the proposed designs will reduce the need for maintenance while improving channel stability, riparian conditions, and aquatic habitat. None of the proposed designs caused a rise in excess of 0.3 ft for the 100-year flood, indicating that a LOMR will not be needed for the project in accordance with CWCB rules and regulations (CWCB, 2010).

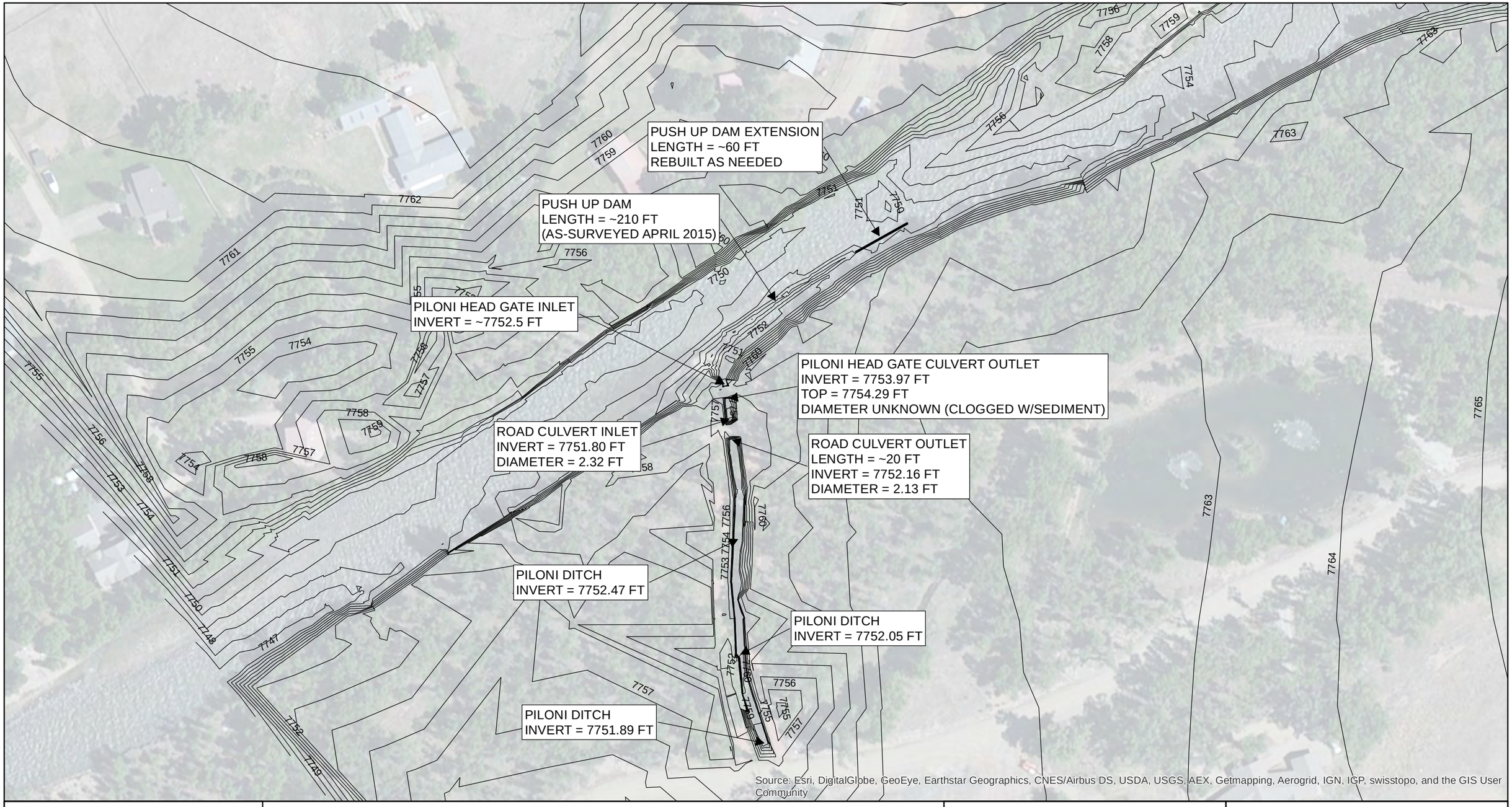
References

Chow, V.T. 1959. Open Channel Hydraulics. The Blackburn Press, Caldwell, New Jersey.

CWCB. 2010. Rules and regulations for regulatory floodplains in Colorado. Colorado Water Conservation Board (CWCB), Department of Natural Resources. 36 pp.

Rosgen, D.L. 2006. Cross-vane, w-weir, and j-hook vane structures: description, design and application for stream stabilization and river restoration. Wildland Hydrology, Fort Collins, Colorado. 32 pp.

US Army Corps of Engineers (USACE). 2010. HEC-RAS River Analysis System. US Army Corps of Engineers, Hydrologic Engineering Center, Davis, California. 790 pp.



Legend

Contour Interval = 1 ft

0 25 50 100 150 200 Feet

N

EXISTING CONDITIONS

DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: A-1	

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COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
PILONI DIVERSION
APPENDIX A

PRELIMINARY DESIGN
NOT FOR CONSTRUCTION

OPTIONAL BOULDER SILL SET AT ELEVATION OF EXISTING STREAM BED AND KEYED INTO OPPOSITE BANK

REPLACE EXISTING PUSH-UP DAM WITH BOULDER VANE SET AT ELEVATION OF PUSH-UP DAM AND EXTENDED ~60 FT UPSTREAM (BASED ON APRIL 2015 SURVEY)

REPLACE EXISTING HEAD GATE WITH NEW CONCRETE STRUCTURE AND SEDIMENT SLUICE

CULVERT IS UNDER SIZED AND WILL NEED TO BE REPLACED TO DELIVER FULL DECREED WATER RIGHT (40 CFS)

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

- Boulder Vane
- Optional Grade Control
- Contour Interval = 1 ft

0 10 20 40 60 80 Feet

N

PROPOSED CONDITIONS	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: A-2	

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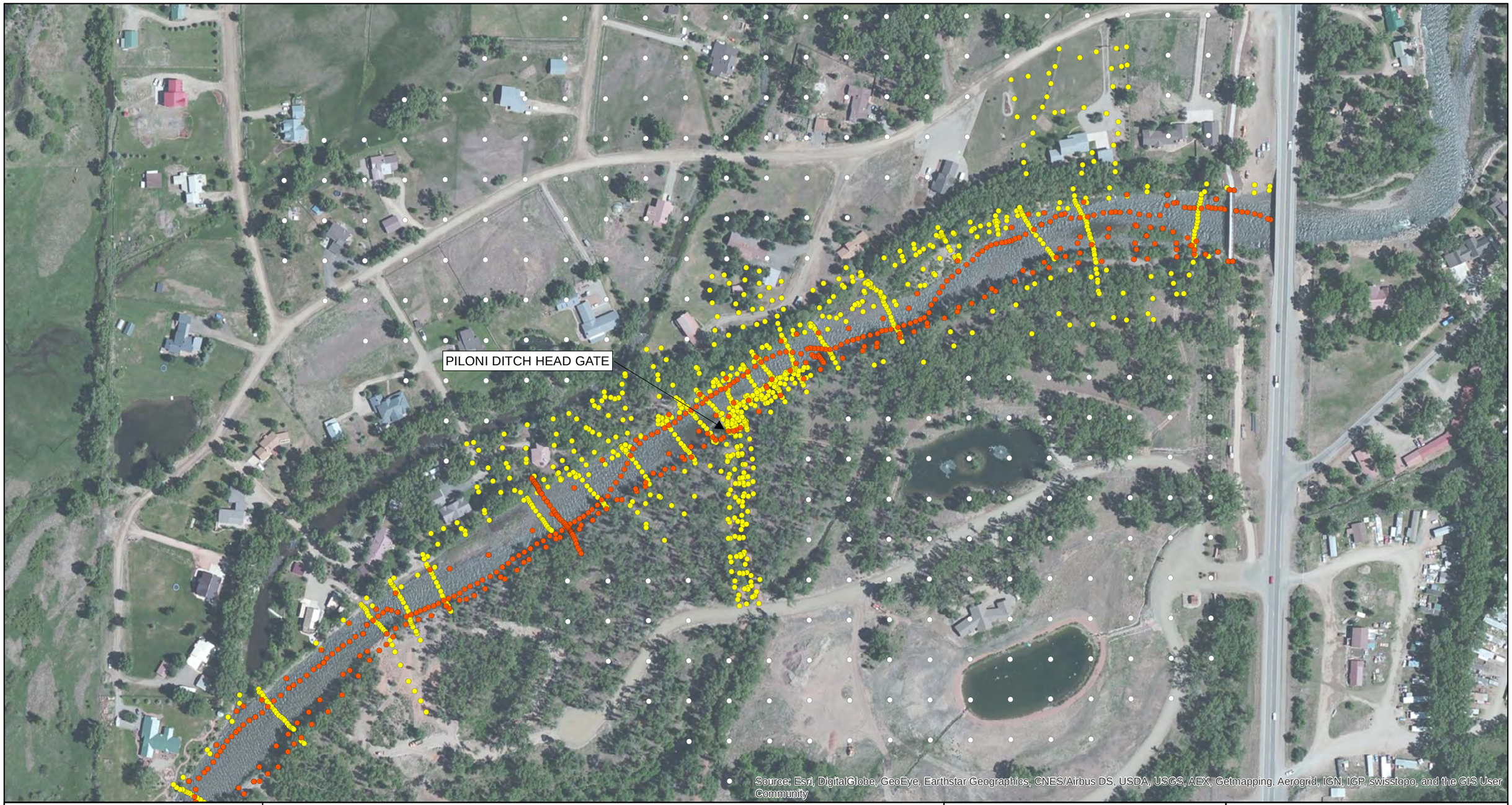

Legend

- Supplemental DEM Data
- Survey Data 2013
- Survey Data 2015

0 60 120 240 360 480 Feet

N

SURVEY LAYOUT	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: A-3	

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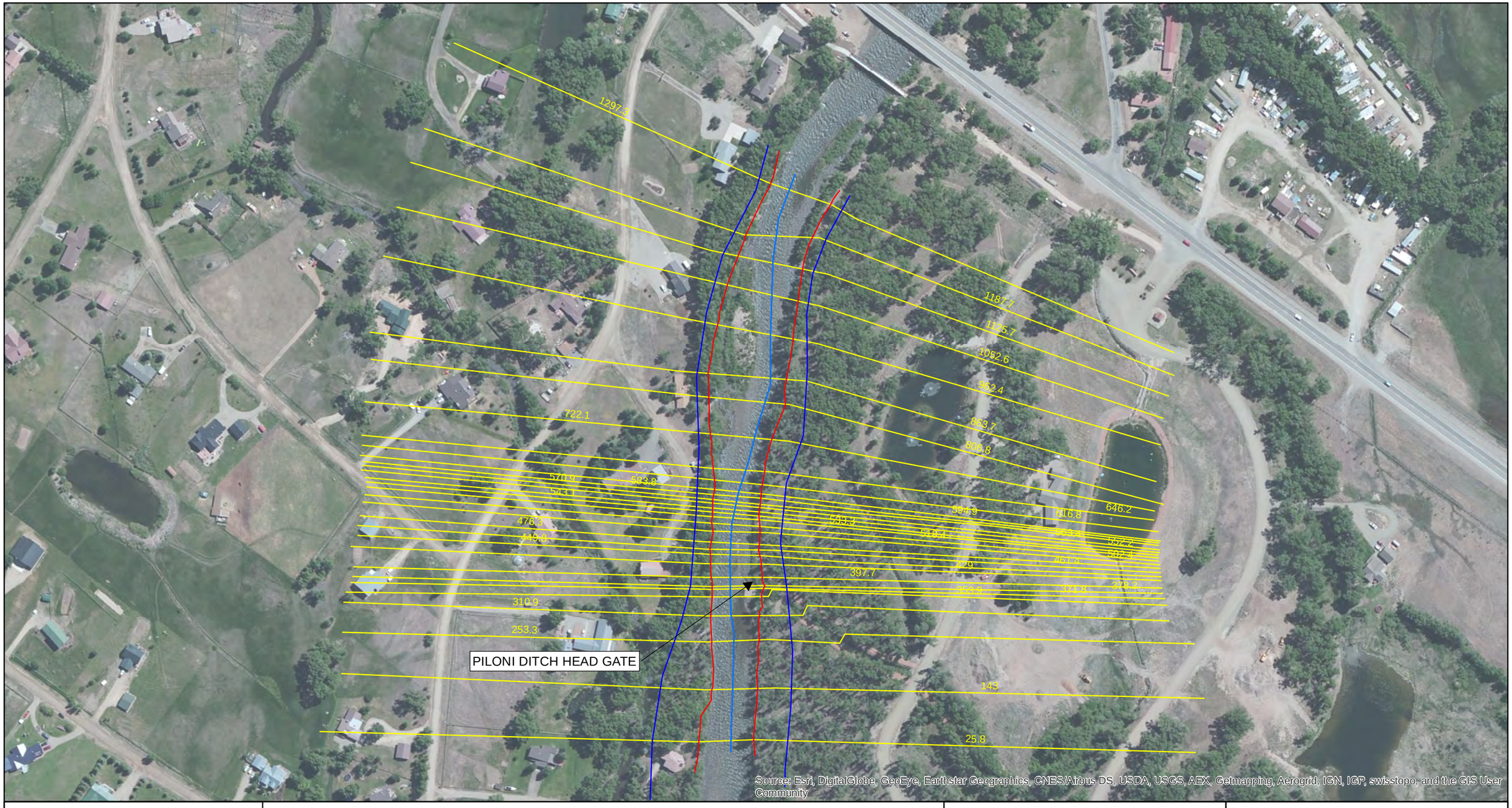

Banks
River
Flowpaths
Cross Sections

0 60 120 240 360 480
Feet

HEC-RAS LAYOUT	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: A-4	

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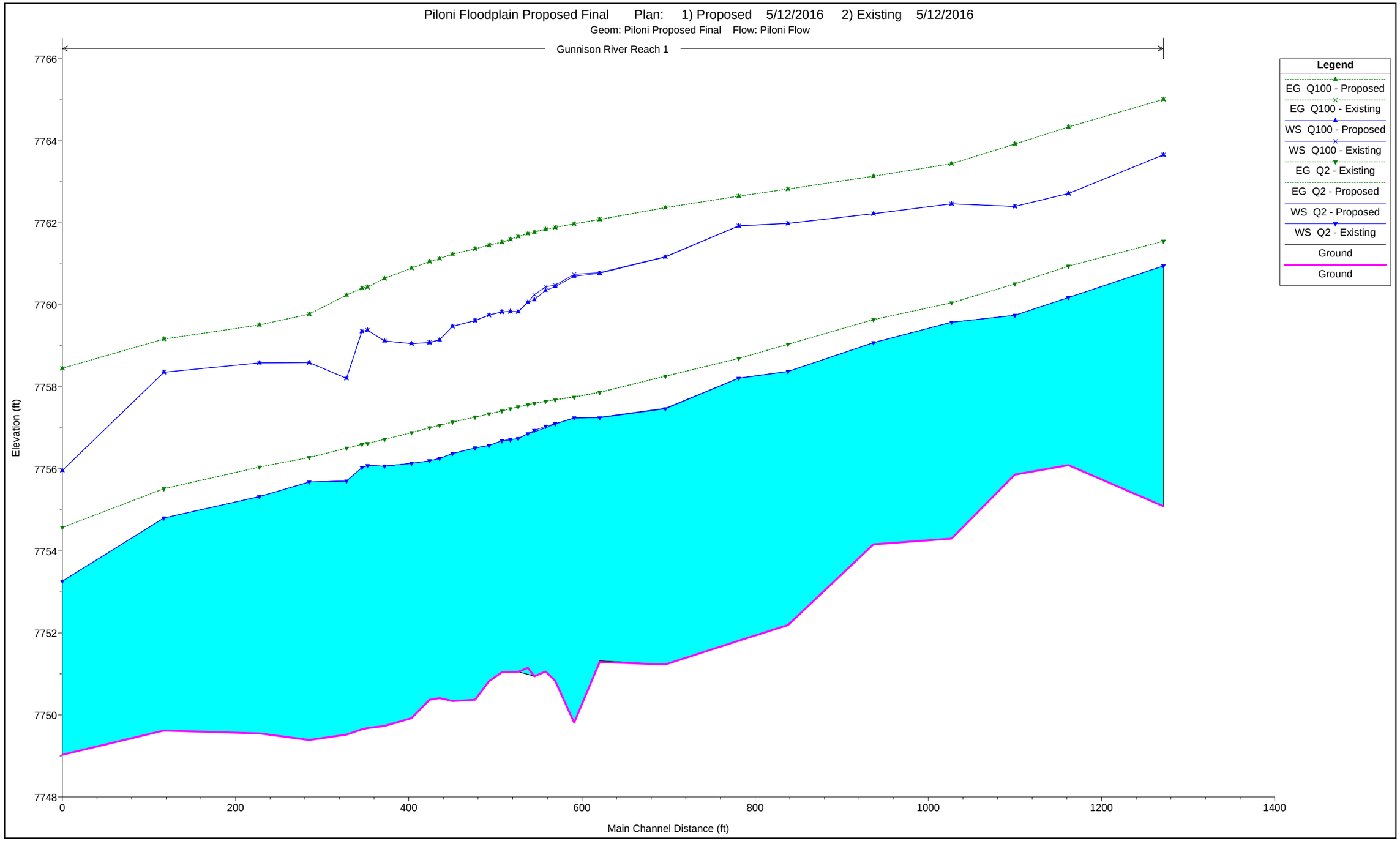
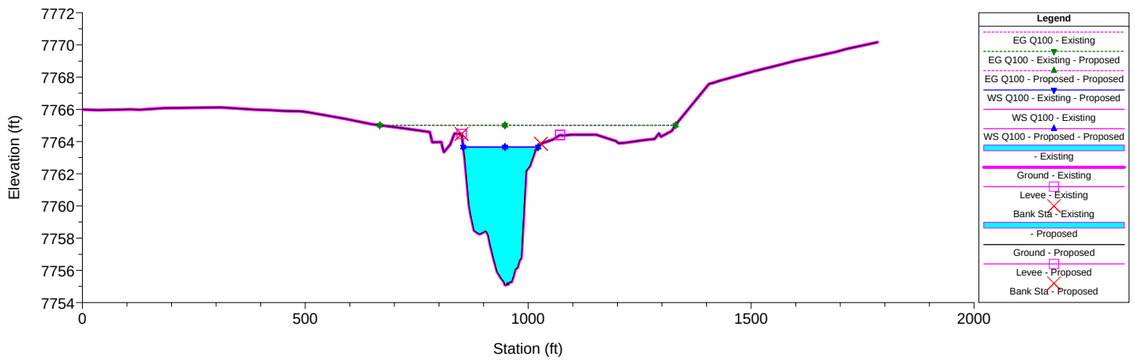

Piloni Floodplain Proposed Final Plan: 1) Proposed 5/12/2016 2) Existing 5/12/2016
Geom: Piloni Proposed Final Flow: Piloni Flow
Gunnison River Reach 1
Legend
EG Q100 - Proposed
EG Q100 - Existing
WS Q100 - Proposed
WS Q100 - Existing
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Proposed
WS Q2 - Existing
Ground
Ground
Elevation (ft)
7766
7764
7762
7760
7758
7756
7754
7752
7750
7748
0
200
400
600
800
1000
1200
1400
Main Channel Distance (ft)

Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 1297.3



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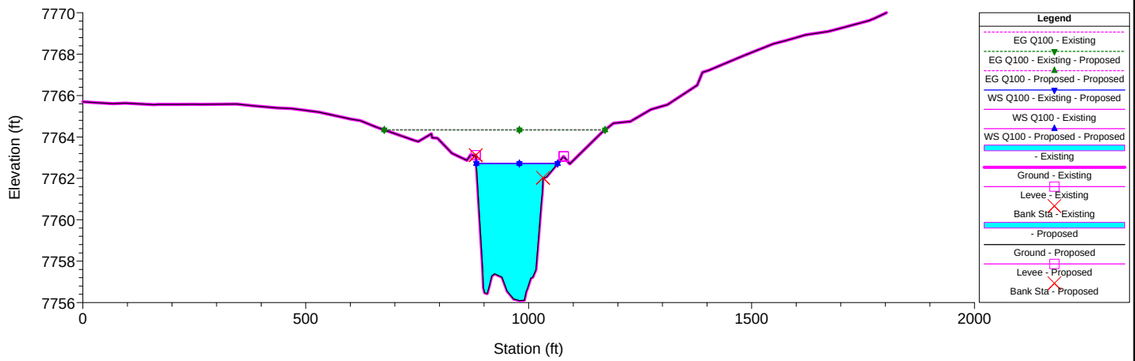
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 1187.7



Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
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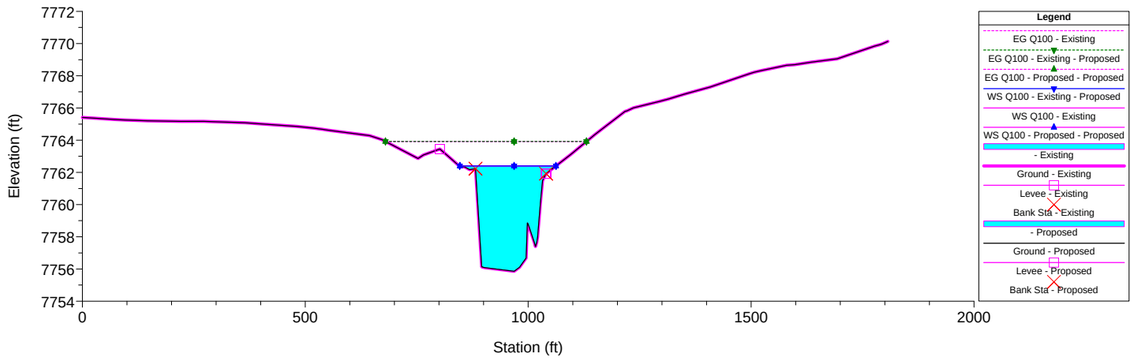

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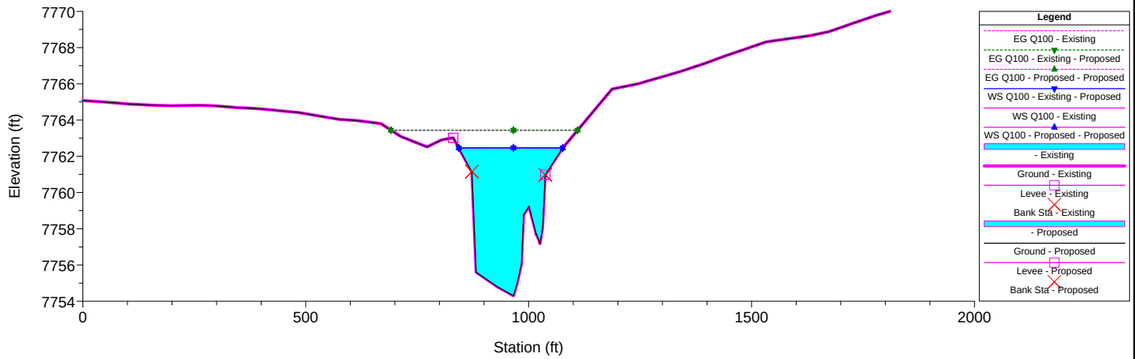
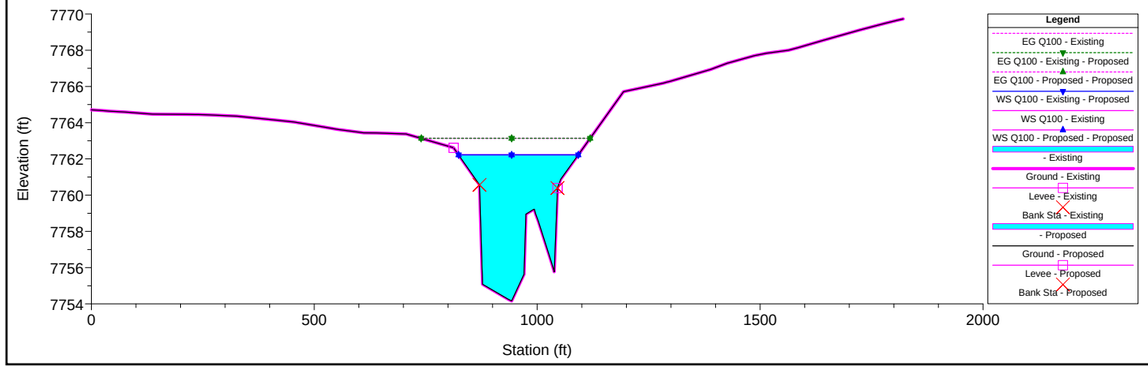
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 1052.6



Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 962.4



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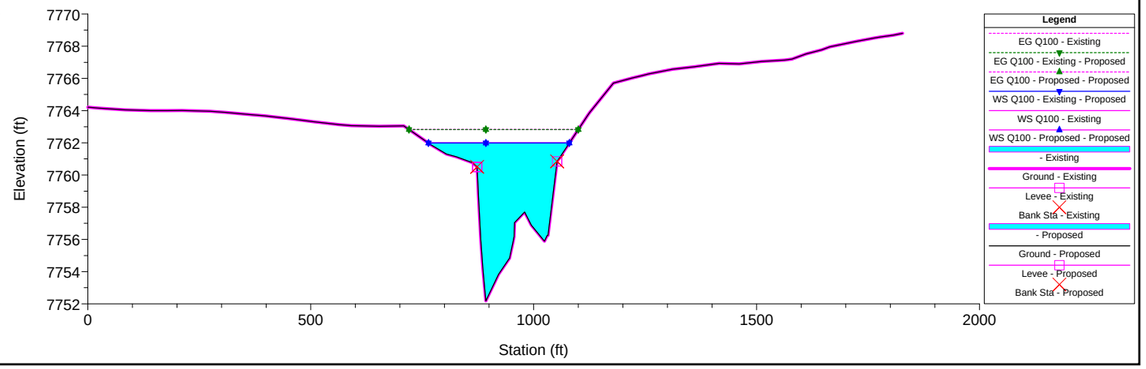
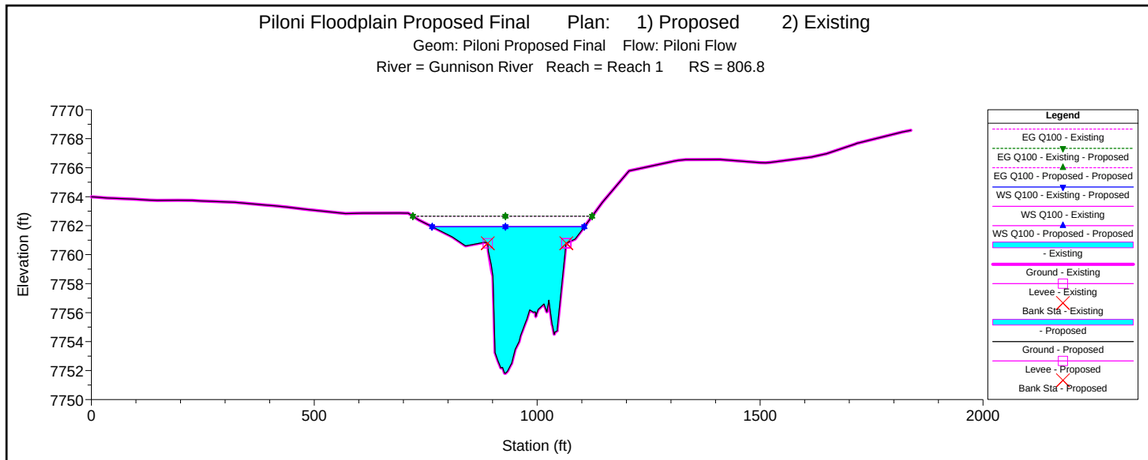
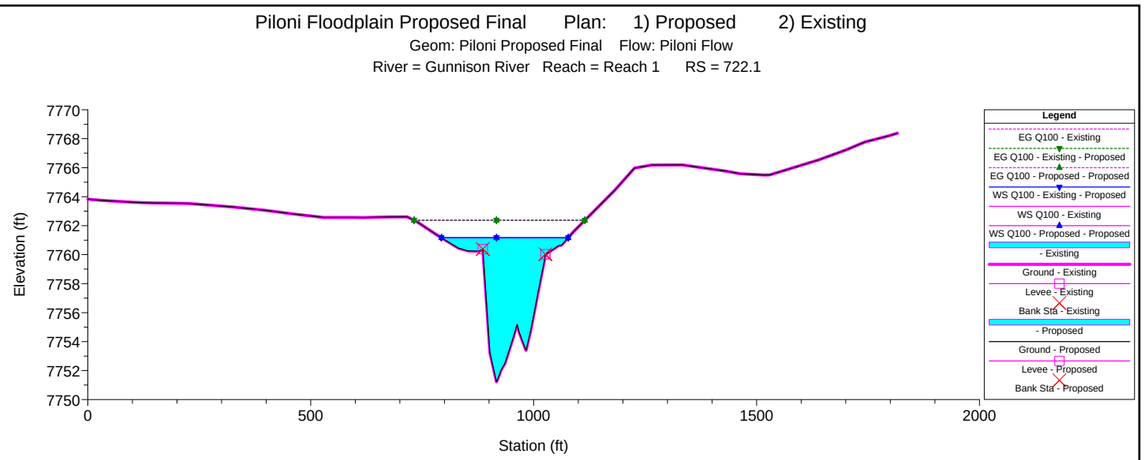
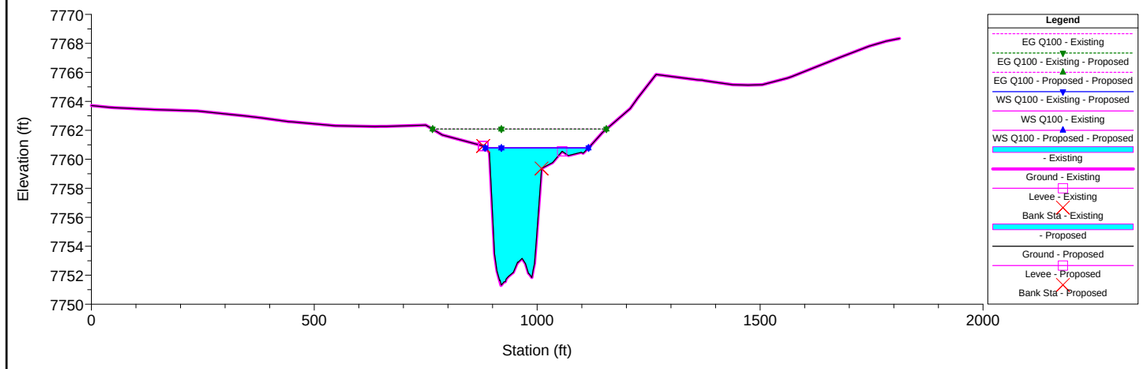
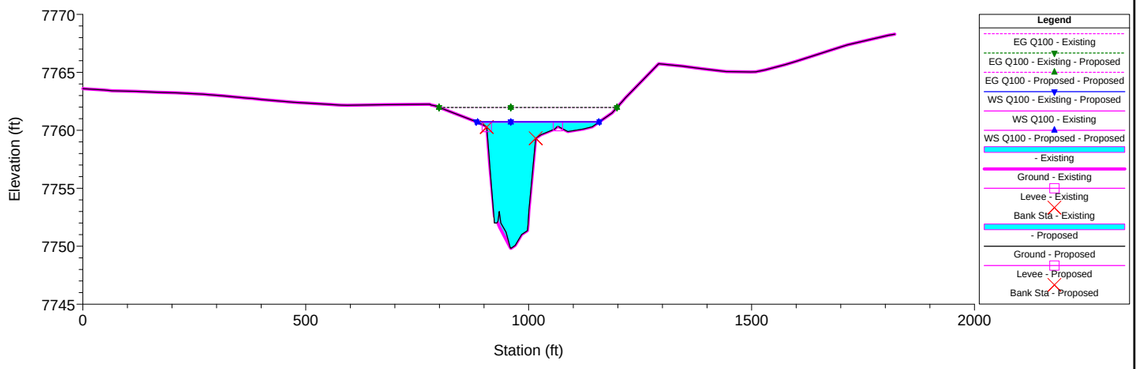
River = Gunnison River Reach = Reach 1 RS = 863.7

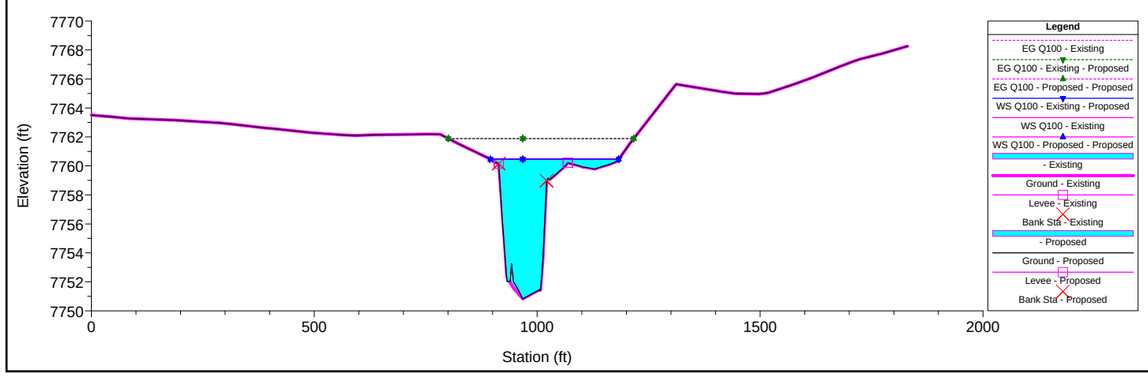



Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 806.8
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 722.1
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 646.2
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 616.8
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed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Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 594.9
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
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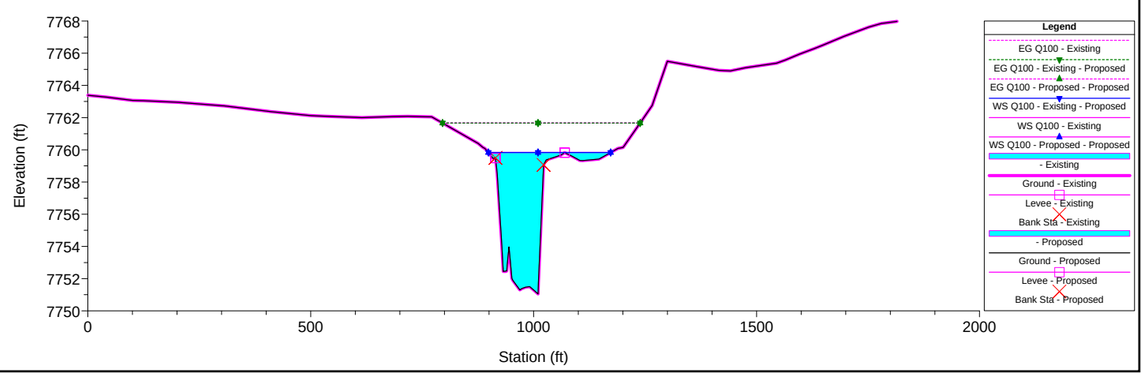
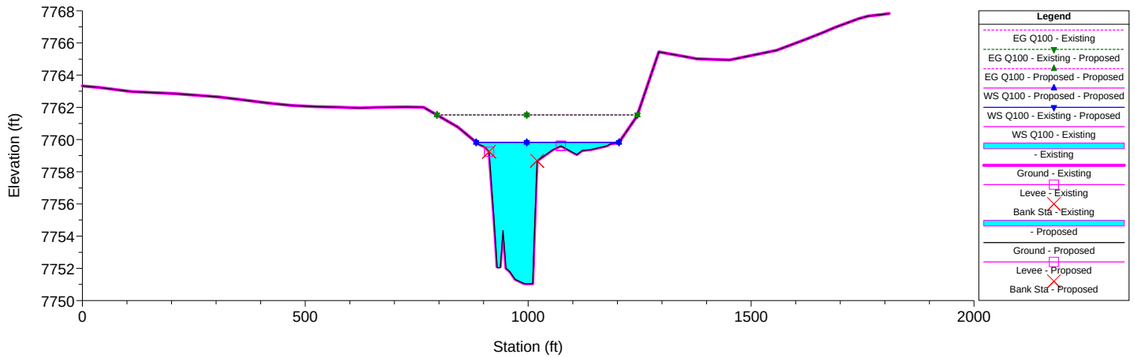
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 552.2
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 533.3



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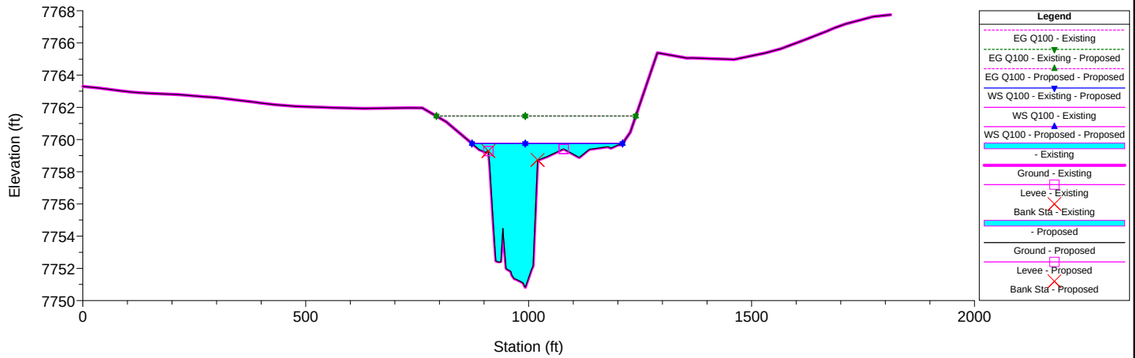
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 518.4



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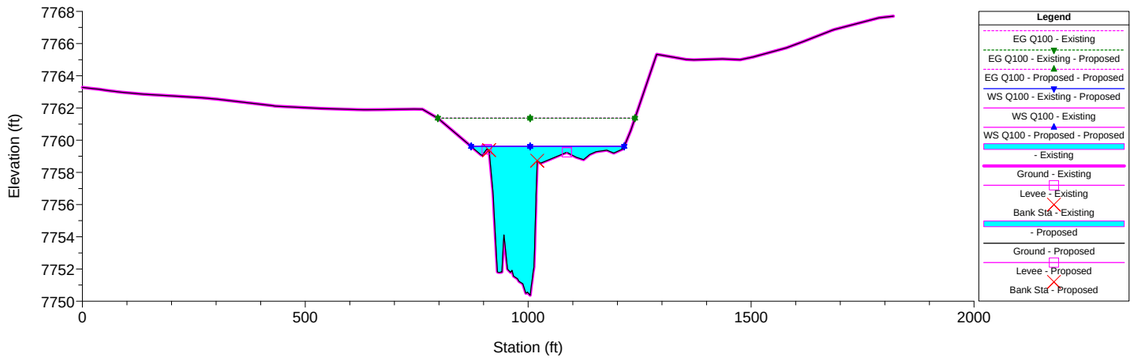
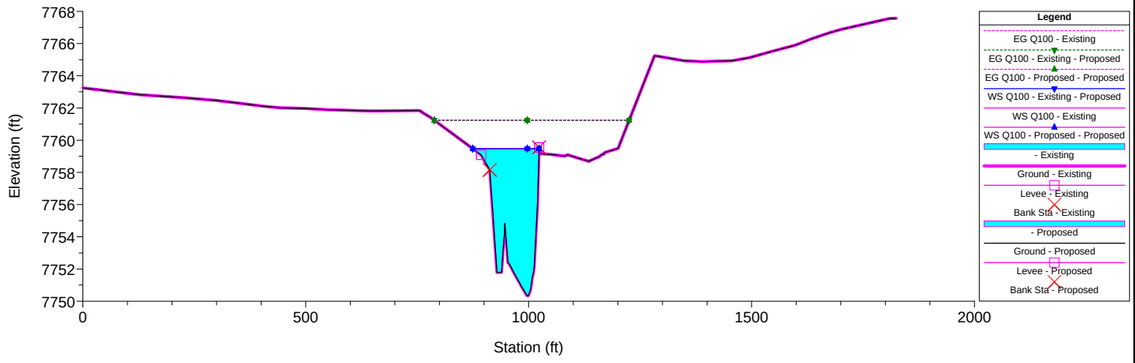
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 502.4



Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 476.3



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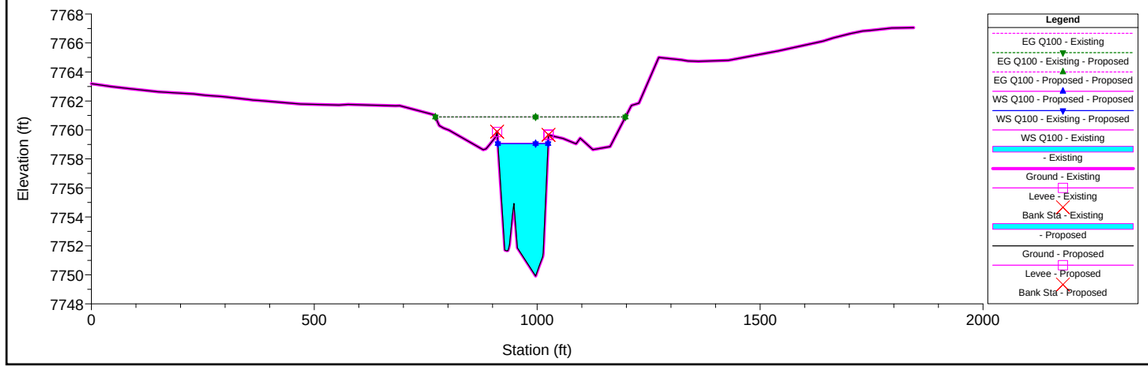
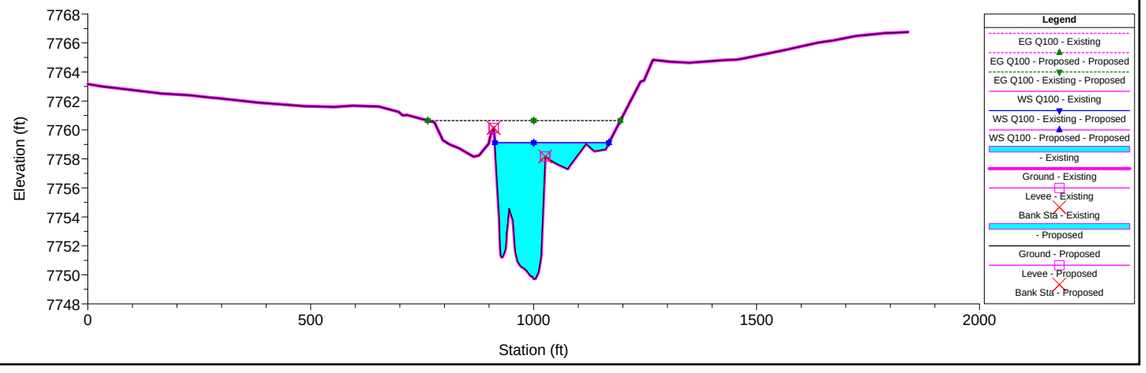
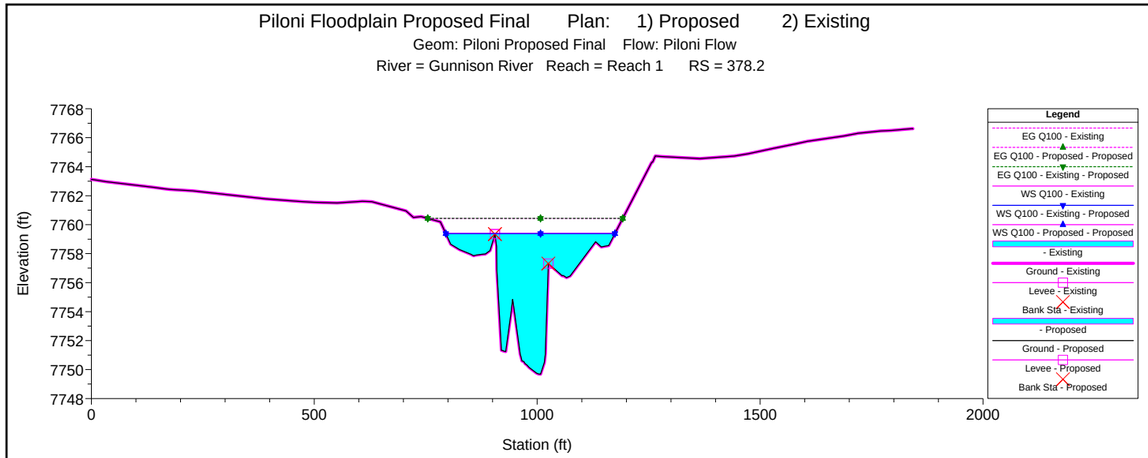
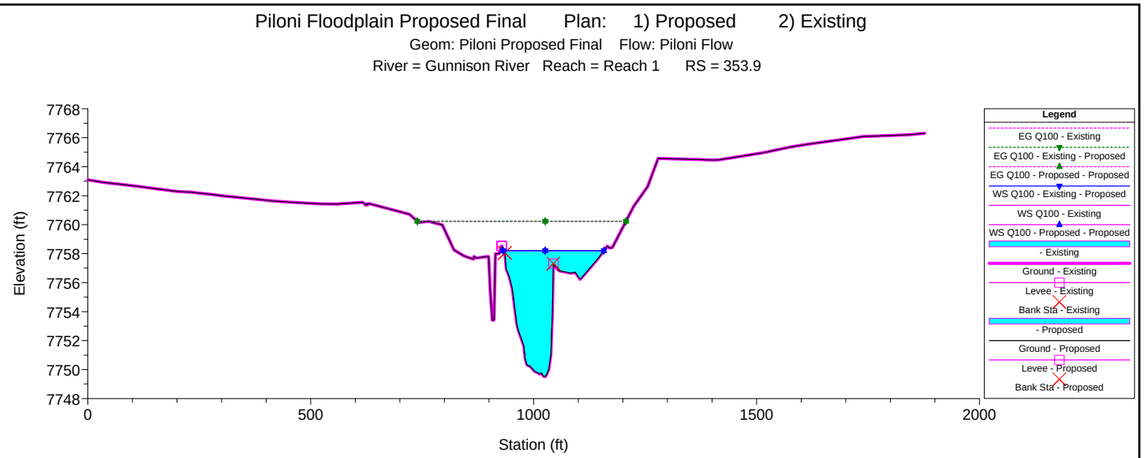
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 429.0

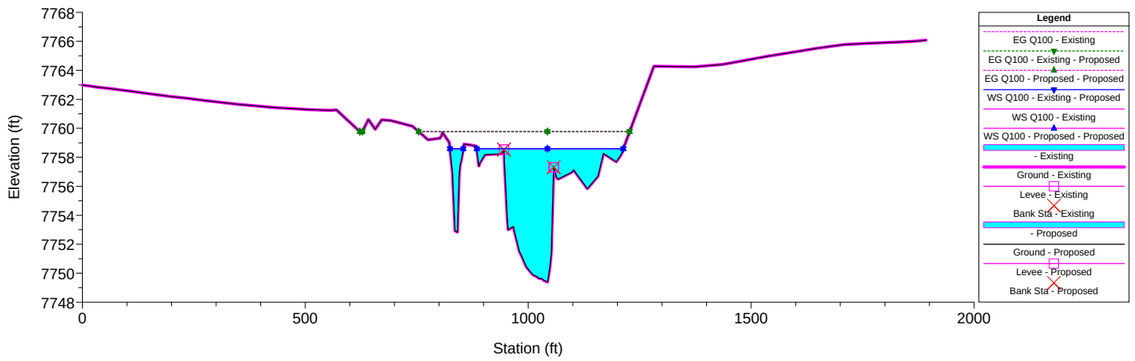


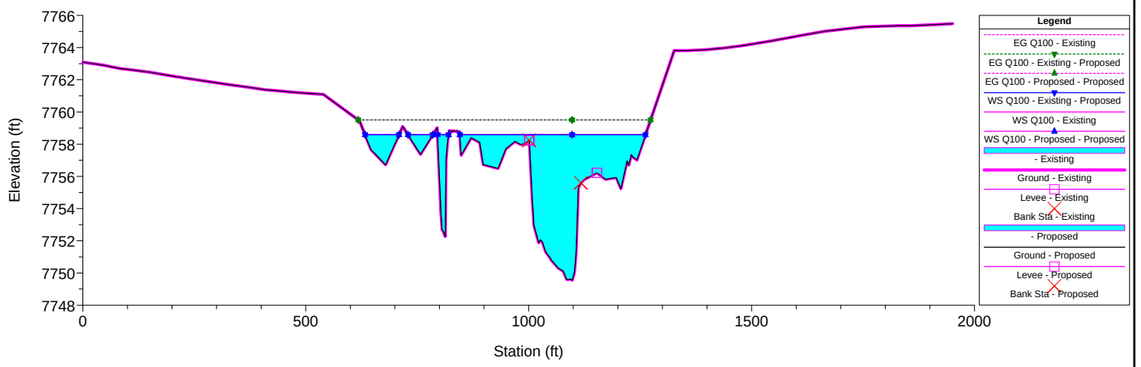
Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 397.7

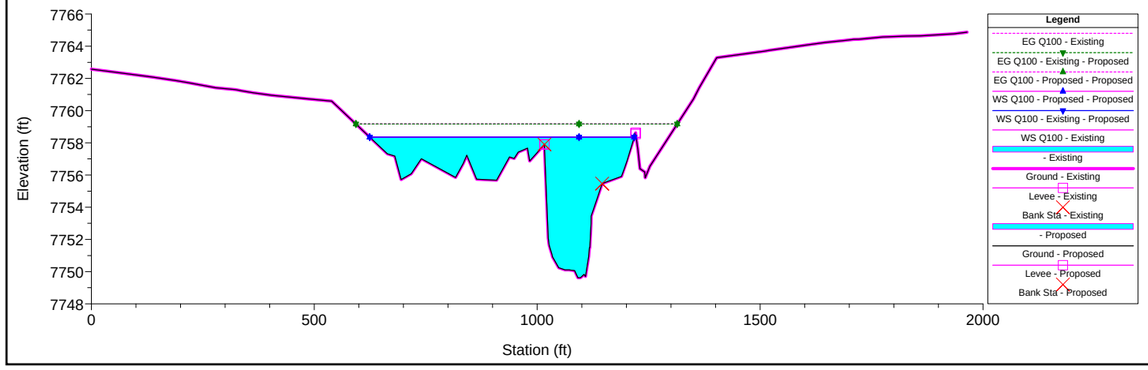


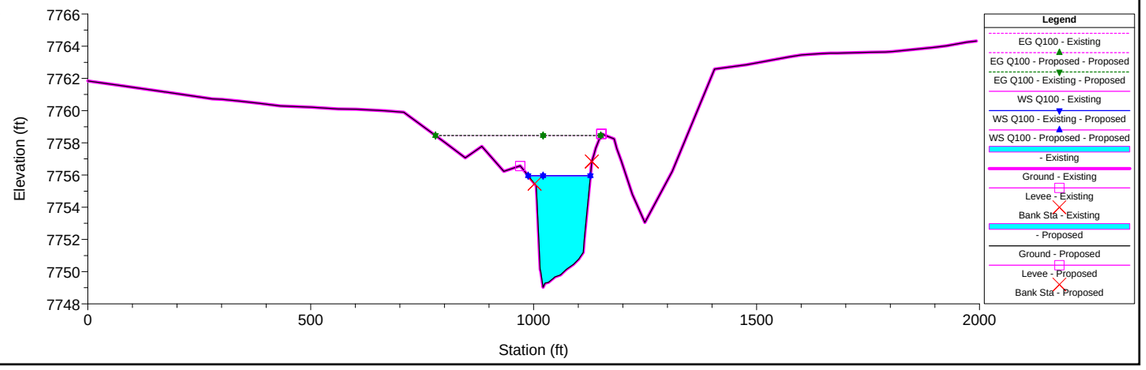

Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 378.2
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed - Proposed
EG Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Existing - Proposed
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 353.9
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 310.9
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 253.3
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 143.0
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Existing - Proposed
EG Q100 - Proposed - Proposed
WS Q100 - Proposed - Proposed
WS Q100 - Existing - Proposed
WS Q100 - Existing
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Piloni Floodplain Proposed Final Plan: 1) Proposed 2) Existing
Geom: Piloni Proposed Final Flow: Piloni Flow
River = Gunnison River Reach = Reach 1 RS = 25.8
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed - Proposed
EG Q100 - Existing - Proposed
WS Q100 - Existing
WS Q100 - Existing - Proposed
WS Q100 - Proposed - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

SEDIMENT AGGRADATION AT INLET TO WILSON DITCH

IRRIGATION DITCH (UNKNOWN)

EXCAVATED SEDIMENT FROM WILSON DITCH
AREA = 0.44 ACRES

EXCAVATED SEDIMENT FROM WILSON DITCH
AREA = 0.50 ACRES

SEDIMENT AGGRADATION

WILSON DITCH HEAD GATE
INVERT = 7723.78 FT

CONCRETE RUBBLE

WILSON DITCH

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

- Concrete Rubble
- Excavated Sediment
- Sediment Aggradation
- Contour Interval = 1 ft

0 20 40 80 120 160 Feet

N

EXISTING CONDITIONS

DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: B-1	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
WILSON DITCH
APPENDIX B

PRELIMINARY DESIGN
NOT FOR CONSTRUCTION

IRRIGATION DITCH (UNKNOWN)
DO NOT DISTURB

FILL AREA FOR SEDIMENT EXCAVATED FROM THE WILSON DITCH, GRADE MATERIAL TO DEVELOP TERRACE FEATURE, SEED WITH UPLAND VEGETATION AND PLANT WITH TREES

NARROW CHANNEL WITH BOULDER/COBBLE TOE AND BACKFILL WITH NATIVE MATERIAL, SOD MATS, AND WILLOW TRANSPLANTS
DESIGN BANKFUL WIDTH = 120-130 FT
DESIGN BANKFULL DEPTH = 3.1-3.3 FT

GRADE MATERIAL TO DEVELOP LOW TERRACE FEATURE AND PLANT WITH RIPARIAN VEGETATION
ELEVATION = ~7729.0 FT

CROSS-VANE DIVERSION WITH TWO STEPS
CREST = 7724.50 FT

CROSS-VANE DIVERSION
STEP 1 = 7723.50 FT

GRADE MATERIAL TO DEVELOP BANKFULL RIPARIAN BENCH UTILIZING SOD MATS AND WILLOW TRANSPLANTS
ELEVATION = 7727.0-7727.5 FT

CROSS-VANE DIVERSION
STEP 2 = 7722.50 FT

GRADE POINT BAR TO INCREASE RADIUS OF CURVATURE

MAINTAIN EXISITNG HEAD GATE FOR WILSON DITCH
INVERT = 7723.78 FT

INCORPORATE SEDIMENT SLUICE INTO HEAD WORKS (NOT SHOWN)

REMOVE CONCRETE RUBBLE, STABILIZE BANK WITH BOULDER/COBBLE AND WOOD-TOE TREATMENTS, AND DEVELOP RIPARIAN BENCH UTILIZING SOD MATS AND WILLOW TRANSPLANTS

WILSON DITCH

0 20 40 80 120 160
Feet

N

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

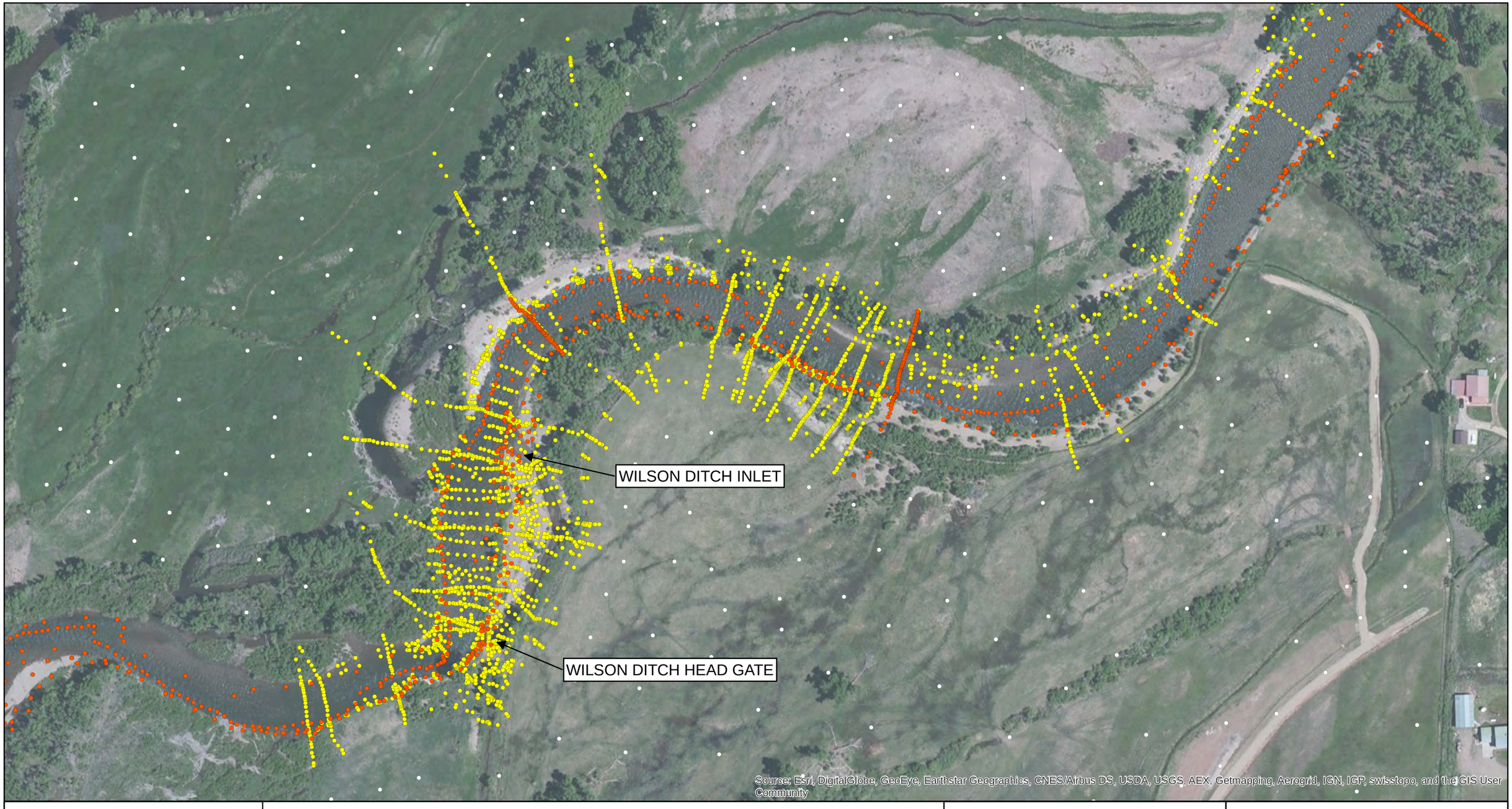
Legend

- Grade Point Bar
- Develop Bankfull Riparian Bench
- Develop Low Terrace
- Fill Area for Excavated Sediment
- Boulder/Cobble Toe
- Cross-Vane Diversion
- Wood Toe
- Contour Interval = 1 ft

PROPOSED CONDITIONS	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: B-2	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
WILSON DITCH
APPENDIX B



Legend

- Supplemental DEM Data
- Survey Data 2013
- Survey Data 2015

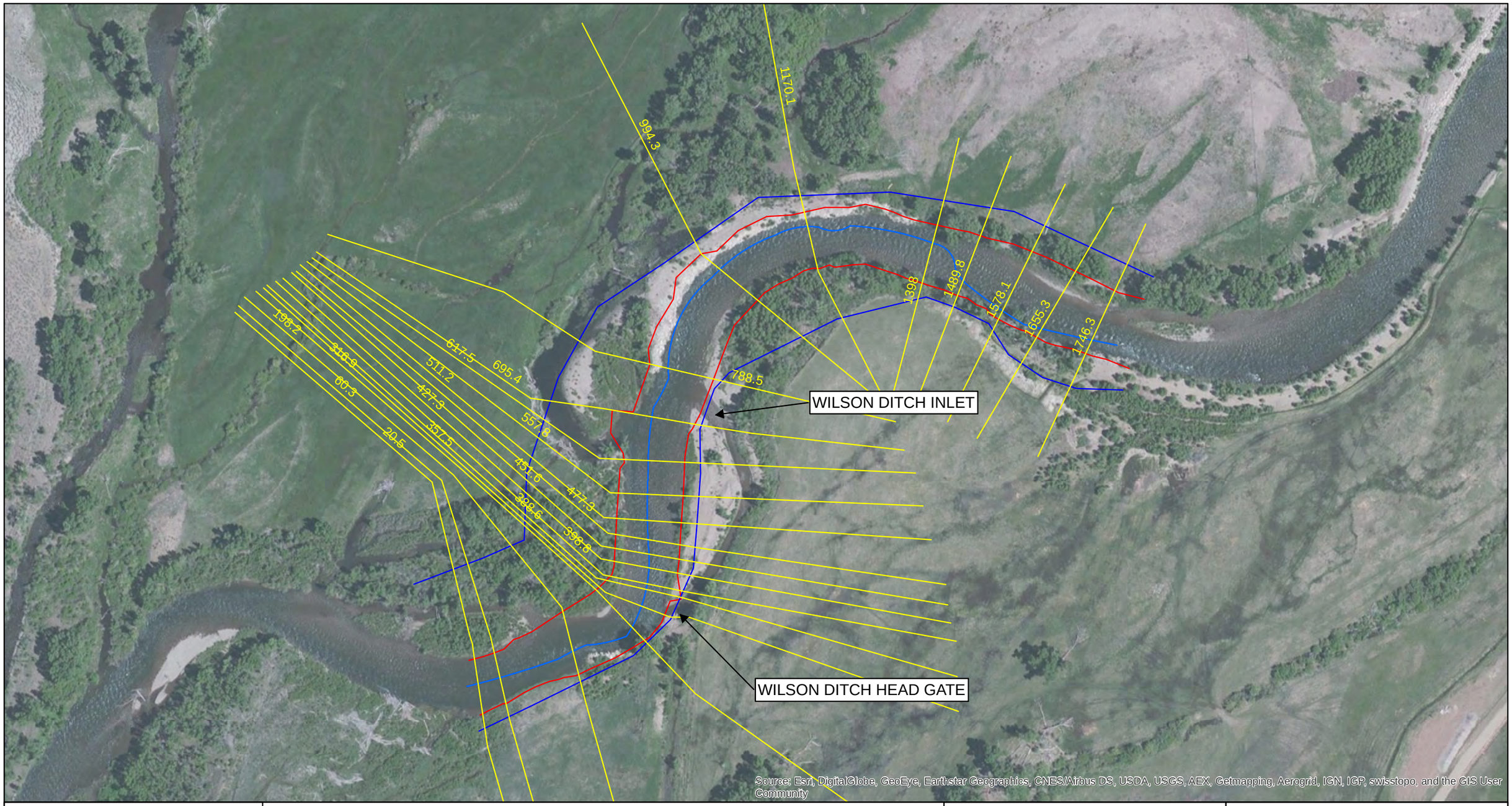
0 50 100 200 300 400 Feet

N

SURVEY LAYOUT	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: B-3	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
WILSON DITCH
APPENDIX B



Banks
River
Flowpaths
Cross Sections

0 45 90 180 270 360
Feet

N

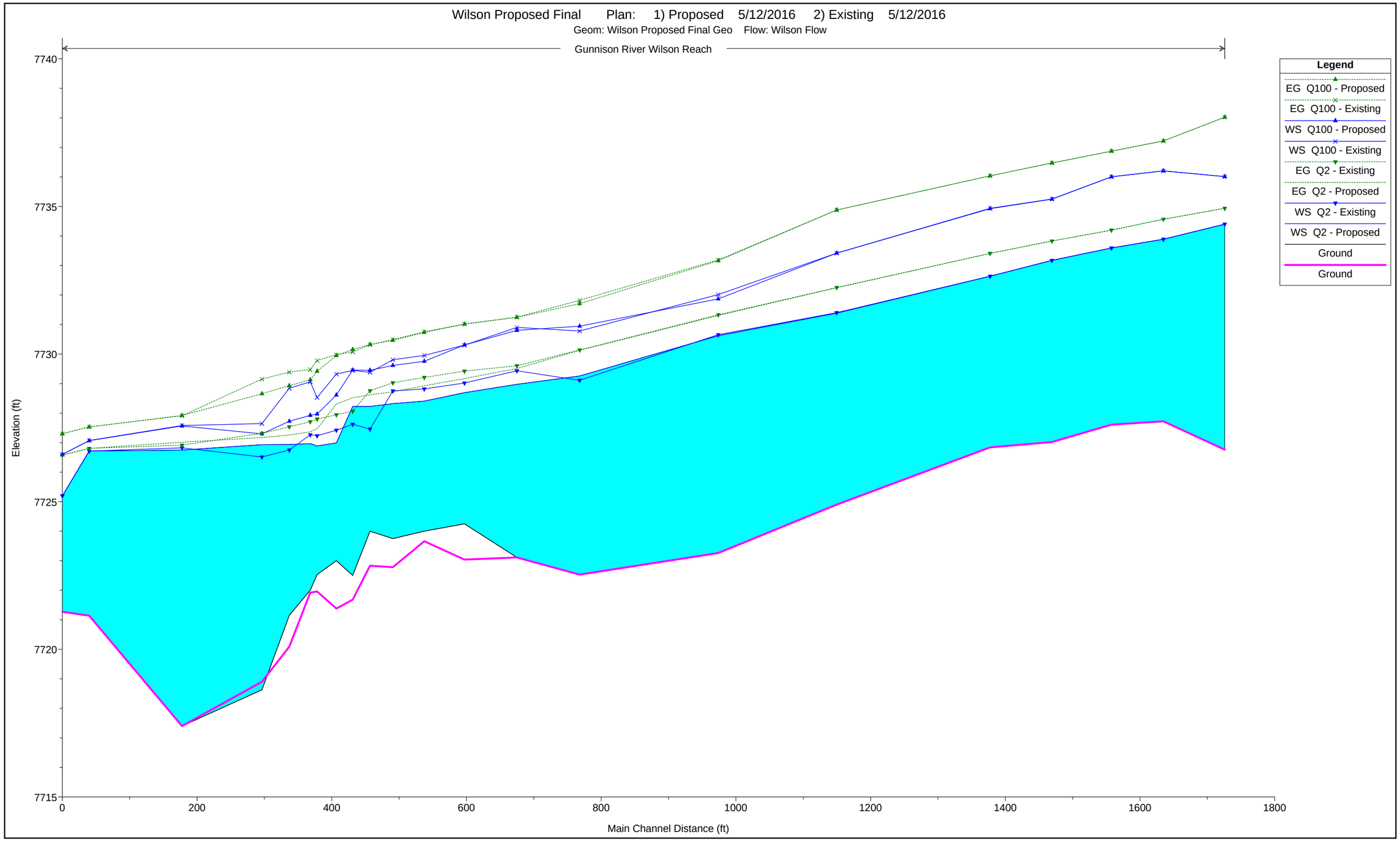
HEC-RAS LAYOUT

DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	

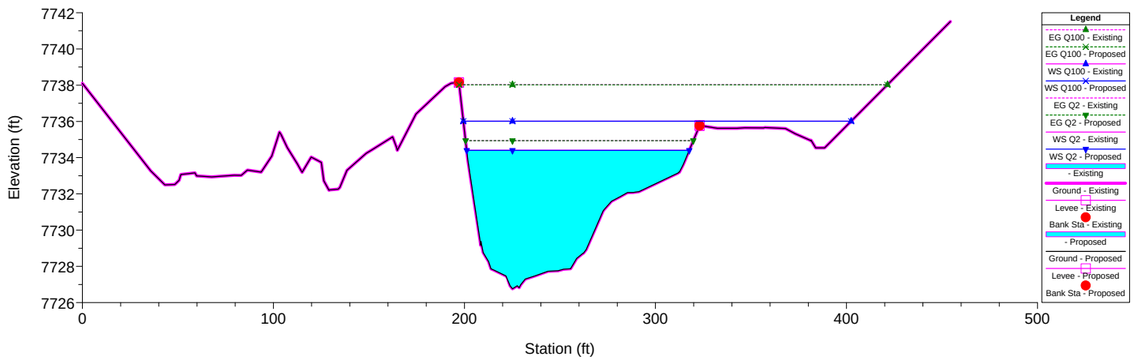
SHEET: B-4

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

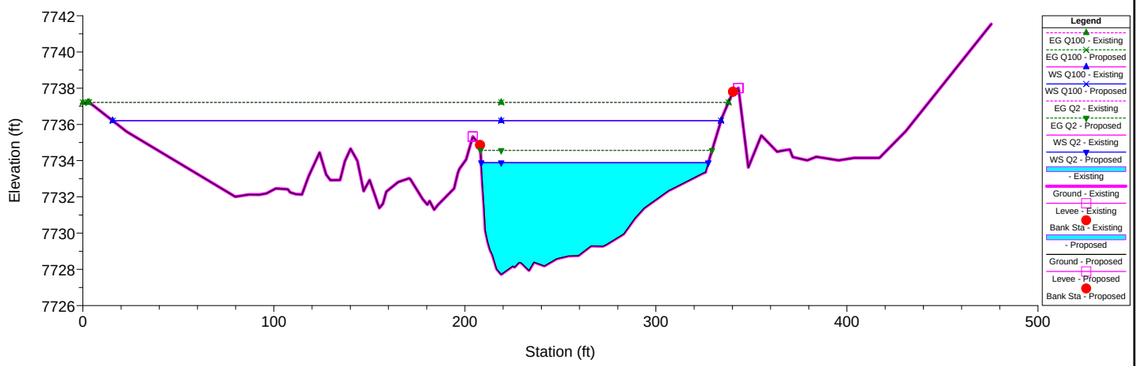
GUNNISON RIVER SWA
WILSON DITCH
APPENDIX B


Wilson Proposed Final Plan: 1) Proposed 5/12/2016 2) Existing 5/12/2016
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
Gunnison River Wilson Reach
Legend
EG Q100 - Proposed
EG Q100 - Existing
WS Q100 - Proposed
WS Q100 - Existing
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
Ground
Ground
Elevation (ft)
7740
7735
7730
7725
7720
7715
0
200
400
600
800
1000
1200
1400
1600
1800
Main Channel Distance (ft)

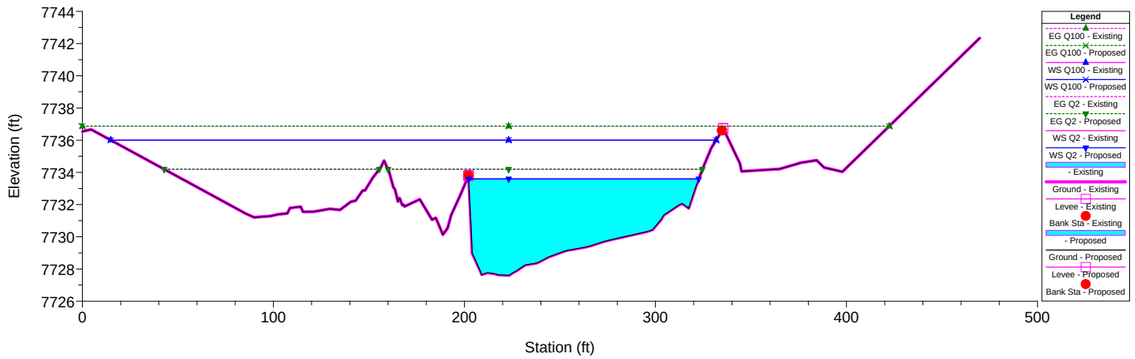
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 1746.3



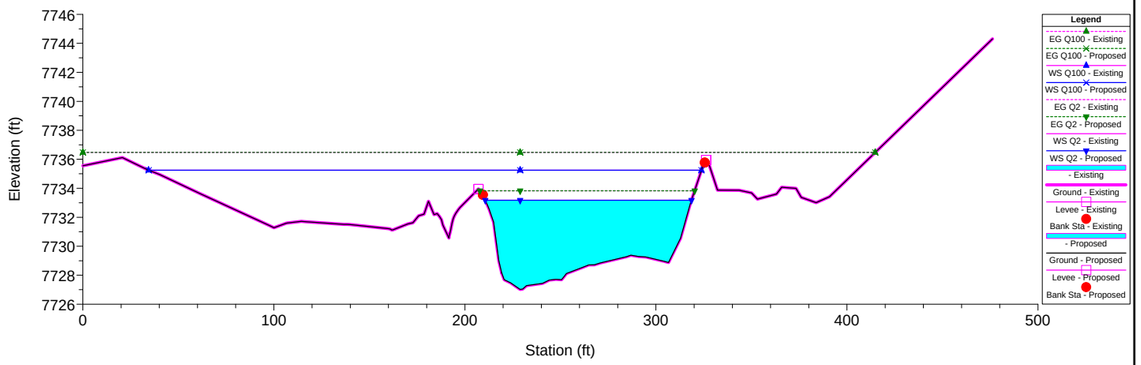
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 1655.3



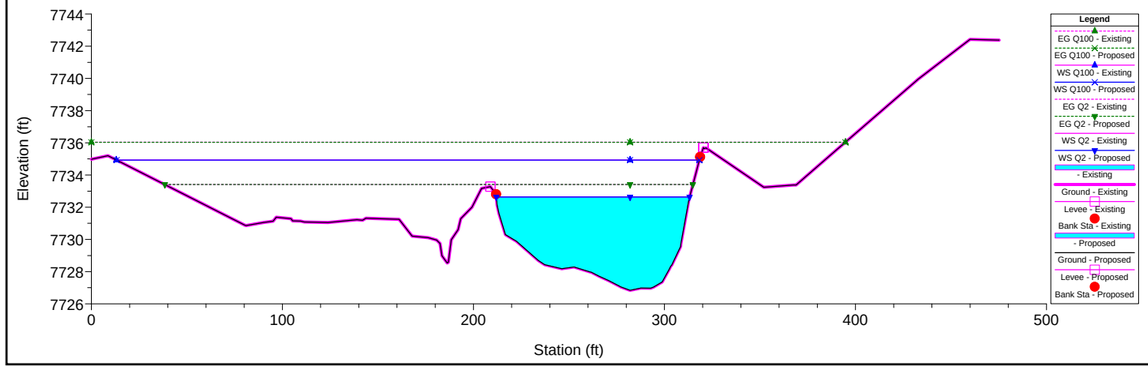
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 1578.1



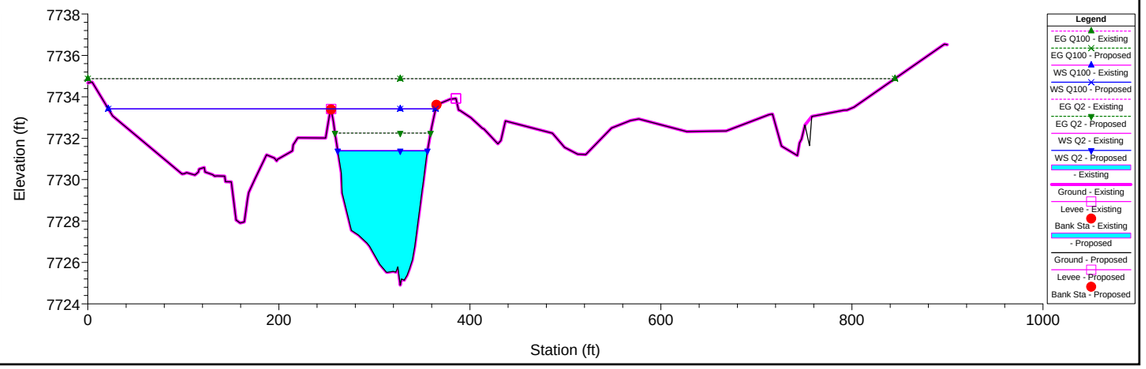
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 1489.8



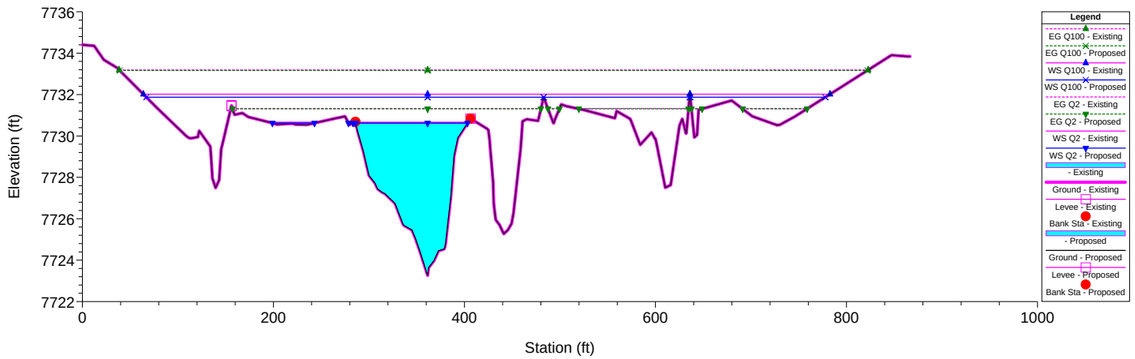
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 1398.0



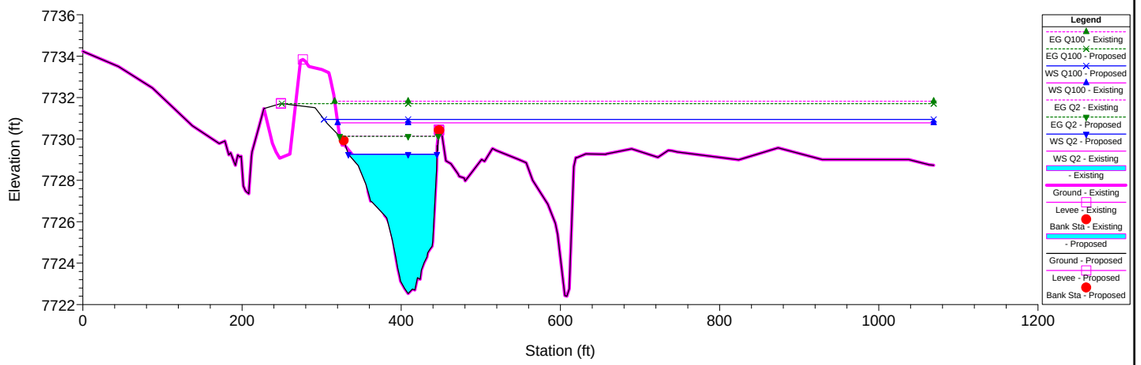
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 1170.1



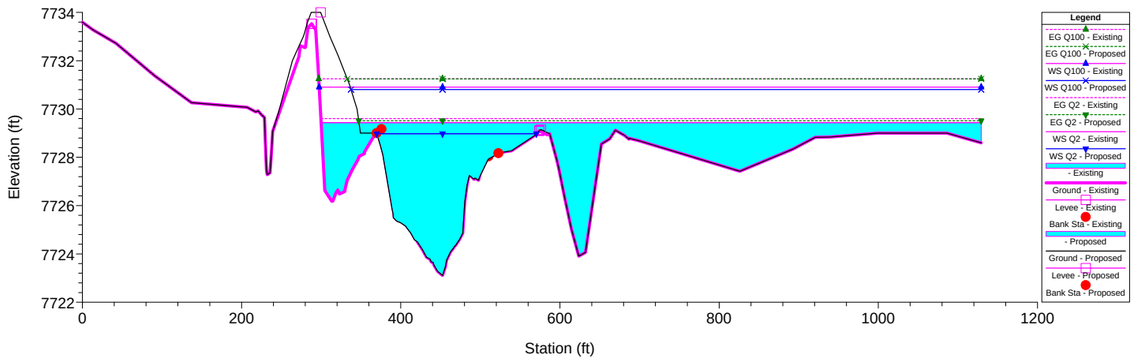
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 994.3



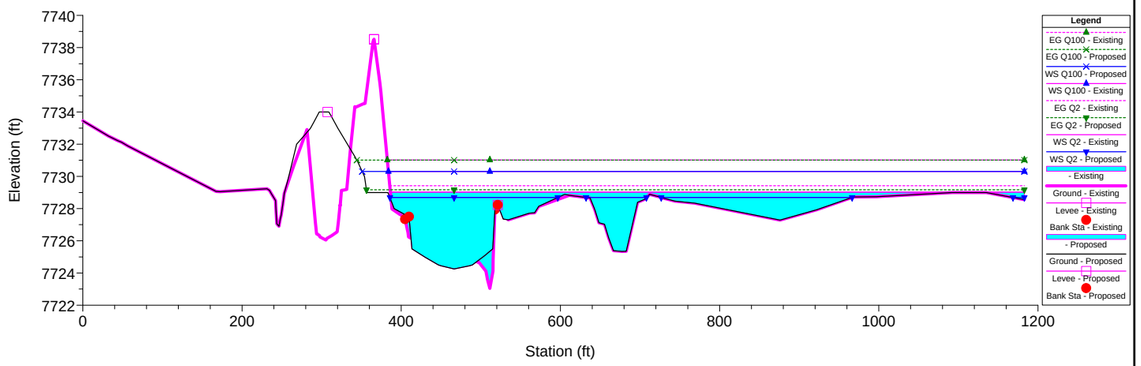
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 788.5



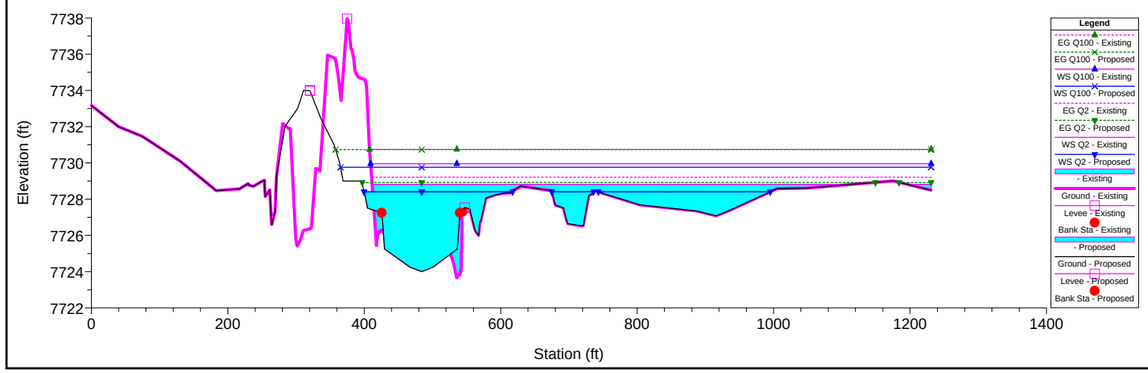
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 695.4



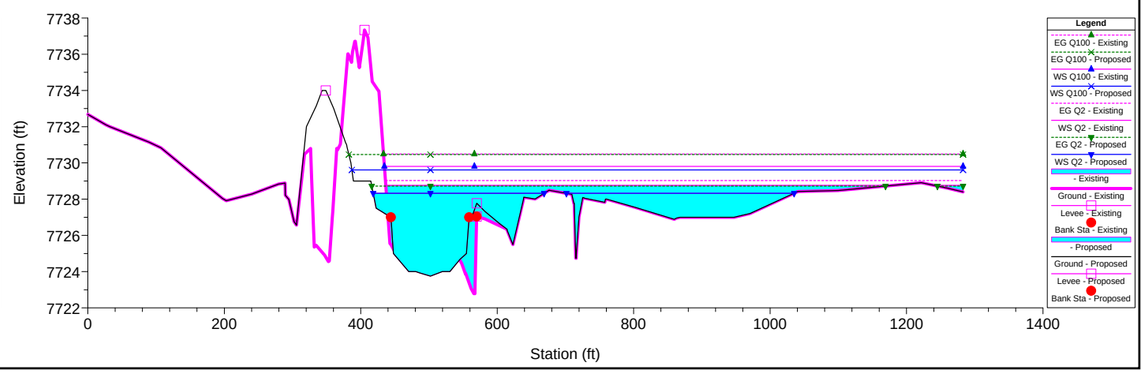
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 617.5

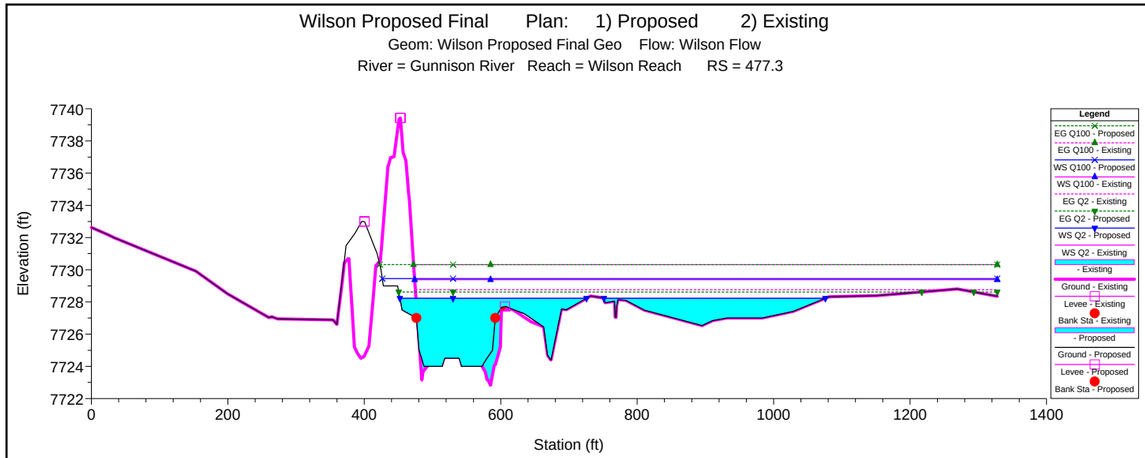


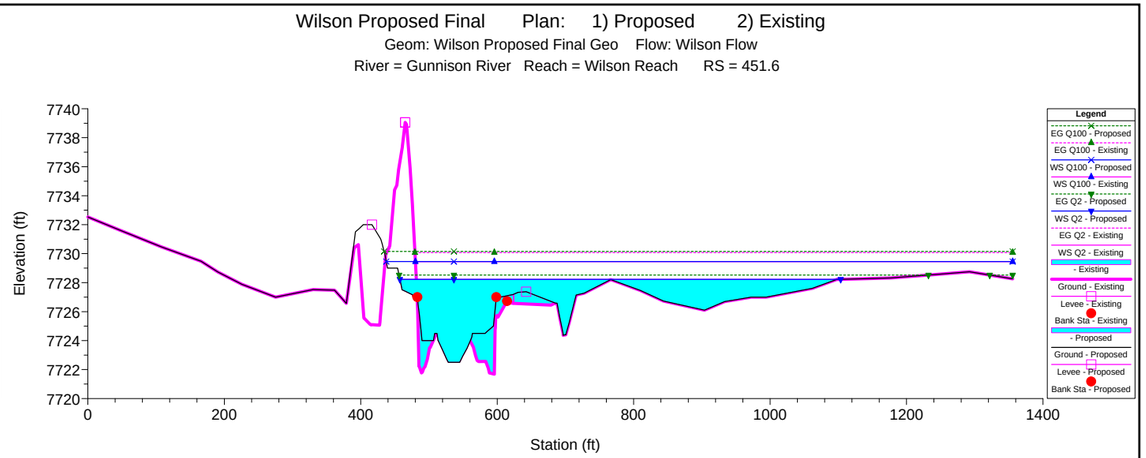
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 557.8

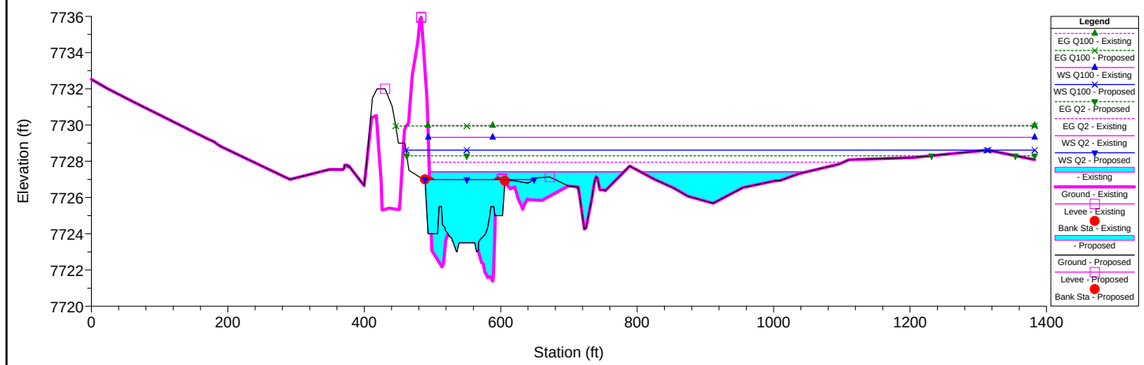


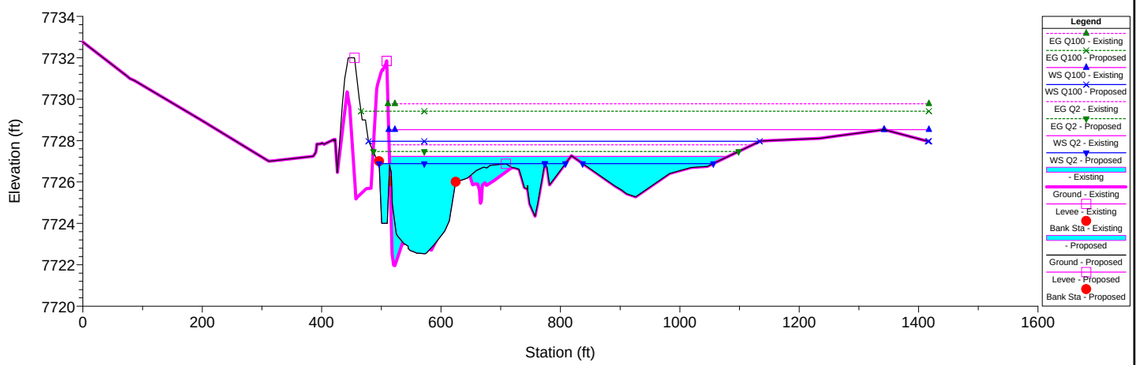
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 511.2

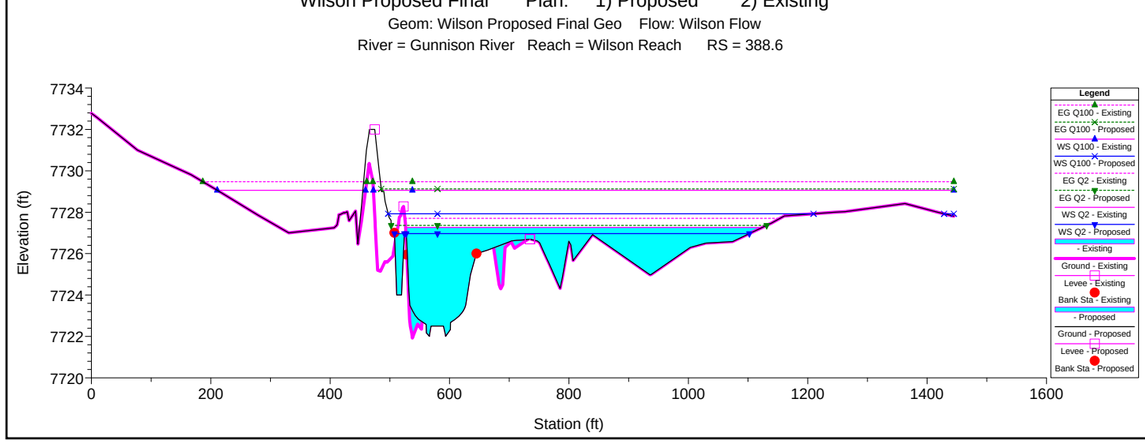


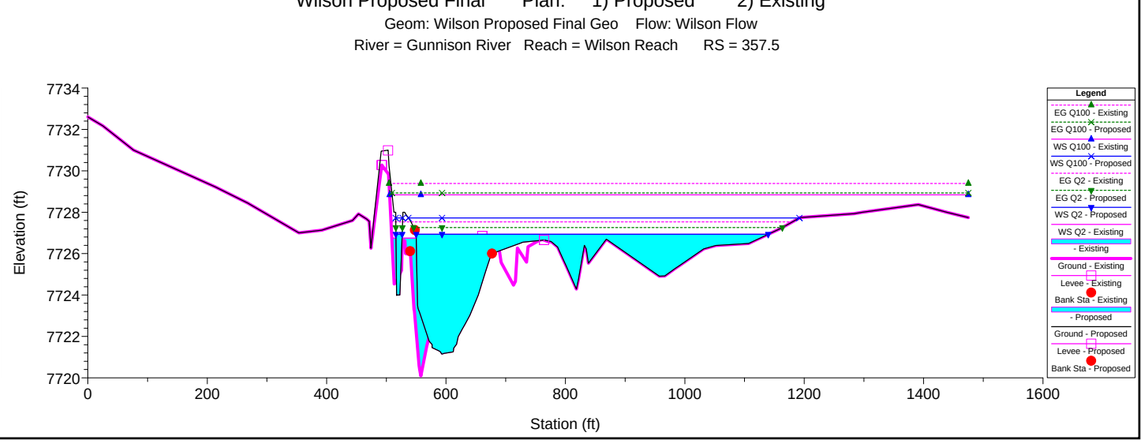

Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 477.3
Elevation (ft)
Station (ft)
Legend
EG Q100 - Proposed
EG Q100 - Existing
WS Q100 - Proposed
WS Q100 - Existing
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Proposed
WS Q2 - Existing
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 451.6
Elevation (ft)
Station (ft)
Legend
EG Q100 - Proposed
EG Q100 - Existing
WS Q100 - Proposed
WS Q100 - Existing
EG Q2 - Proposed
EG Q2 - Existing
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

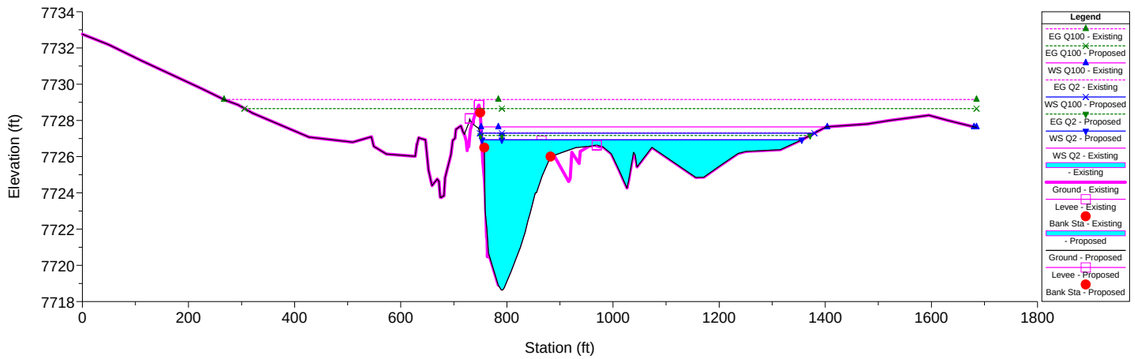

Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 427.3
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Proposed
EG Q2 - Existing
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 398.8
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

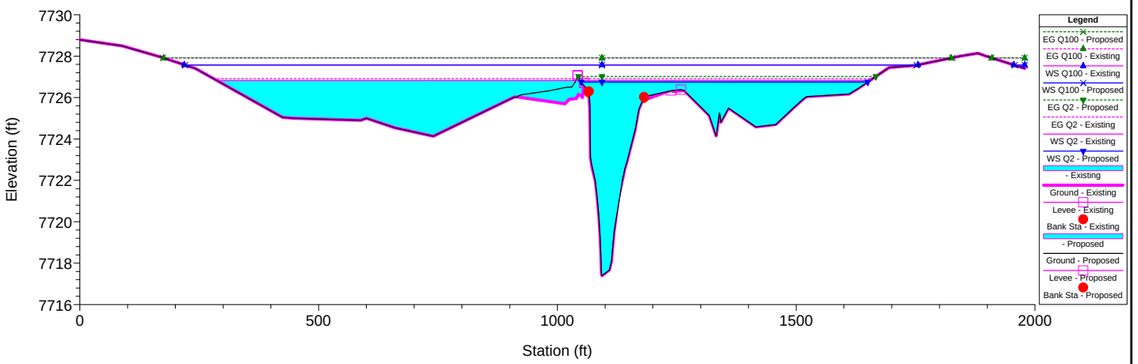

Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 388.6
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 357.5
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

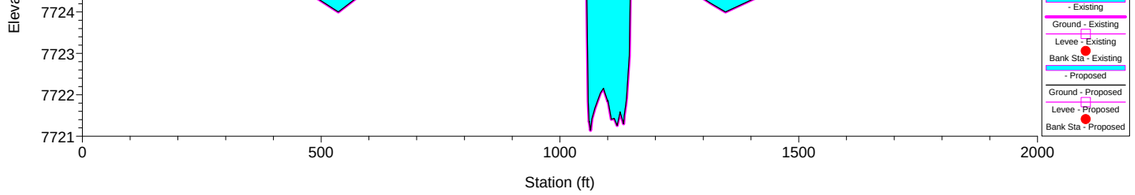
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 316.9



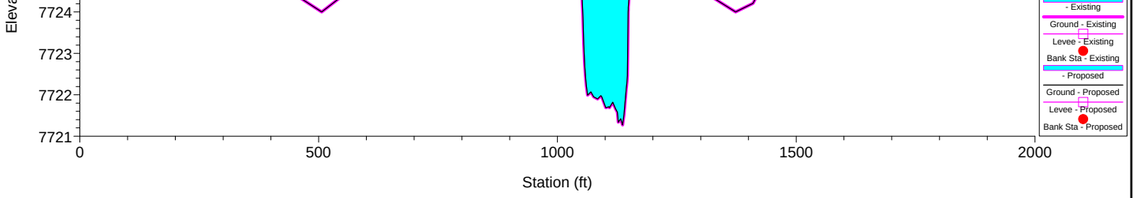
Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 198.2

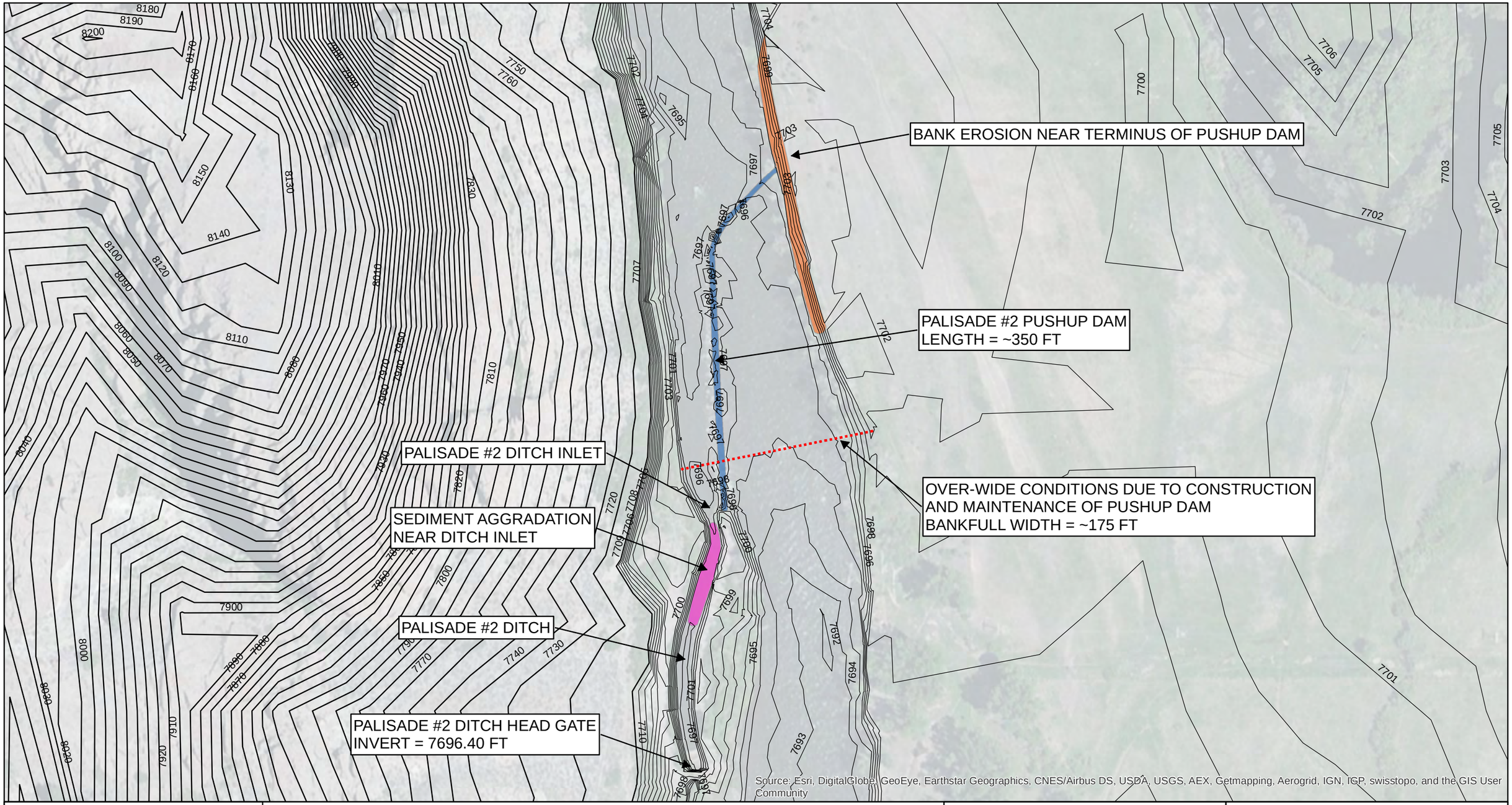


Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 60.3



Wilson Proposed Final Plan: 1) Proposed 2) Existing
Geom: Wilson Proposed Final Geo Flow: Wilson Flow
River = Gunnison River Reach = Wilson Reach RS = 20.5





Legend

- Bank Erosion
- Pushup Dam
- Sediment Aggradation
- Contour Interval = 1 ft
- Contour Interval = 10 ft

0 25 50 100 150 200 Feet

N

EXISTING CONDITIONS	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: C-1	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
PALISADE #2 DITCH
APPENDIX C

PRELIMINARY DESIGN
NOT FOR CONSTRUCTION

REMOVE EXISTING PUSHUP DAM

CROSS-VANE DIVERSION WITH ONE STEP
CREST = 7696.90 FT
TOTAL LENGTH = ~500 FT

CROSS-VANE DIVERSION
STEP = 7695.5 FT

PALISADE #2 DITCH INLET

EXCAVATE SEDIMENT FROM DITCH

INCORPORATE SEDIMENT SLUICE
INTO HEAD WORKS (NOT SHOWN)

MAINTAIN EXISTING HEAD GATE
INVERT = 7696.40 FT

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

- Cross-Vane Diversion
- Remove Pushup Dam
- Excavate Sediment
- Contour Interval = 1 ft
- Contour Interval = 10 ft

0 20 40 80 120 160 Feet

N

PROPOSED CONDITIONS	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: C-2	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
PALISADE #2 DITCH
APPENDIX C

PALISADE #2 PUSHUP DAM

PALISADE #2 DITCH INLET

PALISADE #2 DITCH

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

- Supplemental DEM Data
- Survey Data 2013
- Survey Data 2015

0 40 80 160 240 320 Feet

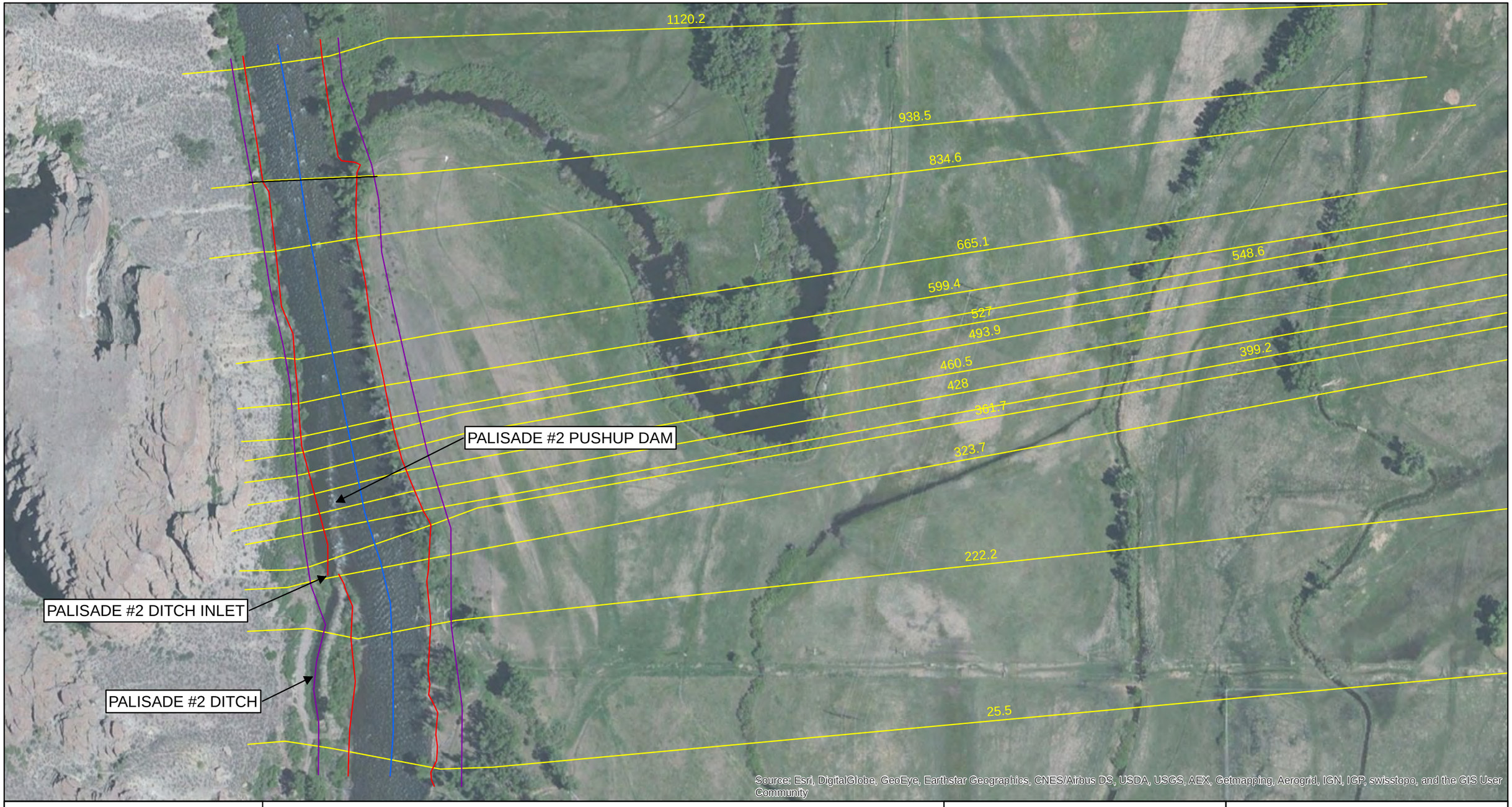
N

SURVEY LAYOUT

DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: C-3	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
PALISADE #2 DITCH
APPENDIX C



Banks
River
Flowpaths
Cross Sections

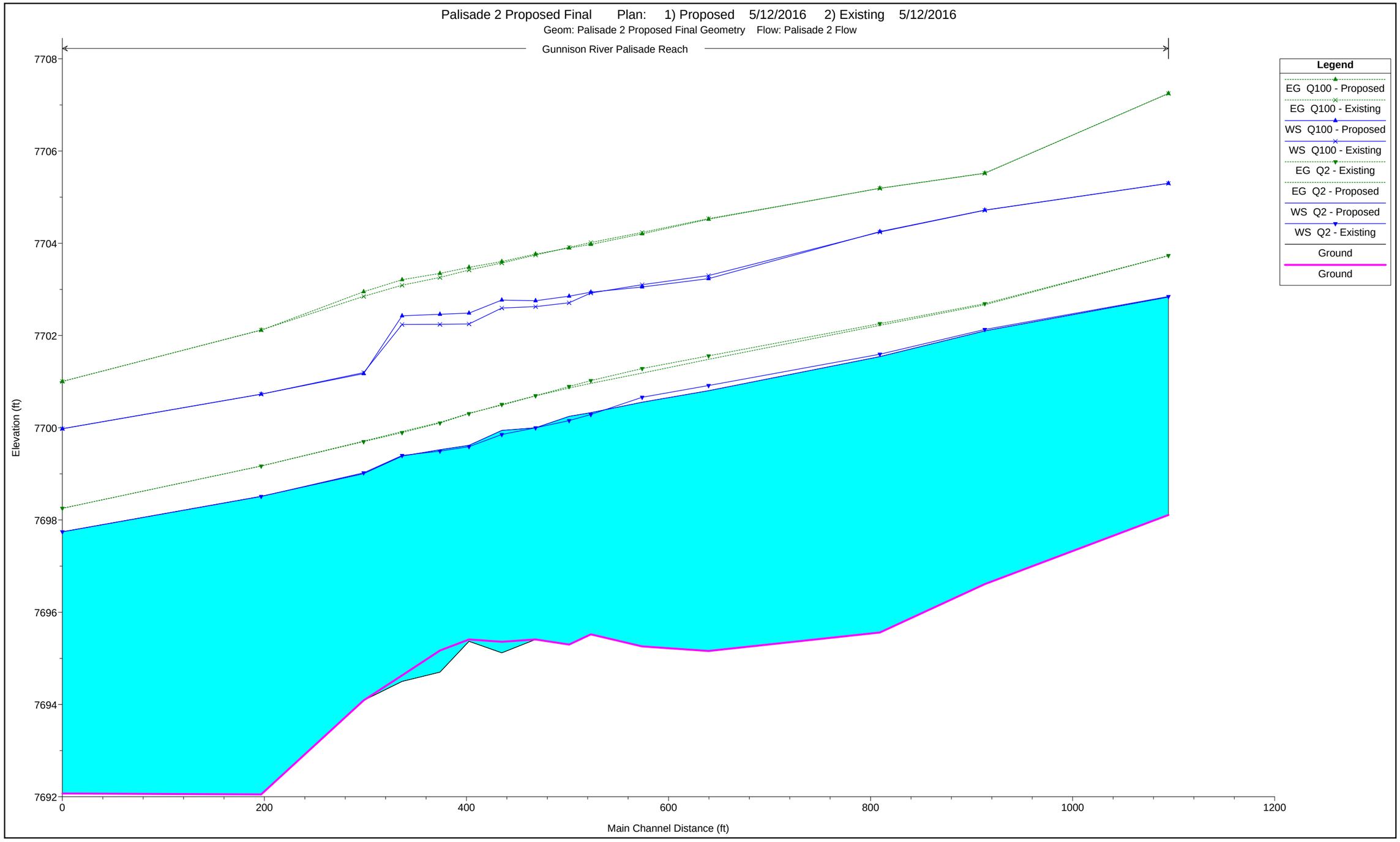
0 40 80 160 240 320 Feet

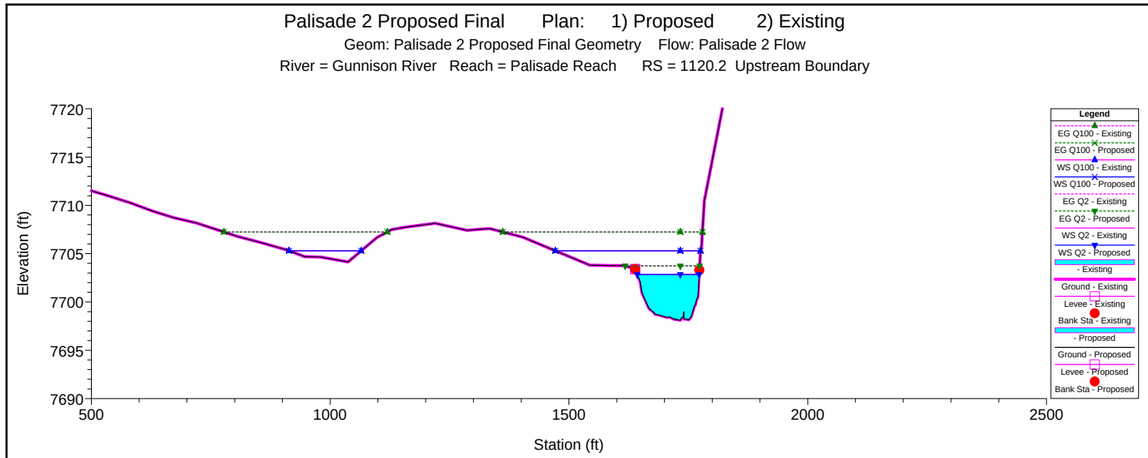
N

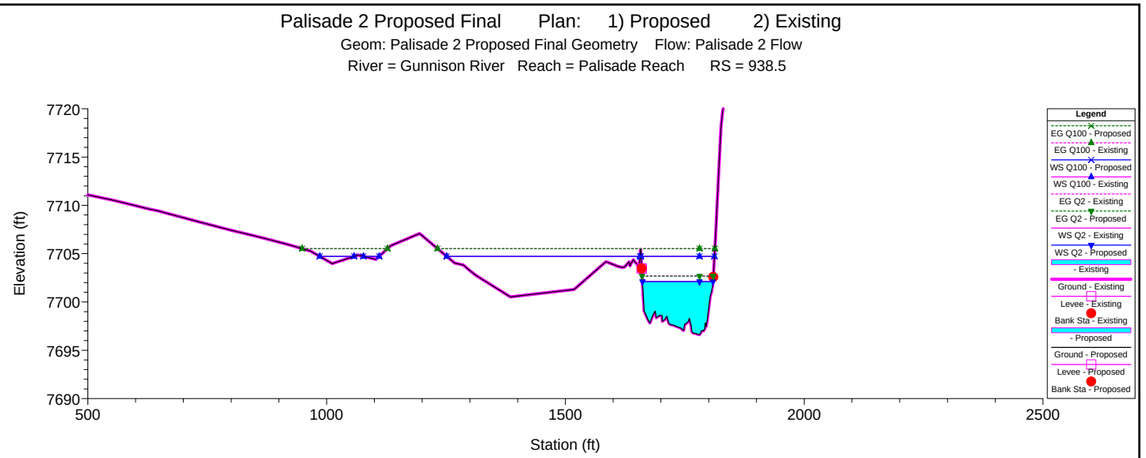
HEC-RAS LAYOUT	
DRAWN: ERICHER	5/13/2016
CHECKED:	
APPROVED:	
SHEET: C-4	

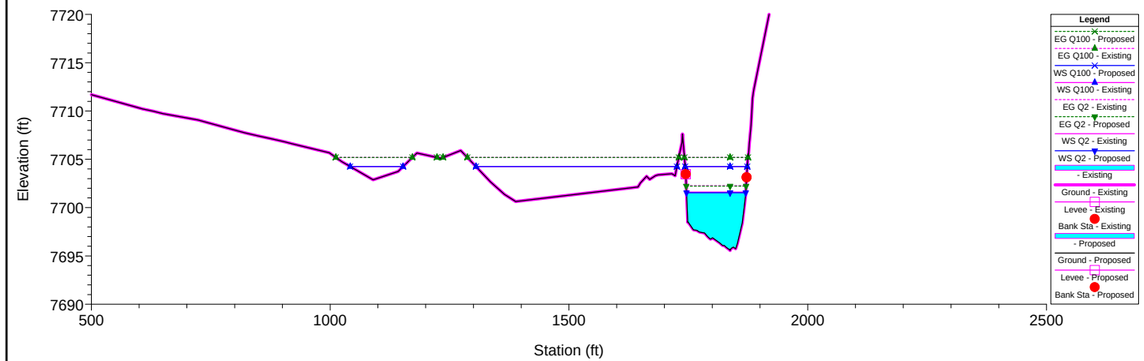
STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

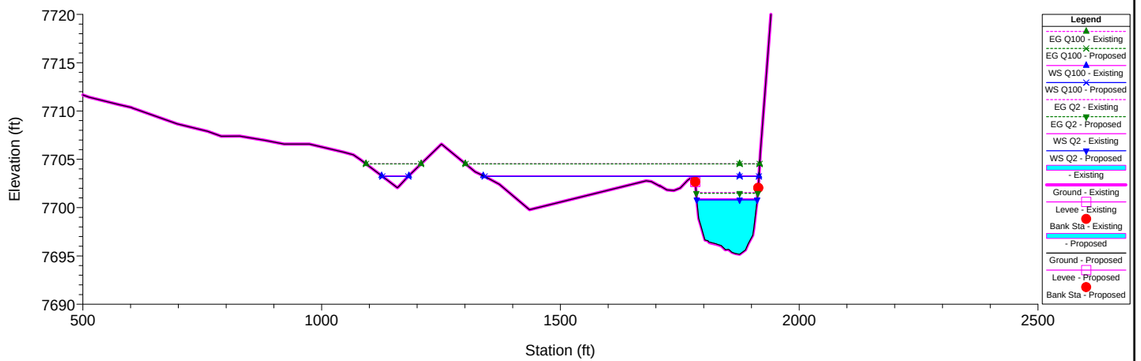
GUNNISON RIVER SWA
PALISADE #2 DITCH
APPENDIX C

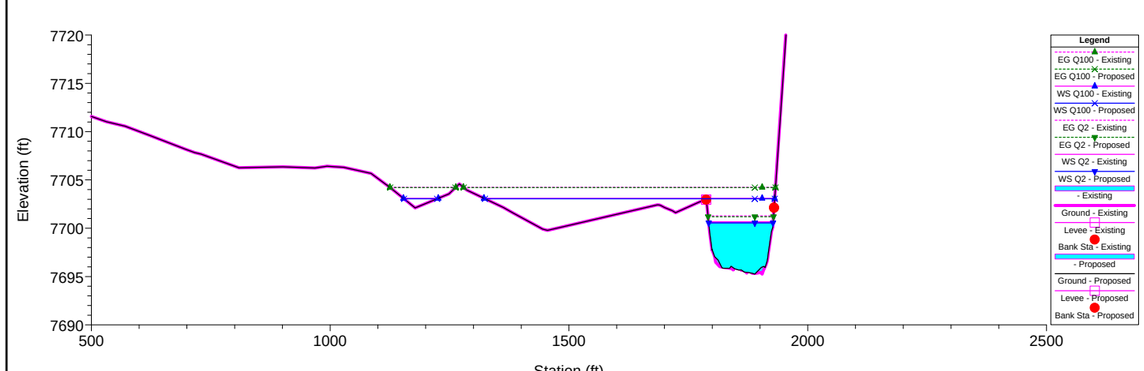

Palisade 2 Proposed Final Plan: 1) Proposed 5/12/2016 2) Existing 5/12/2016
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
Gunnison River Palisade Reach
Legend
EG Q100 - Proposed
EG Q100 - Existing
WS Q100 - Proposed
WS Q100 - Existing
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Proposed
WS Q2 - Existing
Ground
Ground
Elevation (ft)
7708
7706
7704
7702
7700
7698
7696
7694
7692
0
200
400
600
800
1000
1200
Main Channel Distance (ft)

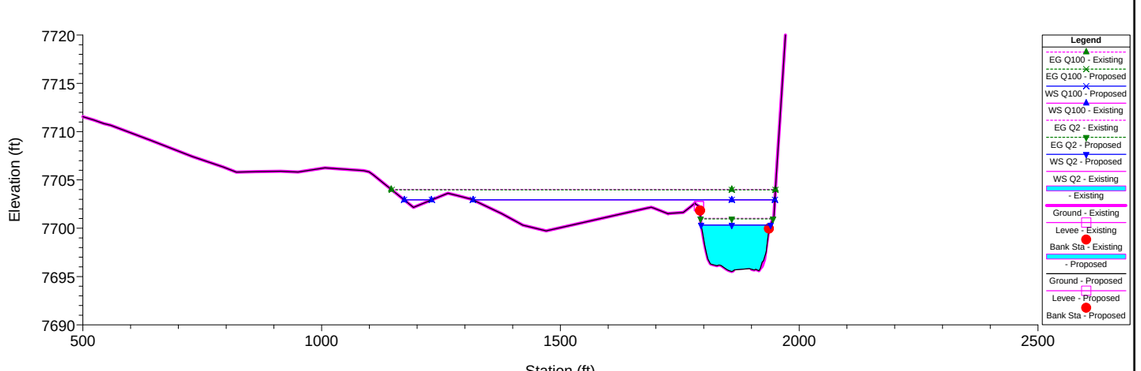

Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 1120.2 Upstream Boundary
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 938.5
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

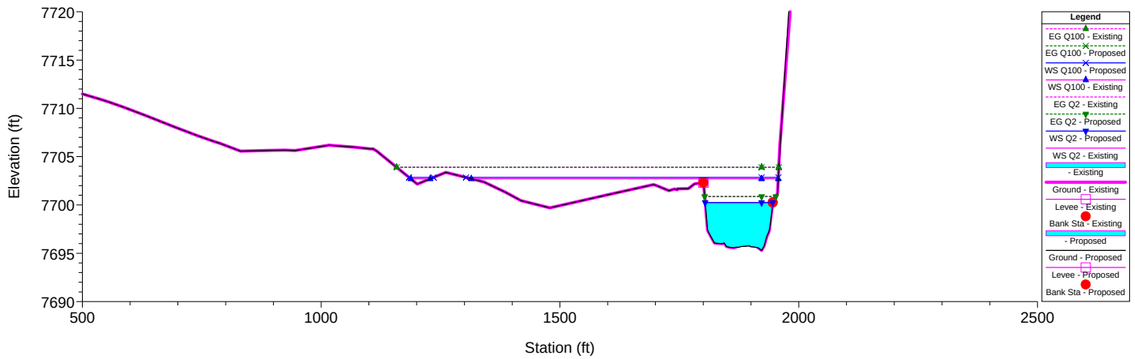

Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 834.6
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 665.1
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

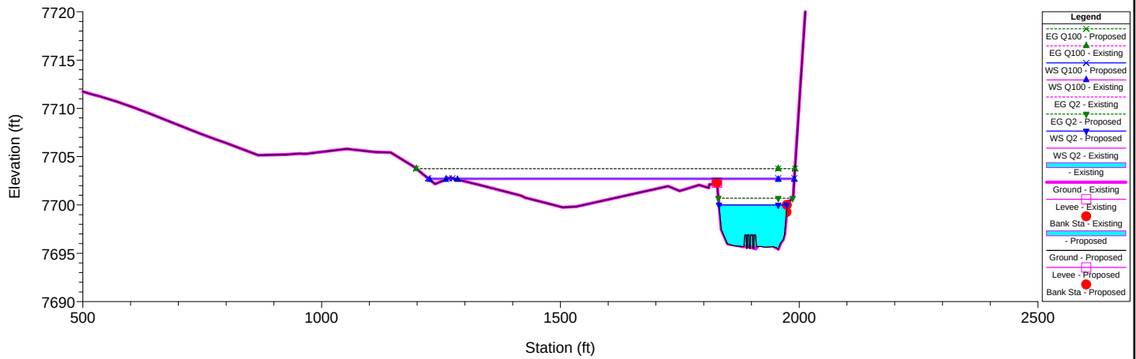

Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 599.4
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 548.6
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Existing
EG Q2 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed

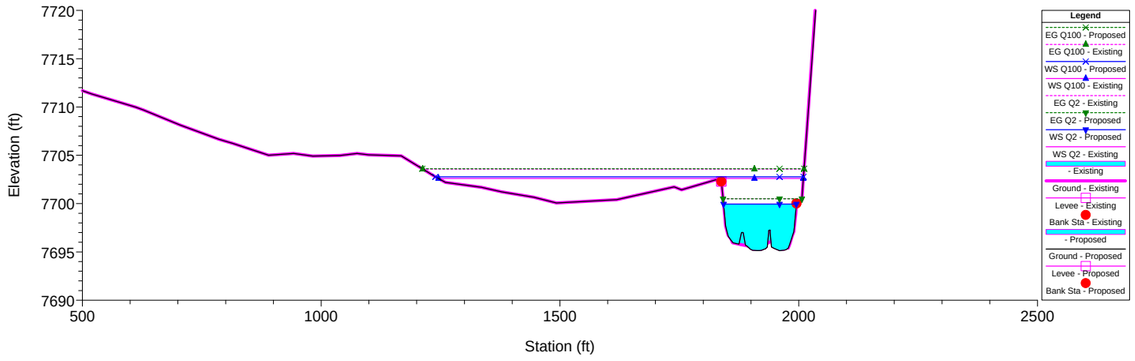
Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 527.0



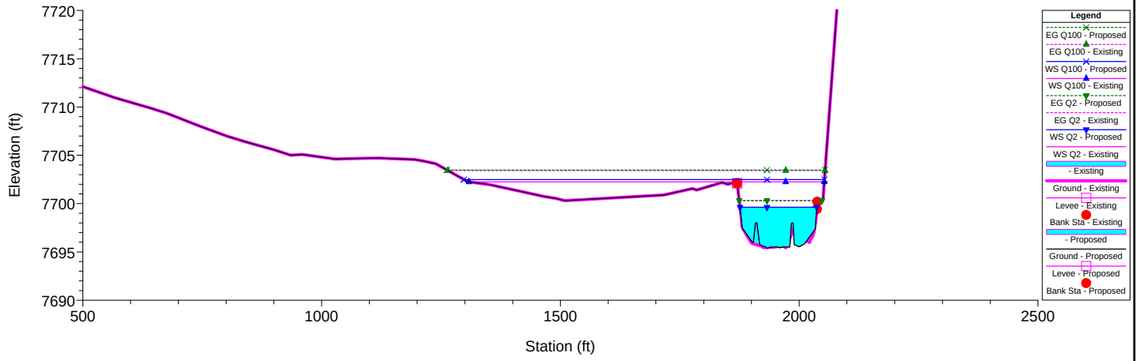
Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 493.9 Cross-Vane Crest



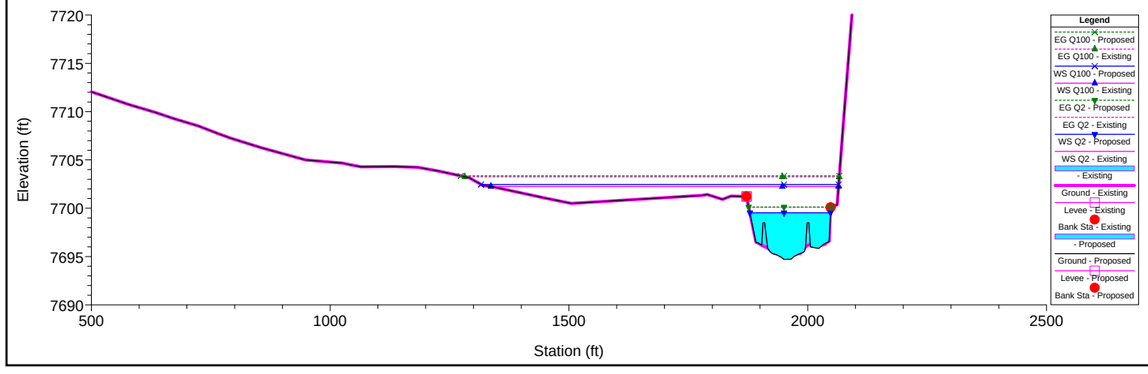
Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 460.5 Cross-Vane



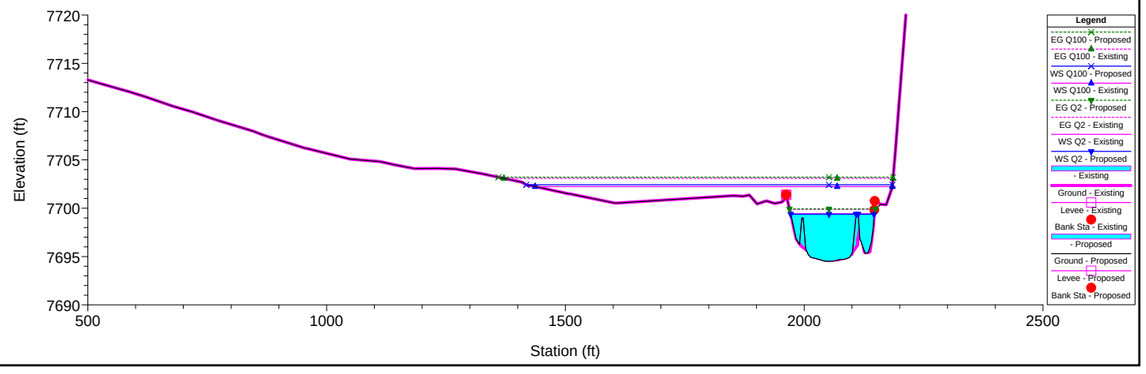
Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 428.0 Cross-Vane Step

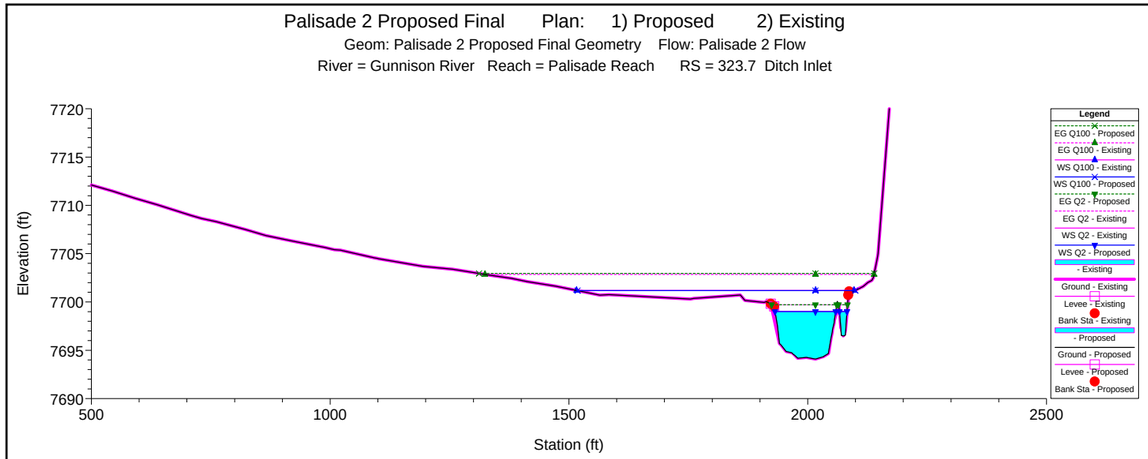


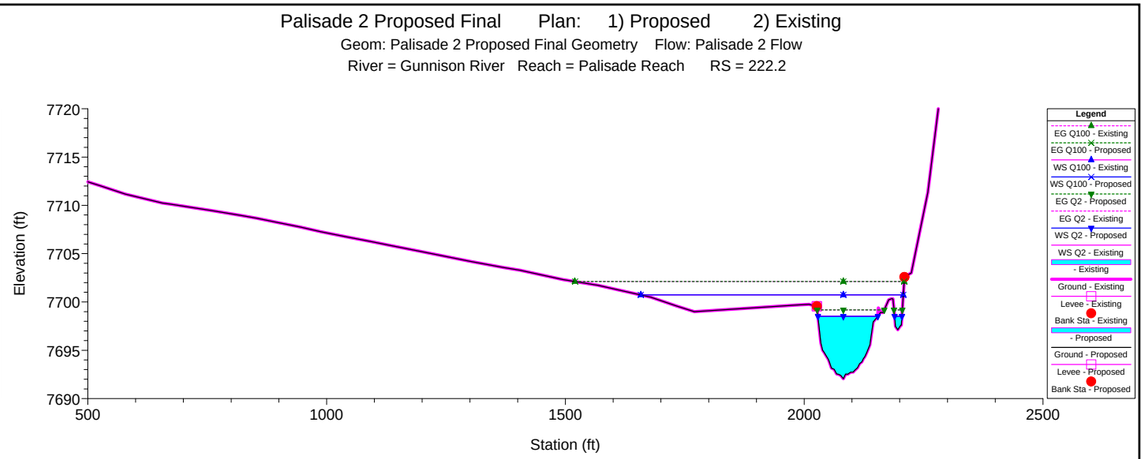
Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 399.2 Cross-Vane

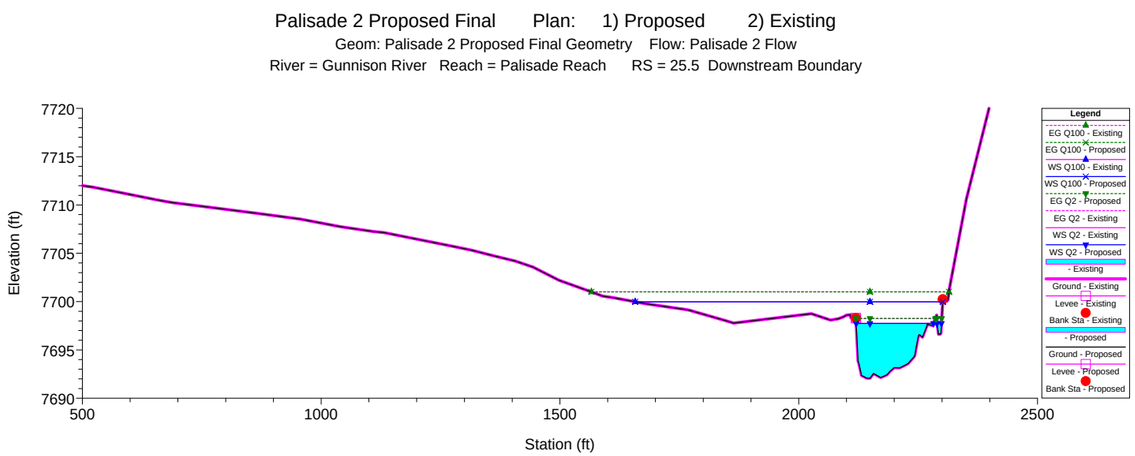


Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 361.7 Cross-Vane




Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 323.7 Ditch Inlet
Elevation (ft)
Station (ft)
Legend
EG Q100 - Proposed
EG Q100 - Existing
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Proposed
EG Q2 - Existing
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 222.2
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Proposed
EG Q2 - Existing
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed


Palisade 2 Proposed Final Plan: 1) Proposed 2) Existing
Geom: Palisade 2 Proposed Final Geometry Flow: Palisade 2 Flow
River = Gunnison River Reach = Palisade Reach RS = 25.5 Downstream Boundary
Elevation (ft)
Station (ft)
Legend
EG Q100 - Existing
EG Q100 - Proposed
WS Q100 - Existing
WS Q100 - Proposed
EG Q2 - Proposed
EG Q2 - Existing
WS Q2 - Existing
WS Q2 - Proposed
- Existing
Ground - Existing
Levee - Existing
Bank Sta - Existing
- Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed