RECLAMATION
Managing Water in the West

Lower Yellowstone Fish Passage Alternatives Planning Study

June – September

2013

Conducted in cooperation with the state of Montana Fish Wildlife and Parks, Montana State Department of Natural Resource Conservation, Montana Water Resources Association, Lower Yellowstone Irrigation Districts, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, the Bureau of Reclamation Technical Service Center, and the Bureau of Reclamation Great Plains Regional Office and Montana Area Office

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Executive Summary

Reclamation convened a Planning Team (PT) for the re-examination of alternatives after stakeholders expressed concerns with the proposed bypass channel alternative intended to provide fish passage at Intake Diversion Dam in Montana. The PT met on several occasions from June 20 to September 13, 2013, to identify and evaluate fish passage alternatives.

The PT identified 20 alternatives consistent with the objectives of the project – to provide Pallid Sturgeon fish passage while maintaining irrigation district viability. From the 20 alternatives, the PT identified five alternative themes for further investigation. Reclamation and the Army Corp of Engineers conducted preliminary hydraulic analyses as well as preliminary cost estimates for these five alternative themes to help the PT evaluate hydraulic feasibility and cost effectiveness. Reclamation also investigated a sixth alternative theme, the Island – Extended Canal theme, even though it received a moderate evaluation for irrigation district viability from the PT, because of strong indications it would be cost effective while meeting fish passage objectives.

The PT concluded that the rock ramp and bypass channel alternatives best meet the objectives of the project based on the hydraulic analysis and cost estimates that were prepared.

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Background

The Intake Diversion Dam and diversion headworks for the Lower Yellowstone Irrigation Project's main canal are located on the Yellowstone River about 17 miles northeast of Glendive, Montana (Figure 1). The main canal diverts water on the north side of the Yellowstone River and water is carried downstream in the main canal 71.6 miles until it returns to the Missouri River near the confluence of the Yellowstone and Missouri Rivers.

The Intake Diversion Dam is a rock filled timber crib weir with a structural height of about 12 feet, a crest length of 700 feet, and a crest elevation of about 1981.0 (original project datum; about 8 feet lower than NAV88 datum). See Figure 2. The dam was completed in 1909. The canal was originally designed with a 30 foot bottom width with a 1.5:1 side slope. The canal is designed to carry at full capacity about 1,400 cubic feet per second at a flow depth of about 10 feet. The canal operates from May 1 through the end of September on a typical year.

Almost annually large riprap is added to the crest of the dam via an overhead cable way to replace riprap lost from the dam due to high flows and/or ice flows (Figure 3). Major rehabilitation projects are conducted about every 30 years to repair accumulated damage to the wooden crest and other portions of the dam.

In 2010 Reclamation and the Army Corps of Engineers produced an Environmental Assessment (2010 EA) and Biological Assessment (2010 BA) that identified the rock ramp and on river screening headworks as the preferred alternative to address passage and canal entrainment. The lead federal agencies made a decision in April 2010 to proceed with the project and the Corps awarded a contract to construct the new headworks and fish screens in July 2010. The Corps also proceeded with activities needed to develop the final design of the rock ramp and issue a contract for its construction in 2011. The conceptual design level cost estimate for the rock ramp was approximately 18 million dollars. In late 2010 and early 2011, the estimated costs for the conceptual rock ramp design increased dramatically. The primary reasons for the increased cost estimate included:

1. The amount of rock needed for the rock ramp significantly increased. The length of the rock ramp would need to be longer than originally considered in the conceptual designs and cost estimates. Input from the Biological Review Team (BRT) regarding the design criteria (principally flow velocity and water depth) indicated that the slope of the rock ramp should be 0.4 percent, which is more gradual than the 1 percent slope the Corps used during development of the conceptual design phase. The more gradual slope means the rock ramp would need to be longer, which means significantly more rock would be needed to extend the length of the ramp.

2. Additional rock would also be required for the rock ramp to provide more point-to-point rock contact in the structure of the ramp needed to maintain its stability given the wide range of flow and environmental conditions in the Yellowstone River.

3. The construction of the rock ramp would likely need to be conducted “in the dry” to ensure that careful placement of the rock is accomplished so that the ramp would be sufficiently stable to withstand the wide range of flow conditions. River diversions and dewatering would be needed which would increase costs.

4. The source of rock for the ramp had not been well-defined. Local rock sources would likely not have acceptable qualities for use in the ramp. Cost estimates to import rock from suitable sources would likely involve long haul distances. Hauling rock from distant sources would significantly increase costs.

As a result of this information it appeared that the estimated cost of the rock ramp could approach 90 million dollars. The Corps and Reclamation, in coordination with the U.S. Fish and Wildlife Service, considered the implications of this new information in early 2011. Under authority of the Water Resources Development Act of 2007 (WRDA 2007) and consistent with the joint agency decision in April 2010, the Corps had committed up to 40 million dollars in Missouri River Recovery Program funding to the entire dam modification project. The potentially significant increase in the cost of the rock ramp, combined with the design and constructability issues described above, led the lead agencies to reconsider the decision to implement the rock ramp alternative for fish passage. In April 2011, the lead agencies determined that further evaluation of other alternatives for improving fish passage was needed to address the new/additional information and issues that had arisen since 2010. In addition to new cost information, new information regarding Pallid Sturgeon behavior also became available. Originally, because of uncertainties in Pallid Sturgeon movement, one of the requirements of the BRT’s passage criteria was full river width passage. Since the long low gradient alternative, a previous version of the bypass channel, would not meet this criterion it was not carried forward in earlier analysis. Based on new technical information documenting Pallid Sturgeon use of side channels (McElroy et. al., 2012; Service, 2012), the BRT relaxed this criterion in 2011. The lead agencies believed there was merit in revisiting a bypass alternative that was previously considered but eliminated from detailed study. Through collaborative efforts, further information, and preliminary design reviews, the lead agencies supported further analysis of a bypass alternative.

In 2013, Stakeholders began voicing concerns about the bypass channel alternative and requested that the lead agencies revisit alternatives that had previously been dropped from consideration. Because of this request, the Corps stopped design work on the bypass channel while Reclamation conducted the re-planning effort described in this document.

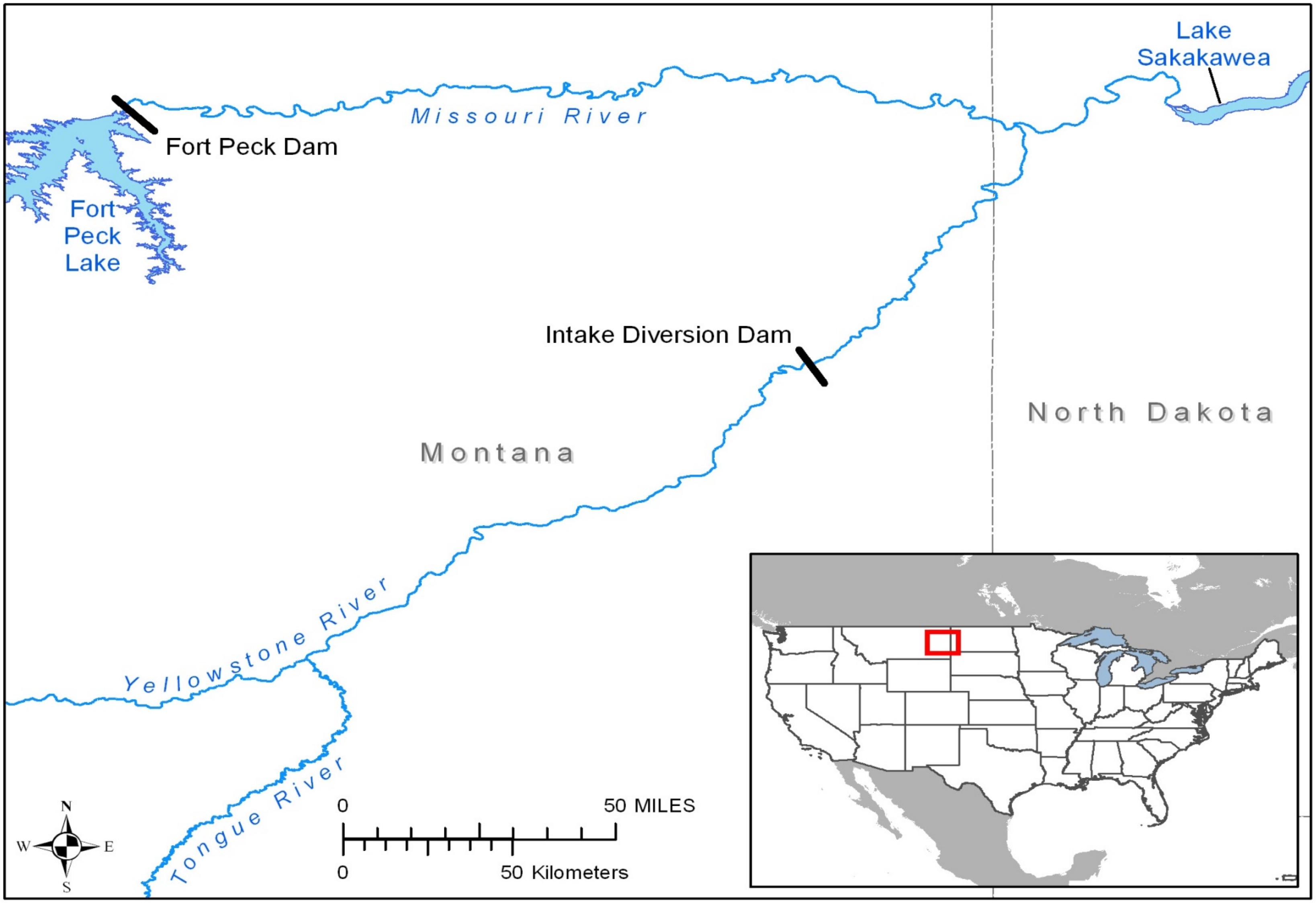

Figure 1: Project Map

Figure 2: Existing Diversion Structure

Figure 3: Rocking Trolley

Planning Process

The planning effort started off by establishing the objectives of the project as well as defining the criteria to be used to evaluate each alternative.

Objectives

- Endangered Species Act (ESA) obligations at Lower Yellowstone Irrigation Project for providing passage of juvenile and adult Pallid Sturgeon.
- Maintain long-term viability of the Lower Yellowstone Irrigation Project.

Criteria

1. *Likelihood of ESA Success* – Probability that the alternative will satisfy the requirements of ESA.

2. *Water Delivery Reliability* – the likelihood that the alternative will provide for continued delivery of water to the irrigation project over the life of the project.

3. *Engineering Design/Constructability* – Degree of confidence with the design and construction of each alternative considering potential complexity of the design and needs to consider site specific issues using standard construction methods.

4. *Acceptability* – Indicator of how acceptable the alternative is expected to be for the identified groups, based on informal consultation and conversations with stakeholders-socioeconomic and political acceptability applied through compliance with National Environment and Planning Agency (NEPA) process.

Each Criteria was ranked from 1–5 with 1 being the lowest score to 5 being the highest score possible.

Each member of the PT was given a list of previous ideas considered (110 ideas) and was asked to identify any alternative that they would like to see reviewed again or come up with a new alternative to present to the group.

Once all alternatives were identified, the group then scored them based on criteria identified above. Once all of the alternatives were ranked, it was determined that a lot of the ideas had similar features that could be grouped into six main alternative themes. These six alternative themes are presented below:

Alternative Theme A. Open Channel with Pumping

- Remove dam and downstream rock rubble (provide a more natural contour)
  - If necessary, include grade-neutral control structure in river at headworks
- Divert irrigation water through headworks
  - Diversion of full water right (1,374 cfs) preliminarily expected at river flows of 25K cfs and higher; diversions expected to decrease proportionately at river flows below 25K cfs
- Supplemental water pumping when under 25K cfs river flows
  - Multiple Ranney wells (basically infiltration galleries placed near the river)
  - Target--provide 80 percent of water supply demands through pumping
  - Target--reduce water supply demand by 20 percent through canal lining, lateral piping, and other conservation improvements
  - Provide power transmission reliability improvements
  - Investigate availability of Pick-Sloan power

Alternative Theme B. Original Rock Ramp

- Replace the existing rock and timber structure with a shallow-sloped, un-grouted boulder and cobble rock ramp
- Design ramp to mimic natural river riffles with lower velocities and turbulence so migrating fish can pass over the ramp
- Ramp crest elevation (1990.5') set to provide 1,374 cfs irrigation diversions when river is flowing at 3,000 cfs

Alternative Theme C. Rock Ramp with Reduced Weir Elevation

- Target--provide 70 percent of water supply with a lower ramp elevation
  - 2.5 foot drop in elevation (estimated; weir elevation at approximately 1988')
  - 500' shorter ramp length (estimated)
  - 400 cfs reduction in diversion (estimated)
- Target--reduce water supply demand by 30 percent (approximately 400 cfs) through conservation improvements & Ranney-type well pumping

Alternative Theme D. Combination Rock Ramp & Weir

- Rock ramp would be approximately ½ the river channel width with a standalone weir across the remainder of the river
- Rock ramp and weir elevation would be at 1990.5' to provide 1,374 cfs irrigation diversions when river is flowing at 3,000 cfs
- Includes a dividing wall running the full length of the rock ramp to separate and control the flows on the rock ramp from the flows going over the weir

Alternative Theme E. Modified Bypass Channel with Reconfigured Weir

- Changes from the 30 percent Bypass Channel design would include:
  - Relocate Bypass Channel so that it is separate from the existing high flow channel
  - Reduce weir crest width from the original proposed 25' to approximately 6'
  - Provide variable flow velocities along weir crest and downstream slope through slight undulations in crest height

Alternative Theme F. Island – Extended Canal

- Remove existing diversion structure and rubble field
- Construct a new 100 ft section of weir near the existing headworks.
- A 9,600 ft long canal would be constructed on the headworks side of the river and be separated from the Yellowstone River by a 3,400 ft-long by 10 ft wide dike.
- This alternative would utilize the existing island in the Yellowstone River upstream of the headworks to split river flows between the canal and the river.
- The entrance to the canal would be set at 1990 (1.5 feet higher than the river invert).
- A concrete sill would be required to stabilize the canal entrance.

Once the group agreed upon the six main alternatives to consider moving forward Reclamation and the Army Corps of Engineers complete preliminary cost estimates as well as hydraulic analysis to determine if they were feasible. Narratives can be found below.

Alternative Themes

Alternative Theme A. Open Channel with Multiple Ranney Wells

Alternative Description:

This proposal consists of four main components: First, the existing headworks would continue to be used to divert irrigation water when river flows are sufficient to do so; Second, replacing the existing diversion dam with multiple pumping stations along the river downstream from the existing weir; Third, implementation of water conservation measures throughout the irrigation delivery system to reduce the amount of water needed for the project (see Conservation Measures supplemental alternative description); and Fourth, installing renewable energy sources to supplement power demand for the pump system. Due to time constraints the renewable energy options were not investigated as part of this proposal.

Proposed Pump Systems:

The multiple pumping stations option consists of numerous radial collector wells installed at seven locations adjacent to the Yellowstone River to supply irrigation water to the Main Canal. Water would be carried from the pumps to the Main Canal by several buried pipelines. Using radial collector well type systems with fixed pumps would eliminate the need to construct permanent structures within the Yellowstone River.

Radial collector wells, one type being a Ranney® collector well, are generally comprised of a vertical reinforced concrete shaft (caisson)—typically 16 feet in diameter—excavated to a target depth at which well screens project laterally outward in a radial pattern. In a practice referred to as riverbank filtration, the wells are designed to induce infiltration from a nearby surface water source, combining the desirable features of groundwater and surface water supplies.

Where alluvial deposits form aquifers that are hydraulically connected with surface water sources, water supply systems can be installed to induce infiltration to recharge the water being pumped from the aquifer, providing water that is naturally filtered to provide very uniform water quality and temperature. As water is pumped from the well, the water table lowers, reversing the hydraulic gradients within the aquifer, which induces recharge to filter through riverbed and riverbank deposits providing a sustained flow of naturally filtered water to the well or infiltration system.

Ranney® collector wells are the preferred method for developing moderate to very high capacity riverbank filtration (RBF) supplies. RBF collector wells will be installed adjacent to the Yellowstone River (surface water source) at seven sites indicated on the Map (Figure 4) with their lateral well screens projected beneath the riverbed to optimize induced infiltration supplies. These wells can be installed with designated setback distances to increase the degree of filtration achieved. The result is an abundant, dependable supply of high-quality water with a constant temperature and low turbidity.

Ranney wells have been designed with capacities up to 123cfs. In this alternative, each well site must produce approximately 200cfs. Two collector wells will be needed at each site. In the right location, a Ranney well will produce the same volume of water as several vertical wells while using less area than a conventional well field. Additionally, a properly designed Ranney well has enough screens to minimize the entrance velocity of groundwater, reducing the frequency of required maintenance.

Irrigation Canal Operation:

The existing canal consists of about 72.5 miles of unlined canal and the flow into the canal is diverted from the Yellowstone River when flows are high enough to allow diversion. The canal currently functions as a conveyance system and is controlled by a downstream operational concept where the water demand or scheduled deliveries determine the flow into the canal. In a report by Henry T. Falvey & Associates, dated April 9, 2009, critiquing the use of multiple pumps to supply water to this system, it was identified that about 80 percent of the flow is distributed in the downstream third of the canal. This report stated that the upper reaches are considered to be a connector system and lower reaches a delivery system.

Ditchriders patrol the canal to maintain the required flows at each irrigation turnout. As reported in the referenced report, the time for water entering the canal to traverse to the end of the canal is approximately 1 ½ days with a mean velocity in the canal of 2.5 ft/sec. Mismatches in the inlet and the delivery flows can be anticipated because delivery orders are taken 1 day in advance of need.

Under the proposed modified operations, the design of the canal with the pumping system is exactly opposite to that of the existing gravity system. A canal that is supplied with pumps is commonly called a collector system and is a supply oriented system. A supply oriented system is operated differently than a demand oriented system and this difference must be recognized in planning and design of modification to the canal system such as requiring the installation of more check structures in the upper reaches to insure that water can be diverted into the existing turnouts.

Learning how to operate the new system will require retraining of both the water master and the ditch riders. The response time of the system can be reduced; however, more emphasis will be placed on leakage and wasting. With this system, the amount of water that is lost will be decreased.

Overall System:

The new headworks at Intake would continue to allow gravity diversion from the Yellowstone River when flows are high enough to supply the head necessary for the system; however, the system would utilize the multiple Ranney Well pump systems at times of lower river flows to supplement the system.

The total power load for the pumping stations would be approximately 17 megawatts (MW). Power could be supplied from existing power supplies and potentially could be supplemented by project-specific sources such as a wind farm or solar generation, but these options were not investigated due to time constraints.

Implementation of the proposed pumping plant would include the following elements:

1) Removal/disposal of the existing diversion dam and restoration of dam site;
2) Construct new pumping plants with site work for roads, parking, and infrastructure; and
3) Construct new high power transmission line to route power to the pumping stations and auxiliary/backup power generation capability in the event of power outages.

Benefits of this design include:

- Existing dam could be removed
- No fishway would be needed

Critical Items to Consider:

- Protection from Ice (offline from river – non issue)
- Protection from floating debris (offline from river – non issue)
- Installation in a Dynamic River Setting (nonissue because wells located in a stable bank some distance away from the river
- Required Maintenance (pumps and other system parts)
    - Required maintenance would include the routine maintenance of the pumps and motors.
    - Changes to O&M of system.
- Labor Requirements – routine maintenance of the system
- Automation and Remote Sensing – supplementing canal flows with the pump system will require a great deal of additional automation to meet the appropriate irrigation demands
- Life Expectancy of System – long life expectancy under normal operating and maintenance procedures. Located in a more controlled environment.
- Pump Design considerations
- Land Disturbance
- Site Access-- Identify landowners and rights-of way required for the new system.
- Structural stability of system
- Power Reliability Issues in project area needs to be addressed
- Determine modifications required to existing power distribution system.
    - Upgrade of Power Grid or Local Backup
    - Cost to construct necessary power infrastructure within project area needs to be investigated
- Power cost to operate multiple pump stations needs to be addressed
- Power Requirements – pipe size may need to be increased to 66” diameter to reduce head loss in pipe lines. Also, it may be necessary to either increase the number of collector sites above seven or provide booster stations
- Determine irrigation demands between and for the pumping stations.
    - Schematics showing areas to be served
    - Pipelines and booster stations, if needed
- Power cost to operate multiple pump stations needs to be addressed

Ways to Implement:

- Standard construction methods.
- Use parts of previous Conceptual Study
  - Seven locations along the Project have been identified (See Figure 1)
  - Estimated diversion requirements of 200 CFS per pump site.
  - New pipelines could deliver water to main canal 1 - 4 miles, or laterals.
  - Irrigators would be able to access water from the pipeline, reducing demands in main canal.
  - Total distance from pumping plants to main canal is 36,850 feet (7 miles).
  - Estimate cost for installed pipe is $100/ft or 3.7 million dollars.
    - Other pipeline alternatives should be investigated
  - Offers unrestricted fish passage across full river channel
  - Does not need control or diversion structures to maintain access to river channel
  - Protective structures in the river to prevent ice damage to facilities would not be needed.
  - Accessing water should not be an issue as the pumps would use infiltration methods
  - Water is filtered allowing easy conversion to center pivots with cost-share from NRCS.
  - Irrigators pulling directly from the pipelines may allow the district to eliminate some of the open laterals within the project.
  - Multiple pumping stations would provide redundancy to allow the district to meet water demands.

Potential Risk

- Risk of substantially increasing O&M costs and power costs on the district.

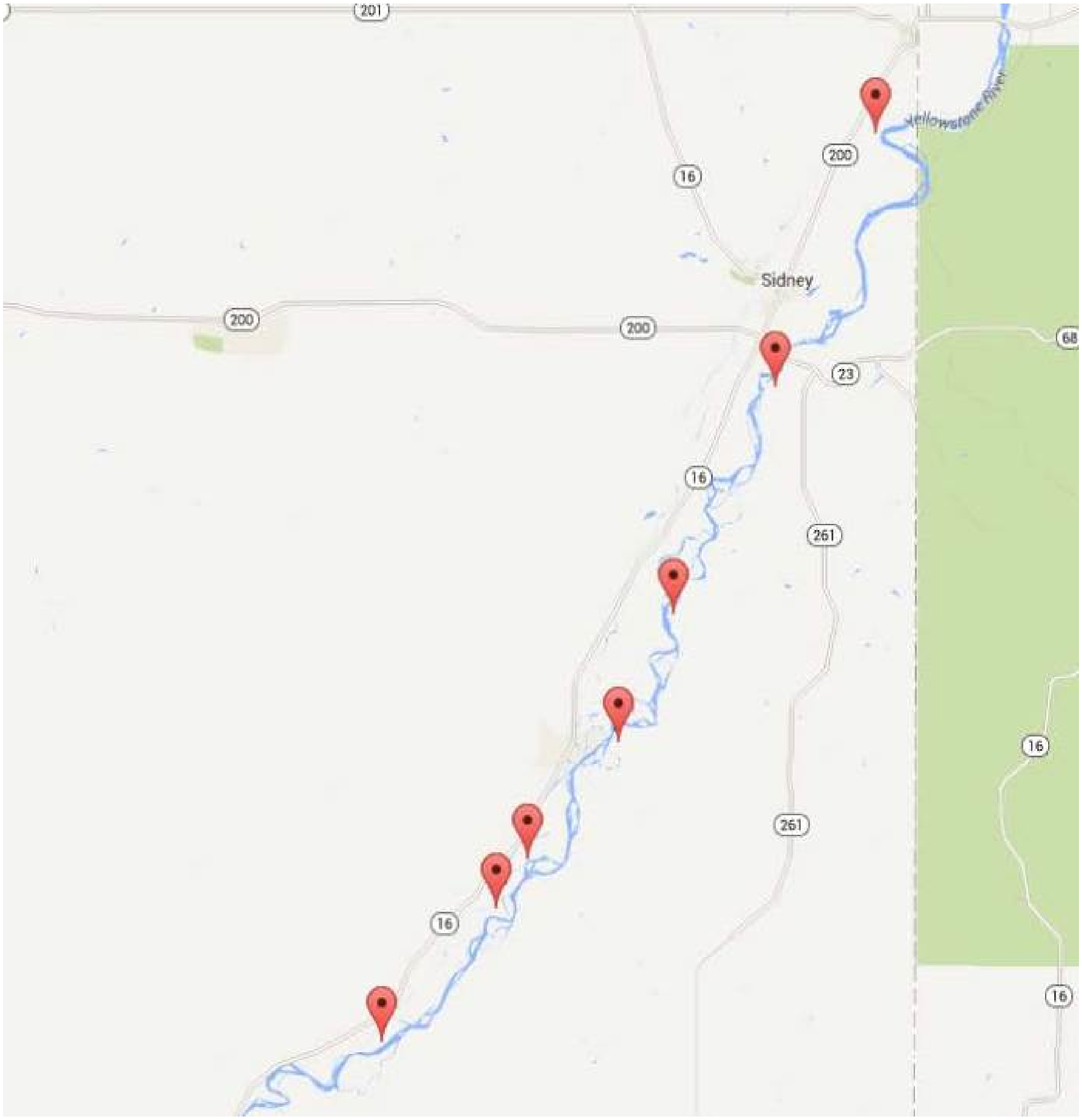

Figure 4: Potential Pumping Locations

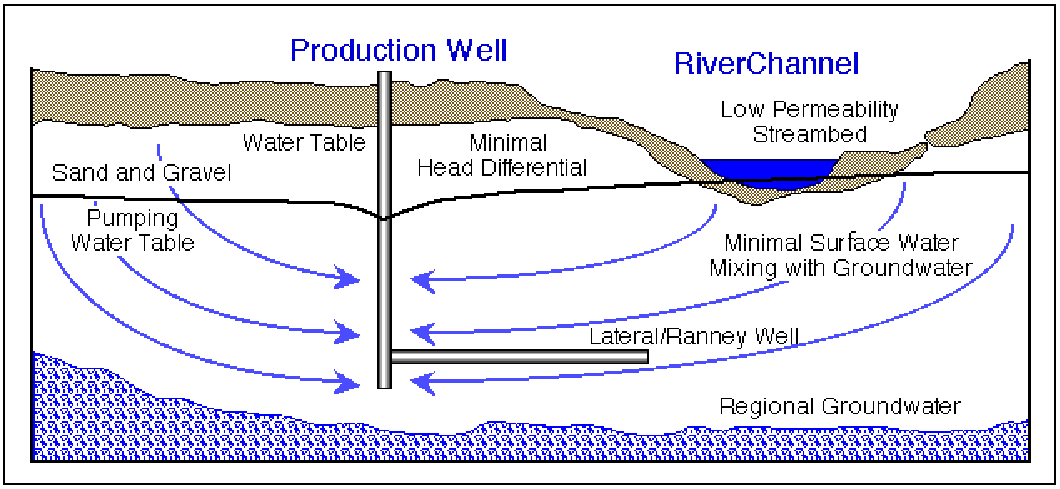

Figure 5: Theme A Pumping

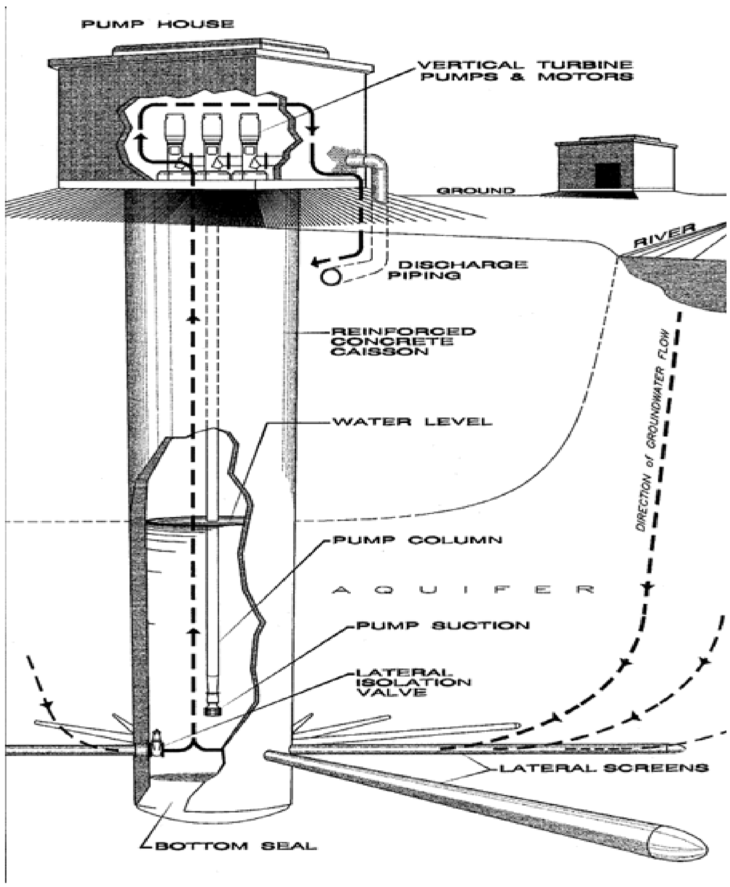

Figure 6: Ranney Well Concept

Alternative Theme B. Original Rock Ramp

Alternative Description:

This alternative would replace the existing rock and timber structure with a new concrete diversion weir along with a shallow-sloped, ungrouted boulder and cobble rock ramp. The ramp would be designed to mimic a natural river riffle that would reduce the river elevation from the top of the weir crest to the toe of the rock ramp over a 2,000 feet length, creating the necessary 0.5 percent slope favorable for pallid sturgeon passage. The ramp crest elevation would be set at 1990.5 to provide 1,374 cfs to the LYIP at flows above 3,000 cfs.

Weir

A replacement concrete weir would be located downstream of the new headworks to elevation 1,990.5 ft which would create sufficient water height to divert 1,374 cfs into the main canal. The new concrete weir would replace the existing timber and rock-filled dam providing for long-term durability, which is currently lacking in the existing structure. The weir would be constructed as a cast-in-place reinforced concrete wedge spanning the entire width of the Yellowstone River Channel. The upstream face of the weir would be designed to withstand damage from blocks of ice moving up and over the weir in the spring of the year.

The weir crest would vary in elevation, including at least one, low flow channel for fish passage during the low flow times of year. The variable crest would offer an array of depth/velocities across the weir to provide different passage options. Channels in the weir crest would be designed to provide fish passage during late summer and early fall low flows and would be approximately 1-2 feet in depth. The downstream side of the weir would tie directly into the rock ramp to provide a seamless transition and unimpeded fish passage as fish migrate upstream.

As an option and for a potential cost savings over the weir described above, the diversion weir could consist of a cantilevered structural wall consisting of “drilled” shafts with a concrete cap. Because of water levels, the shafts would be cased (pipe piles cleaned out and filled with reinforced concrete). The shafts would be spaced such that there would be gaps between them below the cap, but the backfill would be completely around the shafts (and for purposes of retaining wall design, bridge between the shafts). The top of the structure would be a concrete “cap” to protect the top of the structure and provide a smooth surface for ice to pass over. The crest of the new weir would be irregular in elevation to provide a variety of flow volume and velocity.

Rock Ramp

A rock ramp would be constructed downstream of the replacement weir by placing rock and fill material in the river channel to shape the ramp without grout, and then it would be covered with rock riprap. The ramp would be at a .5 percent slope that would provide flow characteristics that meet the swimming abilities of Pallid Sturgeon.

Because Pallid Sturgeon are sensitive to flow velocities and turbulence, the rock ramp would be constructed to be relatively flat over much of its width to keep flow velocities as low as possible with the idea of full river passage.

The new rock ramp would be constructed over the site of the existing Intake Diversion Dam, preserving most of the historic dam in place. The ramp would include at least one low flow channel in conjunction with the low flow channel on the crest of the weir. This would allow fish migration during low flow times of the year. The rocks in the ramp would be sized to withstand high flows and ice jams and range from 1 – 4 ft in diameter. The largest rocks would be placed near the crest to resist ice forces. Approximately 390,000 tons of rock riprap for the ramp, 40,000 tons of spalls/gravel, and another 60,000 tons of riprap for the toe of the ramp (for energy dissipation) would be needed for construction of the ramp.

Flood Plain Control

To help with depths and velocities over the crest of the weir this alternative would incorporate a flood plain control structure. This flood plain control feature was envisioned to be a partial removal of the south (right) bank adjacent to Joe's Island. This bank removal is proposed in a stair-stepped configuration so that the river can experience more "out-of-bank" area as the river flow increases. The number of steps and area exposed at each step needs to be designed; however, the concept is to allow the river flow to spread out at each step in an attempt to reduce the effective depth above the rock weir for a given flow.

This structure would continue to concentrate flows over the rock ramp during low flows but at the same time help disperse high flows over the natural flood plain/riparian area. The idea being that as flows increase within the Yellowstone River velocities over the crest of the weir would increase as well. When the higher flows are spread out into the flood plain the amount of water being forced over the weir would be reduced which would help keep velocities down. Also by spreading flows into the riparian/flood plain area, this could act as another potential passage route for both Pallid Sturgeon and native fish species.

The large eddy that currently forms on the south side of the existing dam is being eliminated by the design of the rock ramp where the feature causing the eddy is filled in with rock.

Benefits of this design include:

- Has potential to provide full river fish passage at various river flows. However, based on Corps numerical modeling and Reclamation’s physical modeling, depths and velocities meeting the criteria for pallid passage would only be met on a small percentage of the river width at any given flow.
- Variety of flows throughout the rock ramp so fish could pick and choose velocities and depths they most prefer.
- Notches in both weir and rock ramp would provide continuous passage in low flow situations.
- Flood Plain stabilization during both high and low flow situations. The large eddy that currently forms on the south side of the existing dam is being eliminated by the design of the rock ramp where the feature causing the eddy is filled in with rock.

- Attraction flows are not needed.
- Irrigation District would receive their full water right down to 3,000 cfs.

Critical Items to Consider:

- The project would need to be designed to minimize impacts due to ice scour and large floating debris (cottonwood trees).
- Project construction timing would need to be determined to avoid high flow periods and fish spawning migrations (April-July).
- Grouting of rock may be necessary to ensure the capacity to withstand ice flows and reduce maintenance. This component of the project may entail coffer-dams and dewatering.
- Replacement of rock. Required future repairs to the ramp may require construction in the dry for it to continue to meet BRT criteria.
- Adaptive Management Costs/constructability.
- Must be constructed to BRT criteria.
- Optional Weir -- drilling shafts for piers could be difficult into or near the old wooden structure.
- Numerical and physical modeling of the original rock ramp indicated marginal areas meeting the BRT's depth and velocity criteria. During high flows, some areas were not continuous upstream to downstream.
- Impacts to boat ramp, fishing access site and campground
- Increased depths/frequency of flooding of campground and private land on left bank

Ways to Implement:

The preferred construction method for the weir has not been determined. There are several possible construction methods, and while each of them is feasible, they each have specific challenges that would need to be addressed during design. The construction required for installing the cast-in-place reinforced concrete wedged weir will use standard methods and sheet pile to divert river flow over one half of river while each half of the cast-in-place weir is being installed. Construction of the rock ramp will require construction in the dry.

The Corps has numerous concerns about implementation and ability to construct both the weir and rock ramp features to meet BRT fish passage criteria. Construction of the rock ramp is significantly more challenging than construction of the weir.

Optional weir configuration would provide the added benefit of allowing the weir to be installed, if the pool could not be lowered significantly during construction, using a work trestle and a concrete cap constructed underwater using a submerged form and tremie concrete methods.

Potential Risks

- The risk of rock loss or shift due to ice scour and or large woody debris impacts would be the most prevalent concern with this design.

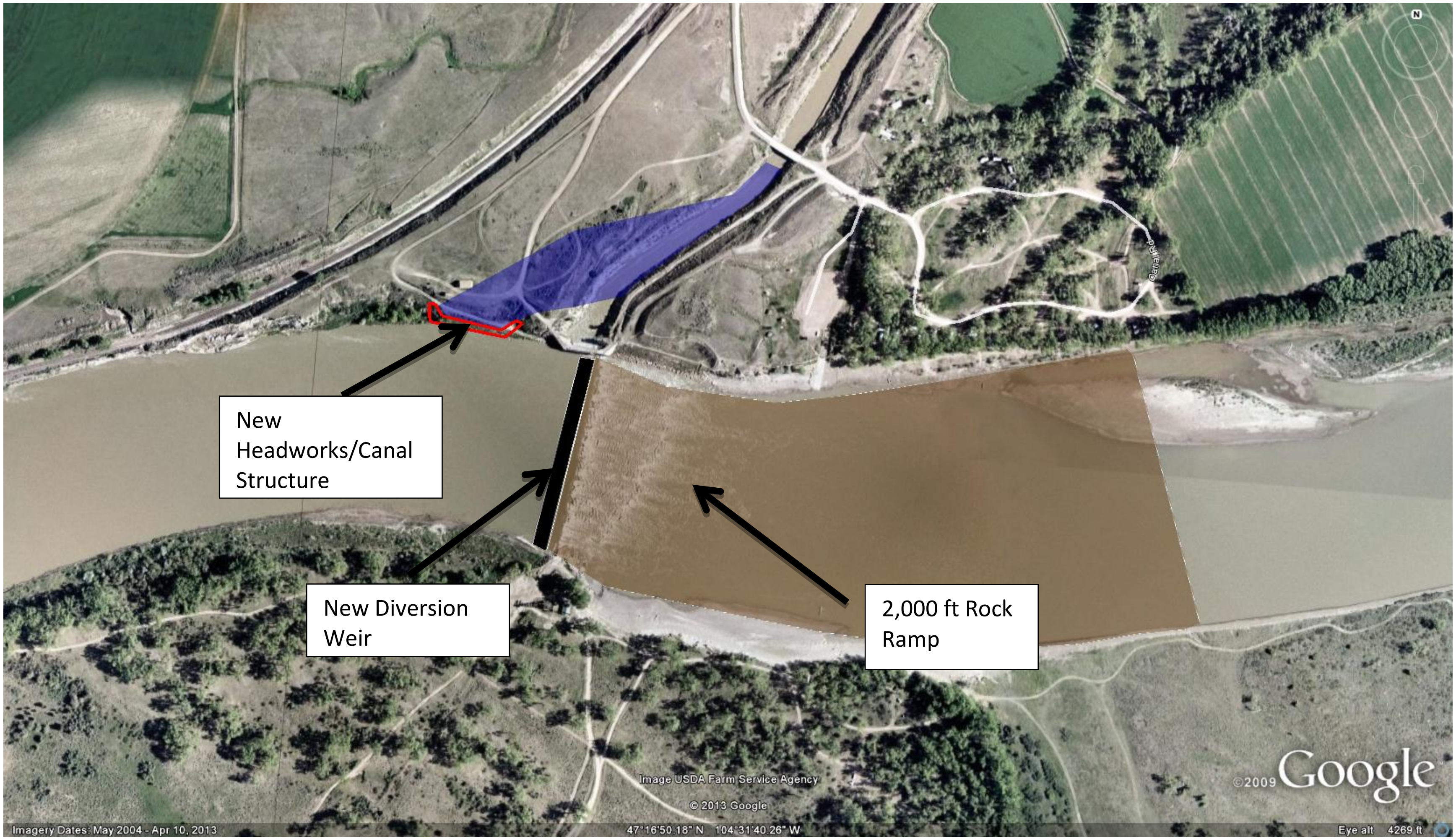

Figure 7: Theme B 2,000 ft Rock Ramp

Alternative Theme C: Rock Ramp with Reduced Weir Elevation

<u>Alternative Description:</u>

This alternative would replace the existing rock and timber structure with a new concrete diversion weir along with a shallow-sloped, ungrouted boulder and cobble rock ramp. The ramp would be designed to mimic a natural river riffle that would reduce the river elevation from the top of the weir crest to the toe of the rock ramp over a 1,500 ft length, creating the necessary 0.5 percent slope favorable for pallid sturgeon passage. The ramp crest elevation would be set at the reduced height of 1989 ft to provide 1,150 cfs to the LYIP at a flow of 3,000 cfs (Figure XX). The remaining water right would be supplemented through pumping and project efficiencies such as center pivots, and canal/lateral linings. The system was designed to run at full capacity so checking structures would need to be incorporated into this alternative to maintain sufficient water height within the main canal.

<u>Weir</u>

A replacement concrete weir would be located downstream of the new headworks to elevation 1989 ft which is approximately 1.5 ft lower than what is needed to divert the full water right at 3,000 cfs. At flows of 6,100 cfs and above the LYIP could divert their entire water right and supplemental pumping would not be needed.

The new concrete weir would replace the existing timber and rock-filled dam providing for long-term durability, which is currently lacking in the existing structure. The weir would be constructed as a cast-in-place reinforced concrete wedge spanning the entire width of the Yellowstone River Channel. The upstream face of the weir would be designed to withstand damage from blocks of ice moving up and over the weir in the spring of the year.

The weir crest would vary in elevation, including at least one, low flow channel for fish passage during the low flow times of year. The variable crest would offer an array of depth/velocities across the weir to provide different passage options. Channels in the weir crest would be designed to provide fish passage during late summer and early fall low flows and would be approximately 1-2 feet in depth. The downstream side of the weir would tie directly into the rock ramp to provide a seamless transition and unimpeded fish passage as fish migrate upstream.

As an option and for a potential cost savings over the weir described above, the diversion weir could consist of a cantilevered structural wall consisting of "drilled" shafts with a concrete cap. Because of water levels, the shafts would be cased (pipe piles cleaned out and filled with reinforced concrete). The shafts would be spaced such that there would be gaps between them below the cap, but the backfill would be completely around the shafts (and for purposes of retaining wall design, bridge between the shafts). The top of the structure would be a concrete "cap" to protect the top of the structure and provide a smooth surface for ice to pass over. The crest of the new weir would be irregular in elevation to provide a variety of flow volume and velocity.

Rock Ramp

A rock ramp would be constructed downstream of the replacement weir by placing rock and fill material in the river channel to shape the ramp without grout, and then it would be covered with rock riprap. The ramp would be at a .5 percent slope that would provide flow characteristics that meet the swimming abilities of Pallid Sturgeon.

Because Pallid Sturgeon are sensitive to flow velocities and turbulence, the rock ramp would be constructed to be relatively flat over much of its width to keep flow velocities as low as possible with the idea of full river passage.

The new rock ramp would be constructed over the site of the existing Intake Diversion Dam, preserving most of the historic dam in place. The ramp would include at least one low flow channel in conjunction with the low flow channel on the crest of the weir. This would allow fish migration during low flow times of the year. The rocks in the ramp would be sized to withstand high flows and ice jams and range from 1 – 4 ft in diameter. The largest rocks would be placed near the crest to resist ice forces. Riprap and gravel quantities would be reduced because of the shortened length.

Flood Plain Control

To help with depths and velocities over the crest of the weir this alternative would incorporate a flood plain control structure. This flood plain control feature was envisioned to be a partial removal of the south (right) bank adjacent to Joe's Island. This bank removal is proposed in a stair-stepped configuration so that the river can experience more "out-of-bank" area as the river flow increases. The number of steps and area exposed at each step needs to be designed; however, the concept is to allow the river flow to spread out at each step in an attempt to reduce the effective depth above the rock weir for a given flow.

This structure would continue to concentrate flows over the rock ramp during low flows but at the same time help disperse high flows over the natural flood plain/riparian area. The idea being that as flows increase within the Yellowstone River velocities over the crest of the weir would increase as well. When the higher flows are spread out into the flood plain the amount of water being forced over the weir would be reduced which would help keep velocities down. Also by spreading flows into the riparian/flood plain area, this could act as another potential passage route for both pallid sturgeon and other native fish species.

Efficiencies/Weir Height Reduction

This proposal looks at the opportunity to reduce the height of the rock ramp proposed in Alternative Theme B by reducing the peak demand required by the LYIP. The rock ramp in Alternative Theme B is designed to convey the full water right of 1,374 cfs at a minimum river flow of 3,000 cfs. This alternative will combine several levels of improved water management and supply augmentation, with the corresponding reduction of Rock Ramp height to attempt to identify the most advantageous combination of this hybrid proposal.

Ramp Elevation	Demand reduction	Ramp Cost	Construction /Augmentation Cost
1989	324 cfs	57.8 Million	15 – 20 Million
1987	699 cfs	51.1 Million	30 – 40 Million
1985	999 cfs	46.1 Million	> 50 Million

Benefits of this design include:

- Reduced weir elevation would cut down on the cost of this alternative and shorten the length of the rock ramp.
- District efficiencies would leave more water in the river to increase available in stream flow. This would have the greatest impact during low flow conditions.
- Has potential to provide full river fish passage at various river flows. However, based on Corps numerical modeling and Reclamation's physical modeling, depths and velocities meeting the criteria for pallid passage would only be met on a small percentage of the river width for a given flow.
- Variety of flows throughout the rock ramp so fish could pick and choose velocities and depths they most prefer.
- Notches in both weir and rock ramp would provide continuous passage in low flow situations.
- Flood Plain stabilization during both high and low flow situations.
- Attraction flows are not needed.

Critical Items to Consider:

- Implementation timeline for project efficiencies and supplemental pumping. Efficiencies and supplemental pumping need to be in place before the new weir is constructed to alleviate concerns of a water shortage until these measure are put in place.
- Optional Weir -- drilling shafts for piers could be difficult into or near the old wooden structure.
- The project would need to be designed to minimize impacts due to ice scour and large floating debris (cottonwood trees).
- Project construction timing would need to be determined to avoid high flow periods and fish spawning migrations (April-July).
- Grouting of rock may be necessary to ensure the capacity to withstand ice flows and reduce maintenance. This component of the project may entail coffer-dams and dewatering.
- Replacement of rock. Required future repairs to the ramp may require construction in the dry for it to continue to meet BRT criteria.
- Adaptive Management Costs/constructability.
- Must be constructed to BRT criteria.
- Numerical and physical modeling of the original rock ramp indicated marginal areas meeting the BRT's depth and velocity criteria. During high flows, some areas were not continuous upstream to downstream.
- Impacts to boat ramp, fishing access site and campground.

- Increased depths/frequency of flooding of campground and private land on left bank
- Design flood plain control to accommodate high flow condition and alleviate concerns of back eddies.

Ways to Implement:

The preferred construction method for the weir has not been determined. There are several possible construction methods, and while each of them is feasible, they each have specific challenges that would need to be addressed during design. The construction required for installing the cast-in-place reinforced concrete wedged weir will use standard methods and sheet pile to divert river flow over one half of river while each half of the cast-in-place weir is being installed. Construction of the rock ramp will require construction in the dry.

The Corps has numerous concerns about implementation and ability to construction both the weir and rock ramp features to meet BRT fish passage criteria. Construction of the rock ramp is significantly more challenging than construction of the weir.

Optional weir configuration would provide the added benefit of allowing the weir to be installed, if the pool could not be lowered significantly during construction, using a work trestle and a concrete cap constructed underwater using a submerged form and tremie concrete methods.

Potential Risks

- The risk of rock loss or shift due to ice scour and or large woody debris impacts would be the most prevalent concern with this design.

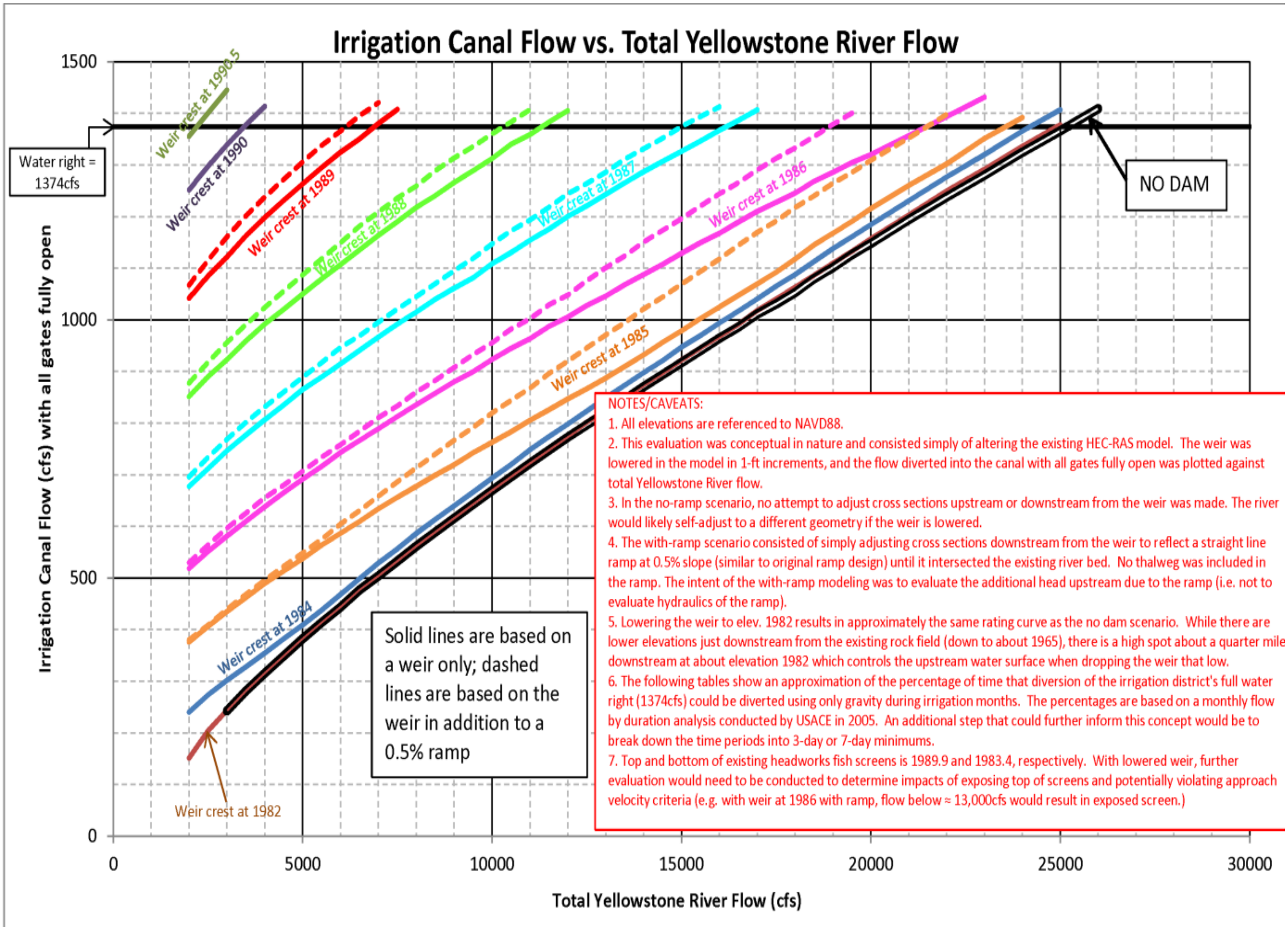

Figure 8: Diversion Height vs. Canal Flow

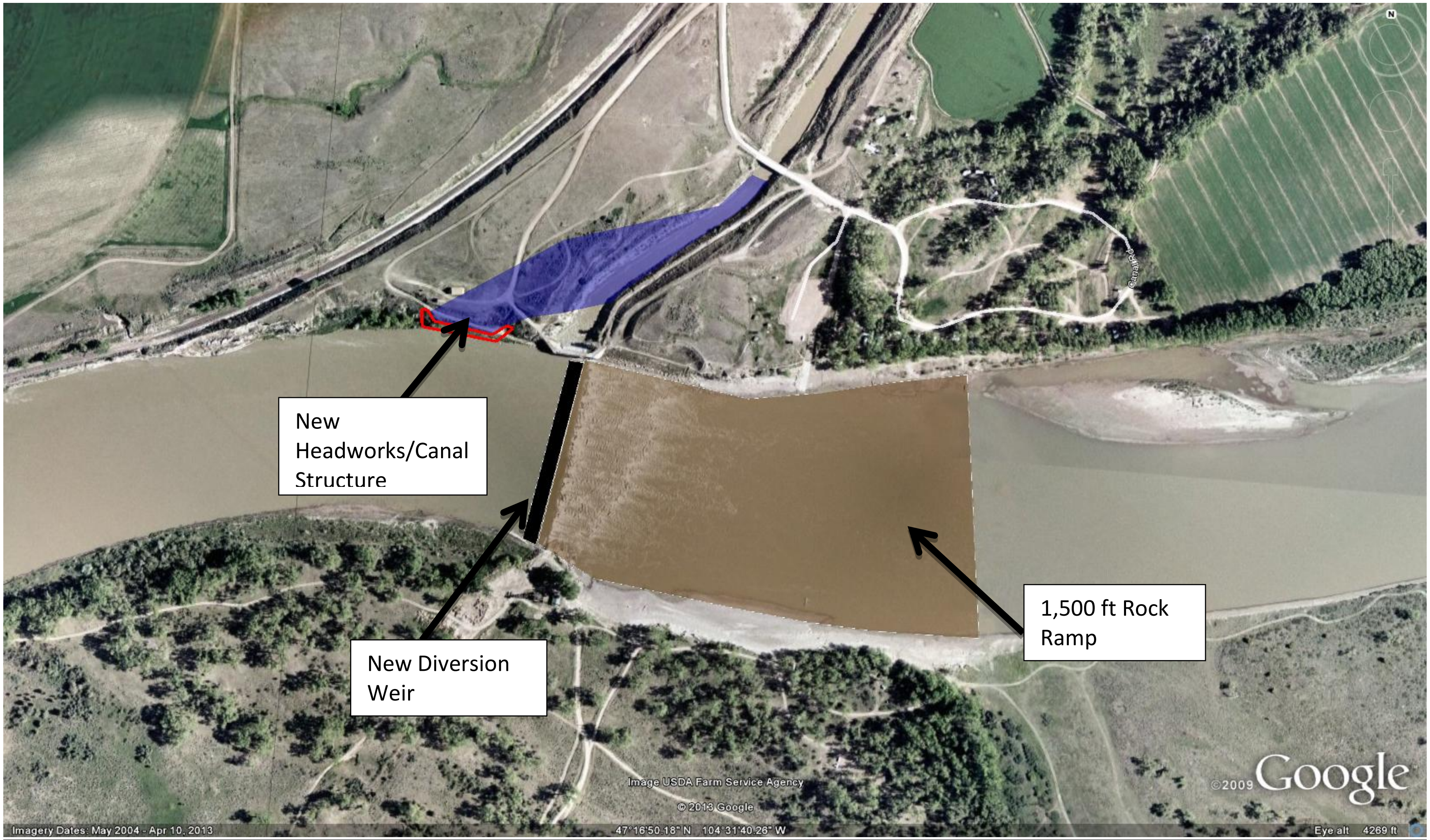

Figure 9: Theme C Reduced Weir Elevation (1989') With 1,500 ft Rock Ramp

Alternative Theme D: Combination Rock Ramp and Weir

Alternative Description:

This alternative would replace the existing rock and timber structure with a new concrete diversion weir across the entire river along with a shallow-sloped, ungrouted boulder and cobble rock ramp across approximately half of the river width. The ramp would be designed to mimic a natural river riffle that would reduce the river elevation from the top of the weir crest to the toe of the rock ramp over a 2,000 foot length, creating the necessary 0.5 percent slope favorable for Pallid Sturgeon passage. The ramp crest elevation would be set at a height of 1990.5 ft to provide 1374 cfs to the LYIP at a flow of 3,000 cfs and higher.

Weir

A replacement concrete weir would be located downstream of the new headworks to elevation 1990.5 ft which is needed to divert the full water right at 3,000 cfs. The new concrete weir would replace the existing timber and rock-filled dam providing for long-term durability, which is currently lacking in the existing structure. The weir would be constructed as a cast-in-place reinforced concrete wedge spanning the entire width of the Yellowstone River Channel. The upstream face of the weir would be designed to withstand damage from blocks of ice moving up and over the weir in the spring of the year.

The weir crest would vary in elevation, including at least one, low flow channel for fish passage during the low flow times of year. The variable crest would offer an array of depth/velocities across the weir to provide different passage options. Channels in the weir crest would be designed to provide fish passage during late summer and early fall low flows and would be approximately 1-2 feet in depth. The downstream side of the weir would tie directly into the rock ramp to provide a seamless transition and unimpeded fish passage as fish migrate upstream.

As an option and for a potential cost savings over the weir described above, the diversion weir could consist of a cantilevered structural wall consisting of "drilled" shafts with a concrete cap. Because of water levels, the shafts would be cased (pipe piles cleaned out and filled with reinforced concrete). The shafts would be spaced such that there would be gaps between them below the cap, but the backfill would be completely around the shafts (and for purposes of retaining wall design, bridge between the shafts). The top of the structure would be a concrete "cap" to protect the top of the structure and provide a smooth surface for ice to pass over. The crest of the new weir would be irregular in elevation to provide a variety of flow volume and velocity.

Rock Ramp

A rock ramp would be constructed downstream of the replacement weir on approximately half of the river. The ramp would be built by placing rock and fill material in the river channel to shape the ramp without grout, and then it would be covered with rock riprap. The ramp would be at a .5 percent slope that would provide flow characteristics that meet the swimming abilities of Pallid Sturgeon.

Because Pallid Sturgeon are sensitive to flow velocities and turbulence, the rock ramp would be constructed to be relatively flat over much of its width to keep flow velocities as low as possible with the idea of full river passage.

The new rock ramp would be constructed over the site of the existing Intake Diversion Dam, preserving most of the historic dam in place. The ramp would include at least one low flow channel in conjunction with the low flow channel on the crest of the weir. This would allow fish migration during low flow times of the year. The rocks in the ramp would be sized to withstand high flows and ice jams and range from 1 – 4 ft in diameter. The largest rocks would be placed near the crest to resist ice forces. Riprap and gravel quantities would be reduced by half compared to the original rock ramp.

<u>Flood Plain Control</u>

To help with depths and velocities over the crest of the weir this alternative would incorporate a flood plain control structure. This flood plain control feature was envisioned to be a partial removal of the south (right) bank adjacent to Joe's Island. This bank removal is proposed in a stair-stepped configuration so that the river can experience more "out-of-bank" area as the river flow increases. The number of steps and area exposed at each step needs to be designed; however, the concept is to allow the river flow to spread out at each step in an attempt to reduce the effective depth above the rock weir for a given flow.

This structure would continue to concentrate flows over the rock ramp during low flows but at the same time help disperse high flows over the natural flood plain/riparian area. The idea being that as flows increase within the Yellowstone River velocities over the crest of the weir would increase as well. When the higher flows are spread out into the flood plain the amount of water being forced over the weir would be reduced which would help keep velocities down. Also by spreading flows into the riparian/flood plain area, this could act as another potential passage route for both Pallid Sturgeon and native fish species.

<u>Benefits of this design include:</u>

- Reduced ramp width would cut down on the cost of this alternative
- Has potential to provide fish passage on half of the river at various river flows. However, based on Corps numerical modeling and Reclamation’s physical modeling, depths and velocities meeting the criteria for pallid passage would only be met on a small percentage of the river width for a given flow.
- Variety of flows throughout the rock ramp so fish could pick and choose velocities and depths they most prefer.
- Notches in both weir and rock ramp would provide continuous passage in low flow situations.
- Flood Plain stabilization during both high and low flow situations.

Critical Items to Consider:

- Divider wall to keep flows on the rock ramp.
- The project would need to be designed to minimize impacts due to ice scour and large floating debris (cottonwood trees).
- Project construction timing would need to be determined to avoid high flow periods and fish spawning migrations (April-July).
- Grouting of rock may be necessary to ensure the capacity to withstand ice flows and reduce maintenance. This component of the project may entail coffer-dams and dewatering.
- Replacement of rock. Required future repairs to the ramp may require construction in the dry for it to continue to meet BRT criteria.
- Adaptive Management Costs/constructability.
- Must be constructed to BRT criteria.
- Numerical and physical modeling of the original rock ramp indicated marginal areas meeting the BRT's depth and velocity criteria. During high flows, some areas were not continuous upstream to downstream.
- Impacts to boat ramp, fishing access site and campground.
- Increased depths/frequency of flooding of campground and private land on left bank.
- Design flood plain control to accommodate high flow condition and alleviate concerns of back eddies.
- Implementation timeline for project efficiencies and supplemental pumping. Efficiencies and supplemental pumping need to be in place before the new weir is constructed to alleviate concerns of a water shortage until these measure are put in place.
- Design flood plain control to accommodate high flow condition and alleviate concerns of the back eddies.
- Optional Weir -- drilling shafts for piers could be difficult into or near the old wooden structure.

Ways to Implement:

The preferred construction method for the weir has not been determined. There are several possible construction methods, and while each of them is feasible, they each have specific challenges that would need to be addressed during design. The construction required for installing the cast-in-place reinforced concrete wedged weir will use standard methods and sheet pile to divert river flow over one half of river while each half of the cast-in-place weir is being installed. Construction of the rock ramp will require construction in the dry.

The Corps has numerous concerns about implementation and ability to construction both the weir and rock ramp features to meet BRT fish passage criteria. Construction of the rock ramp is significantly more challenging than construction of the weir.

Optional weir configuration would provide the added benefit of allowing the weir to be installed, if the pool could not be lowered significantly during construction, using a work trestle and a concrete cap constructed underwater using a submerged form and tremie concrete methods.

Potential Risks

- The ability to keep enough water on the rock ramp and keep depths/velocities passable for Pallid Sturgeon.
- Constructability of the divider wall.
- The risk of rock loss or shift due to ice scour and or large woody debris impacts remain a concern with this design.

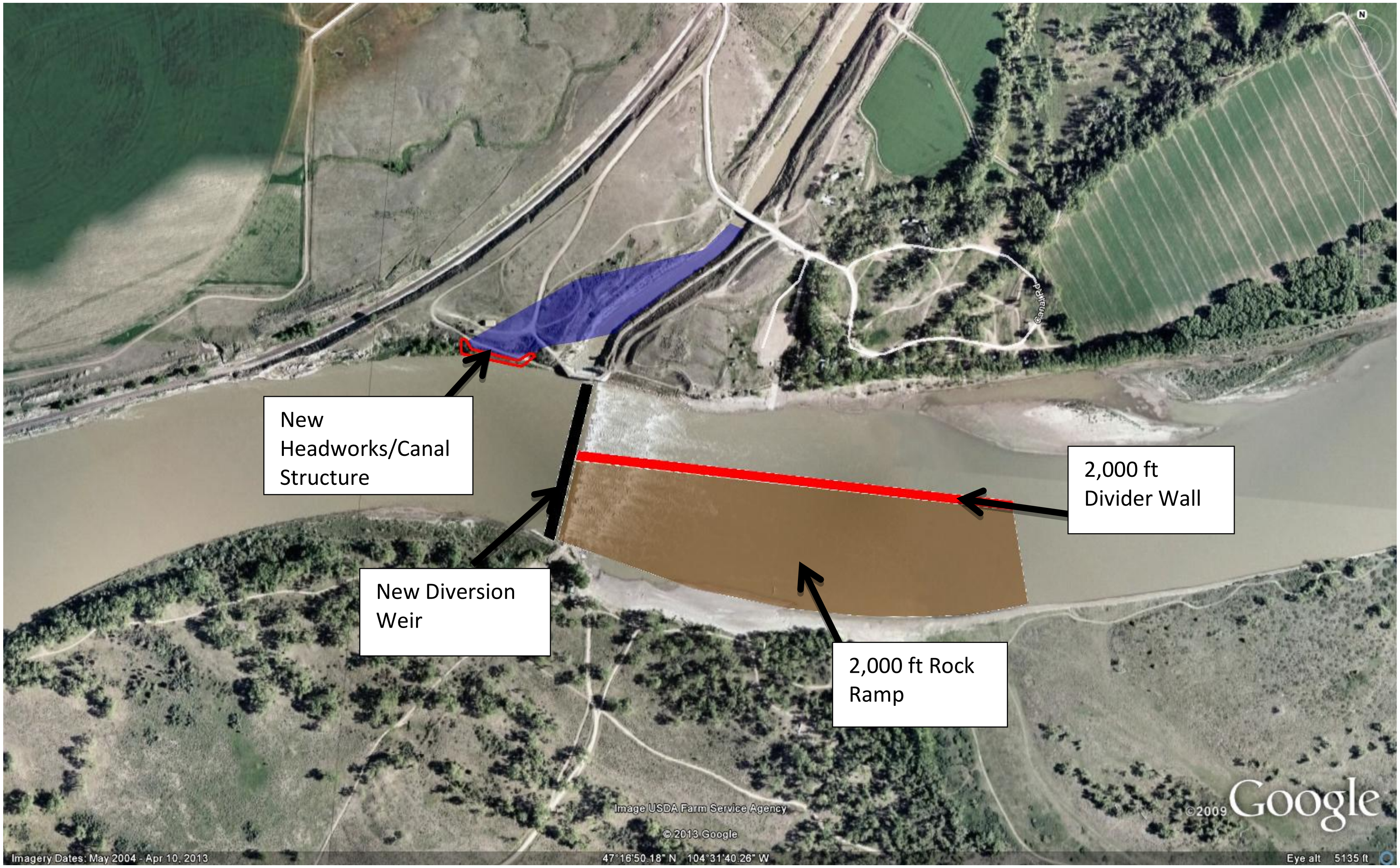

Figure 10: Theme D Combination Weir and 2,000 ft Rock Ramp

Alternative Theme E. Realigned By-pass Channel with Modified Weir

<u>Alternative Description</u>

The Corps of Engineers has designed a bypass channel around the existing diversion structure that is currently at the 30 percent design stage. This alternative modifies the Corps' current design by:

- Relocating the bypass channel to maintain the integrity of the existing high flow channel.
- Reducing the upstream to downstream width of the weir crest from 25' to approximately 6'.
- Providing variable flow velocities on the weir crest and downstream slope through slight undulations in crest height.

A primary feature of this alternative would be the construction of a bypass channel to divert approximately 15 percent of total river flow into the bypass under all flow scenarios above 3,000 cfs. The original By-pass channel was designed to typically divert 15 percent of the total flow during typical spring and summer discharges and diversion percentages varied from 10 percent at extreme low flows to 17 percent at extreme high flows. Under this Alternative with existing high flow channel still active, either the bypass channel would not take the same percentage of flow at high flows (during migration) or the weir would need to be raised to account for flow into existing high flow chute.

The proposed bypass channel alignment would be modified from the existing alignment to isolate it completely from the existing high flow channel along the south side of Joe's Island. This would be accomplished primarily by relocating the river entrance to the bypass downstream to avoid the mouth of the high flow channel. The current alignment is approximately 15,500' long with a slope of approximately 0.0006 ft/ft (natural Yellowstone River slope is approximately 0.0004ft/ft to 0.0007 ft/ft). It is expected the re-aligned bypass channel would comply with the BRT's recommendations regarding flow velocity and depth and would likely approximate the "original" dimensions. The bypass channel cross-section would be 40' wide at the bottom with side slopes varying from 1V:12H to 1V:3H. The original By-pass Channel design required excavating approximately 1.2 million cubic yards of material from Joe's Island; however, this would increase considerably if the upstream end of the existing chute was not used.

A structure designed to control flow into the bypass would be constructed at the river entrance to the bypass channel. The structure would likely be composed of riprap with a concrete sill and would be backfilled with natural river rock to give the appearance of a seamless channel invert.

Two vertical control structures (riprap sills) would be constructed to maintain channel slope and provide for early identification of channel migration. These structures would be constructed by over-excavating and backfilling the excavation with river rock to appear as a seamless channel invert while providing stability. A riprap sill would also be constructed at the fish entrance to the bypass to maintain channel elevations. Additionally, riprap would be installed on at least two outside bends with higher potential for failure. Additional protection may be required in the future if, through adaptive management, assumptions about channel stability are proven incorrect and channel migration or degradation begins to impact passage efficacy.

A new concrete weir would be constructed approximately 40’ upstream of the existing rock structure to provide sufficient water surface elevations to divert the appropriate flows through the bypass channel and headworks. The existing rock structure would be integrated into the new concrete structure by placing fill between the new and old structures. The new diversion weir would consist of a cantilevered structural wall consisting of “drilled” shafts with a concrete cap. Because of water levels, the shafts would be cased (pipe piles cleaned out and filled with reinforced concrete). The shafts would be spaced such that there would be gaps between them below the cap, but the backfill would be completely around the shafts (and for purposes of retaining wall design, bridge between the shafts).

The area between the new weir and existing structure and the area immediately upstream of the new concrete weir would be filled with sands and gravels excavated from the bypass channel and capped with riprap to provide a seamless transition between the old and new structures. The top of the structure would be a concrete “cap” to protect the top of the structure and provide a smooth surface for ice to pass over. The crest of the new weir would be irregular in elevation to provide a variety of flow volume and velocity.

Once Pallid Sturgeon migrate upstream past the weir using the bypass channel, they must also be able to migrate back downstream. The weir design would include a notched section that would produce sufficient depth of flow for downstream passage. Additionally, the existing rock weir and downstream rock field would be modified to create a thalweg of sufficient depth to allow downstream fish passage.

An access road would be constructed along the north side of the river to allow access for heavy equipment during construction. Following completion, the road would be removed and the area would be restored to pre-construction conditions. Existing access roads to Joe’s Island would be improved as needed to allow access.

Features of this alternative would be located primarily on Joe’s Island. This land was acquired by Reclamation during construction of the original Intake Project and is still administered by Reclamation. All construction, staging and disposal would occur on Reclamation lands.

<u>Critical Items to Consider:</u>

- There must be access to the south weir abutment for maintenance of the weir and bypass structure. This may require a bridge across the bypass channel in two locations or building a single access road with one bridge.
- The river inlet to the bypass channel would need to be modified and extended upstream to collect water from the river thalweg and prevent sediment deposition at the inlet. Concrete piles would be needed to prevent ice damage.
- The fish entrance to bypass channel would need to be located close to the weir for fish attraction but not so close that the channel would have an adverse affect on weir integrity. The fish entrance would need to be stabilized where the bypass channel empties into the

Yellowstone River. Physical modeling may be necessary to address the eddy at the fish entrance.

- The existing high flow channel would continue to function naturally and may need to be modified to prevent it from being captured and becoming the bypass channel.
- The bypass channel may require more stability to insure it does not capture the Yellowstone River.
- The bypass channel would need to be constructed to mimic the slope of the Yellowstone River to accommodate sediment transport.
- The Corps has estimated the cost to construct the original bypass channel/weir alternative to be approximately 60 million dollars of which approximately 6 million dollars is allocated for monitoring and adaptive management. The preliminary cost estimate for O&M is approximately $140,000/year.

Ways to Implement:

The construction concept is generally as follows:

- Lower pool for construction (or use a construction trestle to avoid lowering water).
- Build fill for construction access (to just above pool elevation) if pool is lowered and no trestle utilized.
- Install 36-inch diameter x 0.5-inch wall steel casings at 6 feet on center.
- Drill out inside of driven casings.
- Place rebar cages and tremie concrete fill.
- Construct a 5-foot-wide x 5-high-high cast-in-place concrete cap (with cofferdam form if water level is high).

If the pool could not be lowered significantly during construction, a work trestle could be built and the concrete cap constructed underwater using a submerged form and tremie concrete methods. The cost of a 700-foot-long by 28-foot-wide trestle should be on the order of 1.5 million dollars. Construction of the cap would be done by utilizing a tub form supported by the steel casings. Underwater construction would be substantially more expensive than if the pool were lowered. This concept would result in conventional land-based construction methods and a much less expensive permanent structure.

Excavation of the channel can largely be accomplished in the dry using standard construction methods.

Potential Risks

- Bypass channel outflow may affect weir integrity.
- Bypass channel could capture the Yellowstone River and flank the weir.
- Flood events could leave sediment deposits in the bypass channel.
- Attraction flows may not be adequate.
- The eddy may discourage use of the bypass channel.
- There is uncertainty whether the bypass and/or the weir will function as designed, and the costs of O&M or adaptive management measures would ultimately be borne by LYIP.
- Likely higher dependency on backfill downstream of structure to support weir wall.
- Higher dependency on lower water levels during construction if no trestle utilized.
- More specialized foundation work.
- Separating the constructed channel from the high flow channel would reduce the percentage of flow that would be in the bypass channel. This could reduce the effect of attraction flows.

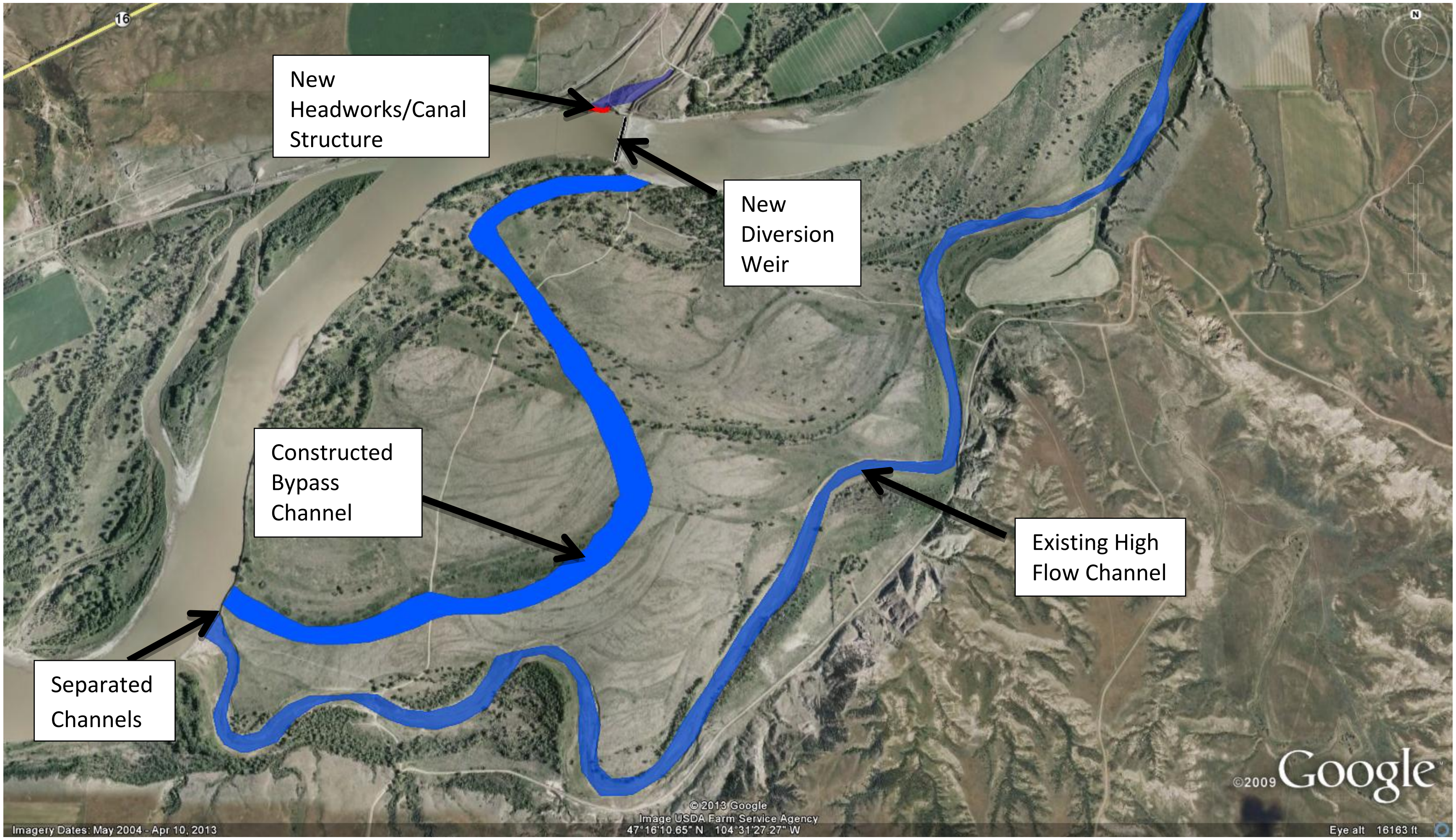

Figure 11: Theme E Realigned Bypass Channel with Modified Weir

Alternative Theme F. Island – Extended Canal

Alternative Description:

This alternative includes utilizing the existing island in the Yellowstone River upstream of the headworks to split river flows between a proposed canal and the Yellowstone River. The proposed constructed canal section would convey flows to the newly constructed (2012) LYIP headworks. The majority (approximately 600 feet) of the existing Intake Dam would be removed and a new 100 foot section of dam would need to be constructed to direct water into the new headworks. A 9,600 foot long canal would be created by constructing a 3,400-ft long by 10-ft wide (top width) dike that extends from the existing headworks to the upstream island. About 100 ft of Intake Dam from the headworks side would be replaced with a newly constructed concrete weir. The new 100 ft wide weir would need to include appurtenances to pass flood flows, sluice sediment, and return fish to the river.

The canal around the island would be approximately the same width as the existing side channel, 150 ft bottom width with 1:1 side slopes. The last 3,400 ft of canal created by the dike would have a 70 ft bottom width with 1:1 side slopes. Excavation along this canal would be required to lower the canal invert to allow for flow conveyance. The entrance of the canal would be at an elevation higher than the river inlet. A concrete sill would also be required to stabilize the canal entrance. The entrance would also need to be designed to reduce debris entrainment (i.e., trash rack) and minimize ice flow damage to the canal.

Hydraulic modeling revealed that this alternative would be technically infeasible without a weir across the entire width of the Yellowstone River (near the new canal entrance) to raise river levels and allow water diversion during low flow. The weir across the Yellowstone River would be located just downstream of the new canal entrance. This weir would have an elevation between 1991 and 1993. At this elevation, given the river bottom at this location the weir will be between 5 to 7 feet higher than the natural river bottom. A fish passage structure will be required, (e.g. rock ramp or bypass channel).

The new 100 ft wide concrete weir next to the existing headworks screening structure would utilize two 10-ft wide radial gates to pass excess water that enters the canal but is not needed for irrigation diversion. These gates would also be used to pass floating debris. Four 8-ft wide by 6-ft tall vertical lift gates would be used to sluice deposited sediments away from the headworks structure. A fish bypass would also be built to return fish that enter back to the river.

The island would be enhanced by placing a ten foot wide rock dike along the river-side perimeter of the existing island. Material dredged from the 9,600 foot long canal would be placed into the interior of the island's rock dike perimeter. The upstream side of the island and upstream floodplain would also require stabilization so that the canal would not get flanked during high flows. The 3,400-ft-long dike would overtop during flood events with a frequency that has yet to be determined. The dike would need to be designed for overtopping.

Design options include:

- Build dike with roller compacted concrete to increase stability and reduce maintence of the structure.
- Include vehicle passage on the weir and dike for maintenance of the canal and entrance.
- Use collapsible gates to divert water into canal instead of concrete weir. "Checking up" the water to obtain a full diversion is only needed for flows less than 7,000 cfs.

Benefits of this design include:

Height of proposed dam structure is smaller than existing dam, potential for "full river width" fish passage with addition of functional ramp. (Note that, based on Corps numerical modeling and Reclamation physical modeling of the original rock ramp alternative, depths and velocities meeting the criteria for pallid sturgeon passage would only be met on a small percentage of the river width for a given river flow. Additional modeling would be required to determine the extent to which this limitation would apply to a rock ramp under this alternative. Additionally, the same constructability concerns previously noted for the original rock ramp design, would also apply to a rock ramp under this alternative).

Critical Items to Consider:

Hydraulics

- A structure is needed within the Yellowstone River to:
- Overcome hydraulic losses between the upstream end of the canal and the screens on the new headworks and
- To have the ability to divert 46 percent (1,374cfs/3,000cfs) of the flow when flows get near 3,000 cfs in the Yellowstone River.
- A similar alternative suggested in a 2005 Reclamation Value Planning Study took advantage of the bend in the river and cut it off, making the proposed canal extension much shorter than the river itself. However, it was determined that a check structure would still be required to divert 1374cfs at 3000cfs Yellowstone River flows.
- Additional flow into the canal may be required for a fish bypass or sediment sluicing.
- Excess debris will have to be cleaned out of the canal during the year.

Channel Control Structure

- Head cutting, bank failure, and channel widening is a likely response to the removal of the existing dam. However, to what exent is not known at this time.
- A grade control structure will be needed to prevent headcutting from progressing upstream.
- It should be noted that a grade control structure in the Yellowstone River may act as a dam if incorrectly located or sized.
- A structure could be constructed flush with the river bottom but scouring on the downstream side of the structure could occur, impacting river passage.
- One method to reduce this scouring is to place an erosion-resistant energy dissipation structure (riprap).
- New weir could be utilized as grade control, however, this may result in a higher weir height relative to the channel bottom.

Dike

- Dike could be constructed of soil (with erosion protection such as riprap), roller compacted concrete, or steel pilling.
- The river side of the dike would likely require heavy armoring to allow for over topping during high flows, erosion and ice forces associated with an outside river bend.
- This structure could also be designed as an access road, this could further increase the cost of this alternative.

Canal Entrance

- The entrance of the canal could be moved upstream to increase the available head, but this is partially offset by the increased headlosses associated with a longer canal. Additionally, moving the entrance upstream substantially increases excavation quantities, espcially once the canal moves out of the existing highflow channel. Even if the canal entrance is moved upstream a weir will still be required to obtain a full diversion at 3,000 cfs in the river.
- A trash rack would need to be looked at for this alternative. A trash rack may decrease O&M costs; however, frequent removal of trash from the entrance of the canal could offset reduced O&M at the headworks structure. Access would be required for trash removal.
- An entrance structure (concrete or riprap) is also likely to be required to provide reliable flow regulation between the river and the canal.

Island Feature

- Stabilization of the island may be required as well as filling in low spots to prevent frequent flood connection and damage to the new canal.
- Some rock from the existing rock field could be used as armoring but the quantity of usuable rock is unknown.

Sediment

- Timely sediment removal is a concern with this alternative. Deposition from a spring runoff event could require removal within 4 to 6 weeks to allow successful diversion as river levels begin to drop. Depending upon removal quantity, method, funding , and contracting, a fast response may not be feasible which would then impact diversion reliability.
- Sediment deposition in the main canal and associated removal will likely be reduced, but may be offset by deposition in the newly created feeder canal.
- Three major impacts would include decreased canal conveyance, inability to diver water at upstream entrance, and inability to lower screens on the new headworks.
- Three potential methods for sediment removal and concerns associated with each include:

    1) Mechanical excavation - Would require a method of dewatering the canal (e.g. gates at the upstream end, perhaps limit to late fall work only with low river levels). Excavation could be required over a 1.8 mile long channel. Removal from the floodplain and disposal.

    2) Dredging - Requires sufficient depth for dredge operation.

    3) Sluicing - Requires large structure to be built within proposed weir with gates and conduits. Effectiveness would need to be evaluated, but would be difficult to effectively sluice sediment from a 1.8 mile long channel.

Reclamation experience indicates potential for sluicing is a couple 100 feet at most. This will be exacerbated by the difference in channel geometry from the upstream end to the narrow bottom width at the headworks. High capacity sluicing may be necessary depending upon design features to minimize deposition during high Yellowstone River flow events. The extent and impact of sediment depostion at the canal entrance would need to be examined further and incorporated into the designs. Sediment sluicing will likely only be effective directly in front of the headworks structure. The rest of the canal will have to be cleaned by other methods.

Flood Plain

- Floodplain impacts need to be assessed before this alternative is moved forward. Protecting the proposed channel from floodplain flows would impact water surface elevation significantly in the project vicinity.
- Areas of the flood plain would have to be protected from high river flows getting into the new canal.

Potential Risks

- Construction of an island to create a side canal and removing most of the existing dam raises the potential to have a significant geomorphic response by the Yellowstone River.
- The island is along an outside bend exposing it to higher velocities, erosive attack, and ice damage.

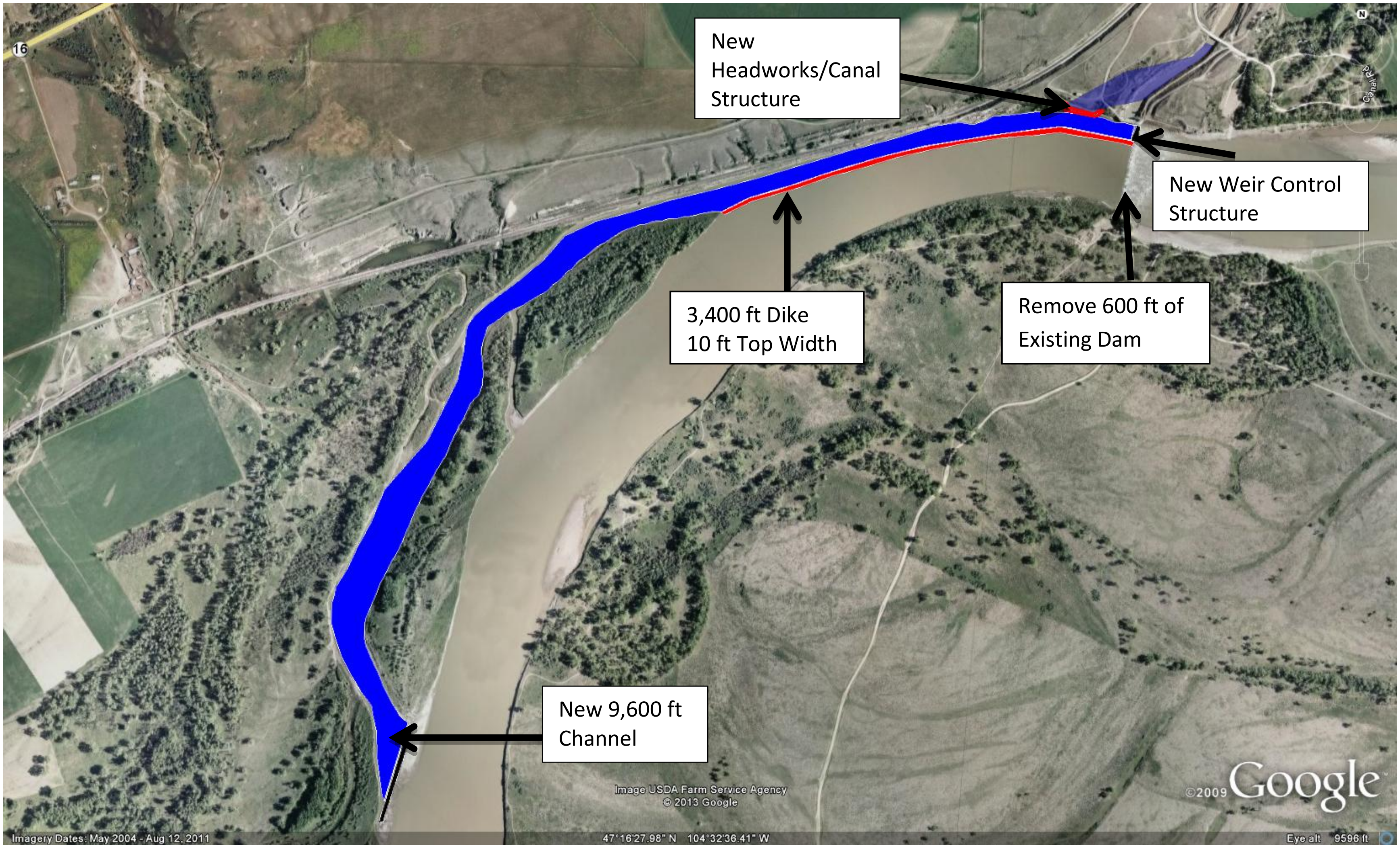

Figure 12: Theme F Island with Extended Canal

Alternative Theme Add –On (Conservation Measures)

<u>Alternative Description</u>

Irrigation water supply augmentation, improved water demand management and water conservation.

The essence of this proposal is the implementation of water conservation measures within the irrigation delivery system to reduce peak demand for water and make efficient use of the water that is diverted, especially at times of lower river flow. Conservation measures considered for this proposal include:

- Installation of water control/check structures within the canal and lateral system.
- Installation of flow measuring devices.
- Conversion of open channel laterals to enclosed piping to reduce evaporation and seepage losses.
- Lining selected sections of canals and laterals to reduce seepage losses.
- Conversion of selected fields from flood to sprinkler irrigation.

Conceptual costs for the water conservation measures were developed to reduce water demand at the canal headworks for various elevations of weir and rock ramp heights are summarized in the table below.

Weir Elevation	Demand Reduction	Conservation and Augmentation Cost
1990.5	0 cfs	$0
1990	35 cfs	$1 Million
1989	220 cfs	$10 Million
1988	410 cfs	$20 Million
1987	610 cfs	$30 Million
1986	780 cfs	$40 Million
1985	940 cfs	$50 Million
1984	1080	>$60 Million

<u>Benefits of this Add-On Option</u>

- Provides potential for cost savings to other alternatives.
- Has potential to improve reliability of fish passage for alternatives such as the rock ramp and concrete weir.
- Provides opportunities for the district to address current delivery problems and provide better, more equitable service to the water users.
- Provides opportunities for the District to alleviate selected O&M headaches.
- Provides opportunities for irrigators to reduce labor time and cost by installing sprinkler systems.
- Potential to improve flood plain stabilization during both high and low flow situations.
- May help address issues related to maintaining a navigable river section.

Critical Things to Consider

- The project would need to be implemented before the fish passage alternative was constructed.
- Power reliability is currently a problem within the region and may limit the ability to implement some of these measures.
- Authority and funding for on-farm measures such as sprinkler systems may require participation and funding from other agencies.

Ways to Implement

- Conventional construction mostly during non-irrigation season.

Potential Risks

- Cost and demand reduction estimates are currently at a low level of confidence and need to be field evaluated and refined.
- Measures would need to be implemented prior to associated weir construction, to be able to meet equivalent of full water diversion.

Alternatives Considered

1. Current bypass channel - collapsible gates
2. Current bypass channel - partial ramp/weir
3. Current bypass channel - ½ weir and ½ open channel
4. Current bypass channel - concrete weir and flow augmentation feature
5. No Action - conservation/supplementation to provide full water right.
6. Remove Dam - gravity feed at flows above 25,000 cfs, conservation/supplementation through groundwater
7. Rock Ramp – shortened, reduce demand through project efficiencies
8. Rock Ramp – shortened, additional diversion points
9. Notch Dam – remove rock, augment with collector wells
10. Remove Dam – pump from Yellowstone River
11. Remove Dam – collapsible gates
12. Original Rock Ramp
13. ½ Rock Ramp – ½ collapsible gates
14. ½ Rock Ramp – ½ weir
15. District Buyout
16. Island – remove weir
17. Island – leave weir in place
18. Rock Ramp - reduced elevation, conservation measures
19. ½ Rock Ramp – L shaped weir
20. Notch Dam – maintain existing rock

Lower Yellowstone - Intake Diversion Dam ESA Modifications - Alternatives Evaluation Matrix

Alternatives	Headworks Cost ($M)	Field Construction Cost ($M)	Conservation Measures Cost ($M)	Total Project Cost ($M)	Annual O&M Cost ($M)	Annual Energy Cost ($M)	Annual Replacement Cost ($M)	Total	Likelihood of ESA Success	Water Delivery Reliability	Constructability	State Acceptability	District Acceptability	BOR Acceptability
Original Rock Ramp (w/conservation measures, and potential lower elevation) - Evaluate if a lower weir and ramp elevation improves fish passage - If lower elevation does improve fish passage potential is there efficiencies within the district to help reduce weir and ramp elevation - Evaluate what these efficiencies can be and cost of these measures	$28	$91.6	$0	$119.6				$0	3	5	2.5	3	5	4
30% Design Bypass Channel(w/modifications and Federal Assurances) - Evaluate options to move the current bypass channel alignment out of the existing high flow channel - Physical modeling of bypass channel entrance and exit - Federal Assurances in writing - Modified weir design, reduce weir crest width from 25' to 6'	$28	$59.9	$0	$87.9	$0.14			$0	3	5	3.5	2	3	3
Alternatives Considered But Dropped														
Open Channel w/ Multiple Ranney Wells	$28	$215.6	$0	$243.6		$2.7		$2.7	5	3	3.5	5	1	3
Rock Ramp w/ Reduced Elevation (1989')	$28	$69.4	$10	$107.4				$0	Did Not Receive A Ranking					
Combination Rock Ramp and Weir	$28	$91.0	$0	$119.0	$0.14			$0	2	5	2.5	2	4	2
Island	$28	$37.0	$0	$65.0				$0	4	2	2.5	4	1	3

Ranking 1 - Low 5 - High

Figure 13: Alternative Rankings

<u>Alternatives Disposition</u>

<u>Alternative Theme A - Open Channel with Multiple Ranney Wells</u>

This alternative was dropped because of the high cost to install the Ranney Well System and the high energy costs that would be placed upon the district. Concerns with power service reliability, brownouts and power outages were also discussed. These issues can cause disruption in canal flows and affect operation of the whole system. It was determined that there were cheaper, potentially effective alternatives remaining.

<u>Alternative Theme C - Rock Ramp with Reduced Elevation (1989')</u>

This alternative was dropped but important components were combined with the original rock ramp alternative. The thought behind the lower ramp elevation was to help reduce the cost of construction. Since significant cost savings were not achieved in this preliminary estimate, it was decided amongst the group to look at the potential improvement to fish passage with the reduced weir elevation (possible lower velocities over the weir) before going further with this alternative.

<u>Alternative Theme D - Combination Rock Ramp and Weir</u>

This alternative was dropped because it was very comparable in cost to the original rock ramp but only provided half the river passage. The original thinking behind this alternative was if you cut the ramp width in half you could potentially cut the costs down by half. In the COE analysis this was not accurate; in order to keep the water on the half rock ramp a very large retaining wall would need to be constructed from the weir crest to the toe of the ramp. This increased costs to the original rock ramp design.

<u>Alternative Theme F - Island with Extended Canal</u>

This alternative was dropped because of concerns regarding the river migrating away from the newly constructed headworks when the diversion dam was removed and the increased O&M potential of the dike on the outside bend of the river. It was also questioned if the hydraulics of this alternative would allow the district to receive their full water right down to 3,000 cfs. The need to use a river-wide control structure to divert water at low flows was considered a significant drawback. Concerns of sediment and fish entrainment were also discussed but not alleviated. The LYIP expressed concerns about stability and O&M costs and could not support this alternative. The group determined that there were other effective alternatives even though it provided full river passage for fish.

Planning Team Attendance

June 20, 2013

Tim Baker	Governor's Office
James Brower	Lower Yellowstone Irrigation District
Richard Cayko	Lower Yellowstone Irrigation District
Mike Murphy	Montana Water Resources Association
Sam Johnson	Department of Natural Resources Conservation
John Tubbs	Department of Natural Resources Conservation
Tim Davis	Department of Natural Resources Conservation
Brad Schmitz	Montana Fish Wildlife and Parks
Caleb Bollman	Montana Fish Wildlife and Parks
Don Skaar	Montana Fish Wildlife and Parks
Mike Backes	Montana Fish Wildlife and Parks
Steve Dalbey	Montana Fish Wildlife and Parks
Mike Volesky	Montana Fish Wildlife and Parks
Bruce Rich	Montana Fish Wildlife and Parks
Chris Fassero	U.S. Army Corp of Engineers
Tiffany Vanosdall	U.S. Army Corp of Engineers
Brent Mefford	Bureau of Reclamation
Christina Lasater	Bureau of Reclamation
David Trimpe	Bureau of Reclamation
Doug Epperly	Bureau of Reclamation
Gary Davis	Bureau of Reclamation
Rae Olsen	Bureau of Reclamation
Brent Esplin	Bureau of Reclamation
Tom Sawatzke	Bureau of Reclamation
Jeff Baumberger	Bureau of Reclamation
Jerry Benock	Bureau of Reclamation
Lenny Duberstein	Bureau of Reclamation
Dale Lentz	Bureau of Reclamation
George Jordan	U.S. Fish and Wildlife Service
Jodi Bush	U.S. Fish and Wildlife Service
Brent Esmoil	U.S. Fish and Wildlife Service
Jeff Berglund	U.S. Fish and Wildlife Service

June 27, 2013

James Brower	Lower Yellowstone Irrigation District
Don Steinbeisser	Lower Yellowstone Irrigation District
Sam Johnson	Department of Natural Resources Conservation
Brad Schmitz	Montana Fish Wildlife and Parks
Caleb Bollman	Montana Fish Wildlife and Parks
Mike Backes	Montana Fish Wildlife and Parks
Curtis Miller	U.S. Army Corp of Engineers
Tiffany Vanosdall	U.S. Army Corp of Engineers
David Trimpe	Bureau of Reclamation
Doug Epperly	Bureau of Reclamation
Gary Davis	Bureau of Reclamation
Rae Olsen	Bureau of Reclamation
Jerry Benock	Bureau of Reclamation
Dale Lentz	Bureau of Reclamation
Amy Whittington	Bureau of Reclamation
Roxanne Peterson	Bureau of Reclamation
Lenny Duberstein	Bureau of Reclamation
George Jordan	U.S. Fish and Wildlife Service

July 12, 2013

James Brower	Lower Yellowstone Irrigation District
Don Steinbeisser	Lower Yellowstone Irrigation District
Conrad Conradsen	Lower Yellowstone Irrigation District
Richard Cayko	Lower Yellowstone Irrigation District
Sam Johnson	Department of Natural Resources Conservation
Brad Schmitz	Montana Fish Wildlife and Parks
Caleb Bollman	Montana Fish Wildlife and Parks
Mike Backes	Montana Fish Wildlife and Parks
Lee Nelson	Montana Fish Wildlife and Parks
Curtis Miller	U.S. Army Corp of Engineers
Chris Fassero	U.S. Army Corp of Engineers
David Trimpe	Bureau of Reclamation
Doug Epperly	Bureau of Reclamation
Gary Davis	Bureau of Reclamation
Lenny Duberstein	Bureau of Reclamation
Dale Lentz	Bureau of Reclamation
Roxanne Peterson	Bureau of Reclamation
Christina Lasater	Bureau of Reclamation
Brent Esplin	Bureau of Reclamation
George Jordan	U.S. Fish and Wildlife Service

July 16, 2013

James Brower	Lower Yellowstone Irrigation District
Don Steinbeisser	Lower Yellowstone Irrigation District
Conrad Conradsen	Lower Yellowstone Irrigation District
Mark Iverson	Lower Yellowstone Irrigation District
Hugo Asbeck	Lower Yellowstone Irrigation District
Steve Pust	Savage Irrigation District
Sam Johnson	Department of Natural Resources Conservation
Mike Murphy	Montana Water Resources Association
Brad Schmitz	Montana Fish Wildlife and Parks
Caleb Bollman	Montana Fish Wildlife and Parks
Mike Backes	Montana Fish Wildlife and Parks
David Trimpe	Bureau of Reclamation
Doug Epperly	Bureau of Reclamation
Gary Davis	Bureau of Reclamation
Lenny Duberstein	Bureau of Reclamation
Jerry Benock	Bureau of Reclamation
Dale Lentz	Bureau of Reclamation
Roxanne Peterson	Bureau of Reclamation
Brent Esplin	Bureau of Reclamation
George Jordan	U.S. Fish and Wildlife Service
Casey Kruse	U.S. Fish and Wildlife Service
Matt Rosendale	State Legislature District 19
Randy Vogel	Congressional – Steve Daines
Lindsay Bell	Congressional – Max Baucus
Rachel Court	Congressional – Jon Tester
Chris Fassero	U.S. Army Corp of Engineers
Tiffany Vanosdall	U.S. Army Corp of Engineers

July 19, 2013

James Brower	Lower Yellowstone Irrigation District
Don Steinbeisser	Lower Yellowstone Irrigation District
Conrad Conradsen	Lower Yellowstone Irrigation District
Mark Iverson	Lower Yellowstone Irrigation District
Hugo Asbeck	Lower Yellowstone Irrigation District
Walter Reichenbach	Lower Yellowstone Irrigation District
Orvin Finsaas	Lower Yellowstone Irrigation District
Kjeld Johnson	Lower Yellowstone Irrigation District
Lee Roy Schmierer	Lower Yellowstone Irrigation District
Bud Groskinsky	Lower Yellowstone Irrigation District
Dan Rice	Lower Yellowstone Irrigation District
Dave Rice	Lower Yellowstone Irrigation District
Dale Danielson	Lower Yellowstone Irrigation District
Todd Cayko	Lower Yellowstone Irrigation District
Philip Hurley	Lower Yellowstone Irrigation District
Steve Pust	Savage Irrigation District
Tim Davis	Department of Natural Resources Conservation
Sam Johnson	Department of Natural Resources Conservation
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Caleb Bollman	Montana Fish Wildlife and Parks
Bruce Rich	Montana Fish Wildlife and Parks
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Brent Esplin	Bureau of Reclamation
Gary Campbell	Bureau of Reclamation
Gina Weinstock	Bureau of Reclamation
David Trimpe	Bureau of Reclamation
Doug Epperly	Bureau of Reclamation
Gary Davis	Bureau of Reclamation
Jerry Benock	Bureau of Reclamation
Dale Lentz	Bureau of Reclamation
Rae Olson	Bureau of Reclamation
George Jordan	U.S. Fish and Wildlife Service
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Mya Agustan	Congressional – Jon Tester
Lindsay Bell	Congressional – Max Baucus
Rachel Court	Congressional – Jon Tester
Nathan Taylor	Congressional – Jon Tester
Matt Davis	Congressional – Jon Tester

August 22, 2013

James Brower	Lower Yellowstone Irrigation District
Don Steinbeisser	Lower Yellowstone Irrigation District
Conrad Conradsen	Lower Yellowstone Irrigation District
Richard Cayko	Lower Yellowstone Irrigation District
Hugo Asbeck	Lower Yellowstone Irrigation District
Steve Pust	Savage Irrigation District
Sam Johnson	Department of Natural Resources Conservation
Mike Murphy	Montana Water Resources Association
Brad Schmitz	Montana Fish Wildlife and Parks
Caleb Bollman	Montana Fish Wildlife and Parks
Mike Backes	Montana Fish Wildlife and Parks
Chris Fassero	U.S. Army Corp of Engineers
David Trimpe	Bureau of Reclamation
Doug Epperly	Bureau of Reclamation
Steph Micek	Bureau of Reclamation
Lenny Duberstein	Bureau of Reclamation
Jerry Benock	Bureau of Reclamation
Dale Lentz	Bureau of Reclamation
Gary Davis	Bureau of Reclamation
Casey Kruse	U.S. Fish and Wildlife Service
George Jordan	U.S. Fish and Wildlife Service
Matt Rosendale	State Legislature District 19
James Corson	Congressional – Max Baucus
Rachel Court	Congressional – Jon Tester
Cathy Kirkpatrick	Congressional – Max Baucus

September 13, 2013

James Brower	Lower Yellowstone Irrigation District
Don Steinbeisser	Lower Yellowstone Irrigation District
Hugo Asbeck	Lower Yellowstone Irrigation District
Jeff Hagener	Montana Fish Wildlife and Parks
Bruce Rich	Montana Fish Wildlife and Parks
Chris Fassero	U.S. Army Corp of Engineers
Brent Esplin	Bureau of Reclamation
David Trimpe	Bureau of Reclamation
Doug Epperly	Bureau of Reclamation
Gary Davis	Bureau of Reclamation
Lenny Duberstein	Bureau of Reclamation
Dale Lentz	Bureau of Reclamation
Jeff Baumberger	Bureau of Reclamation
Larry Gamble	U.S. Fish and Wildlife Service
George Jordan	U.S. Fish and Wildlife Service
Jessica Flint	Congressional – Steve Daines
Jon Cameron	Congressional – John Hoeven (ND)
Rachel Court	Congressional – Jon Tester