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Flathead Irrigation Project

Crow Creeks, Kicking Horse, and Ninepipe Modernization

U.S. Bureau of Indian Affairs
Branch of Irrigation & Power

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CROW CREEKS, KICKING HORSE, AND NINEPIPE RESERVOIR MODERNIZATION

Modernization Plan

Figure 1 on the next page shows the general modernization changes in the Post Canal Unit. The key modernization changes include:

1. Control improvements made at four individual creek crossings along the Pablo Feeder Canal will each:
    a. Limit the downstream flow rate in the Pablo Feeder Canal to safe maximum flows.
    b. Simplify operations to maintain in-stream flows while protecting the Pablo Feeder Canal.
2. Kicking Horse Reservoir is supplied by canals from two creeks. Control changes will be made at the heading of each of these feeder canals.
    a. The headgates for the Kicking Horse Feeder Canal, located at Post Creek, will be automated to maintain a target flow rate in Post Creek while simultaneously diverting all excess flows (up to the canal maximum) into the Kicking Horse Feeder Canal.
    b. The structures at the bifurcation of South Crow Creek and the South Crow Creek Feeder canal will be modified as follows:
        i. A minimum target flow into South Crow Creek will be maintained for in-stream flow requirements.
        ii. Excess creek flows will be diverted into the South Crow Creek Feeder Canal.
        iii. The check structure gates within South Crow Creek will be equipped with actuators and SCADA, so that they can be remotely manually opened during storm events.
3. Two canal restrictions in the Post A Canal will be removed to increase the canal flow capacity.
4. The existing Crow Creek pump station will be upgraded to maximize diversions of excess creek flows into Ninepipe Reservoir.
    a. New VFD pump(s) will maintain a constant upstream water level control in Crow Creek. A constant target flow rate will be maintained for the downstream portion of the creek.
    b. Excess creek flows will be pumped up into a new level pool composed of portions of the Post A and P Canals.
    c. A new water level control structure will maintain the water elevation in the level pool. All excess flows in the level pool will spill to Ninepipe Reservoir via the downstream segment of the Post P Canal.
    d. At the bifurcation of the Post A and Post P canals, a new flow control structure at the head of the remaining Post A Canal will be installed.
5. Multiple new or improved flow measurement sites will be constructed throughout the canal and creek system.
6. Water level control will be improved at individual existing locations.
7. SCADA will be incorporated at key locations to help manage the movement of water during normal operations as well as storm events.

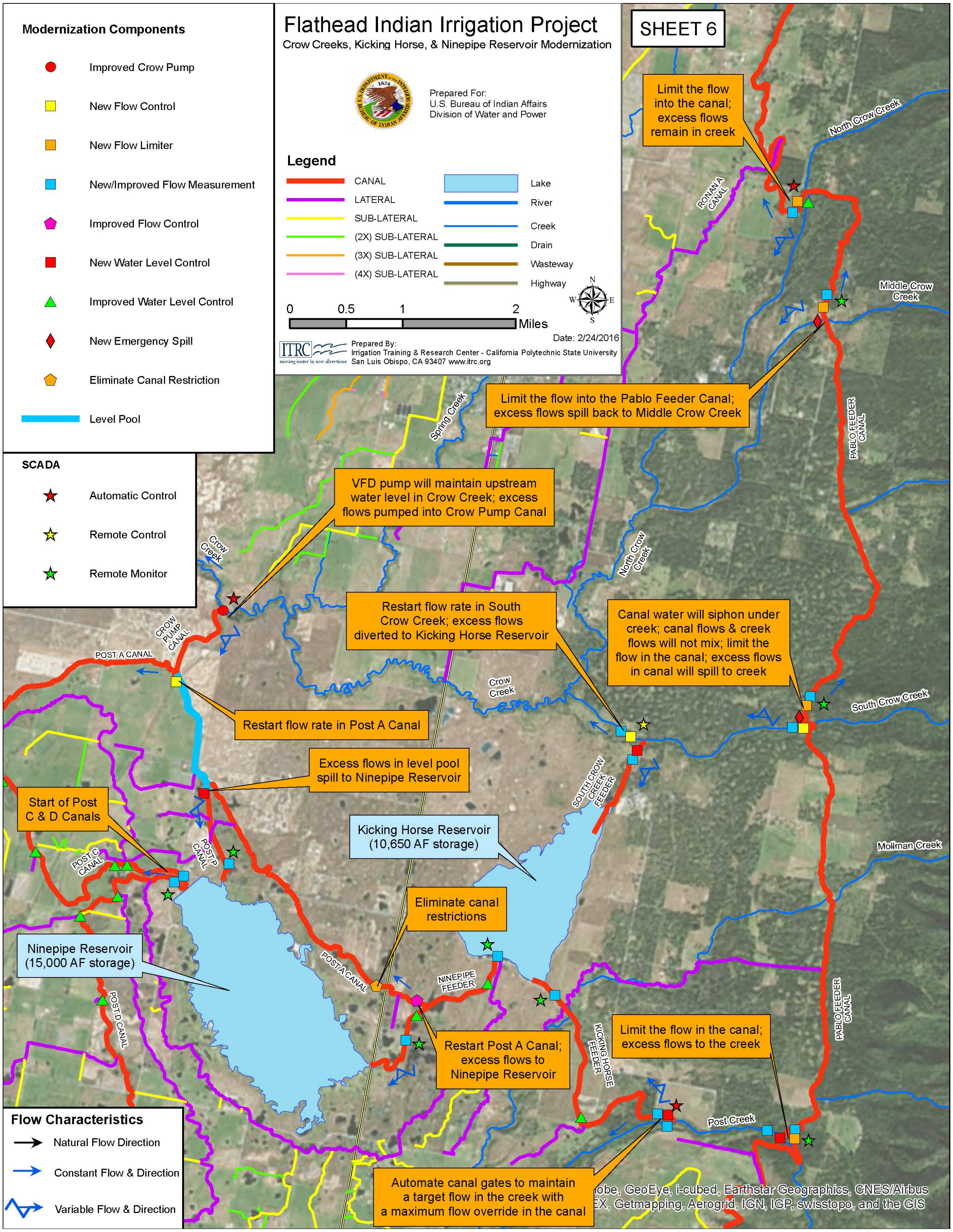

Figure 1. Overall modernization changes near Crow Creeks, Kicking Horse Reservoir, and Ninepipe Reservoir

Pablo Feeder Canal at Post and Three Crow Creek Crossings

Figure 2 shows the major creek inflows to the Pablo Feeder Canal near Kicking Horse and Ninepipe Reservoirs.

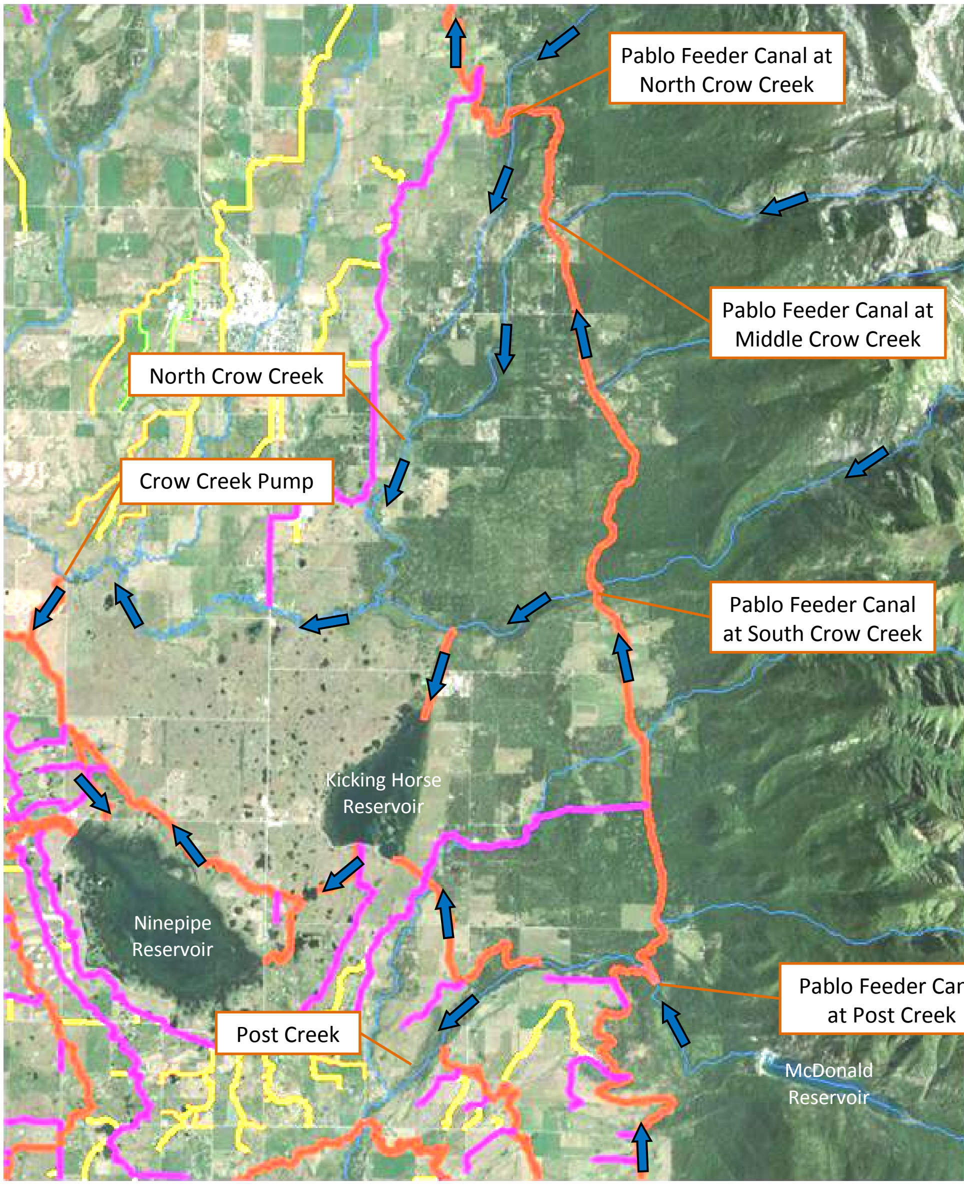

Figure 2. Locations of major creek inflows to Pablo Feeder Canal near Kicking Horse and Ninepipe Reservoir

All three Crow Creeks (South, Middle, North) flow from the mountains directly into the Pablo Feeder Canal; Post Creek does not. Flows in Post Creek are controlled by discharges made at McDonald Reservoir. Water in the canal is sometimes discharged to the creeks to meet in-stream flow requirements. At other times, the creek flows are directed into the Pablo Feeder Canal.

Late spring storm events during the start of the irrigation season cause management and safety problems for FIIP. Problems include:

- During storm events, large runoff flows in the creeks spill into the Pablo Feeder Canal.
- The existing canal infrastructure is not capable of easily handling sudden large canal flow rate increases.
- Operators often have to go to each site to manually make adjustments to the check/waste structures to spill the excess flows back to the creeks. This can occur at night during unsafe working conditions.

Overview of Modernization Changes along the Pablo Feeder Canal

Figure 3 outlines changes for specific sites. Site-by-site changes along the Pablo Feeder Canal are subsequently described.

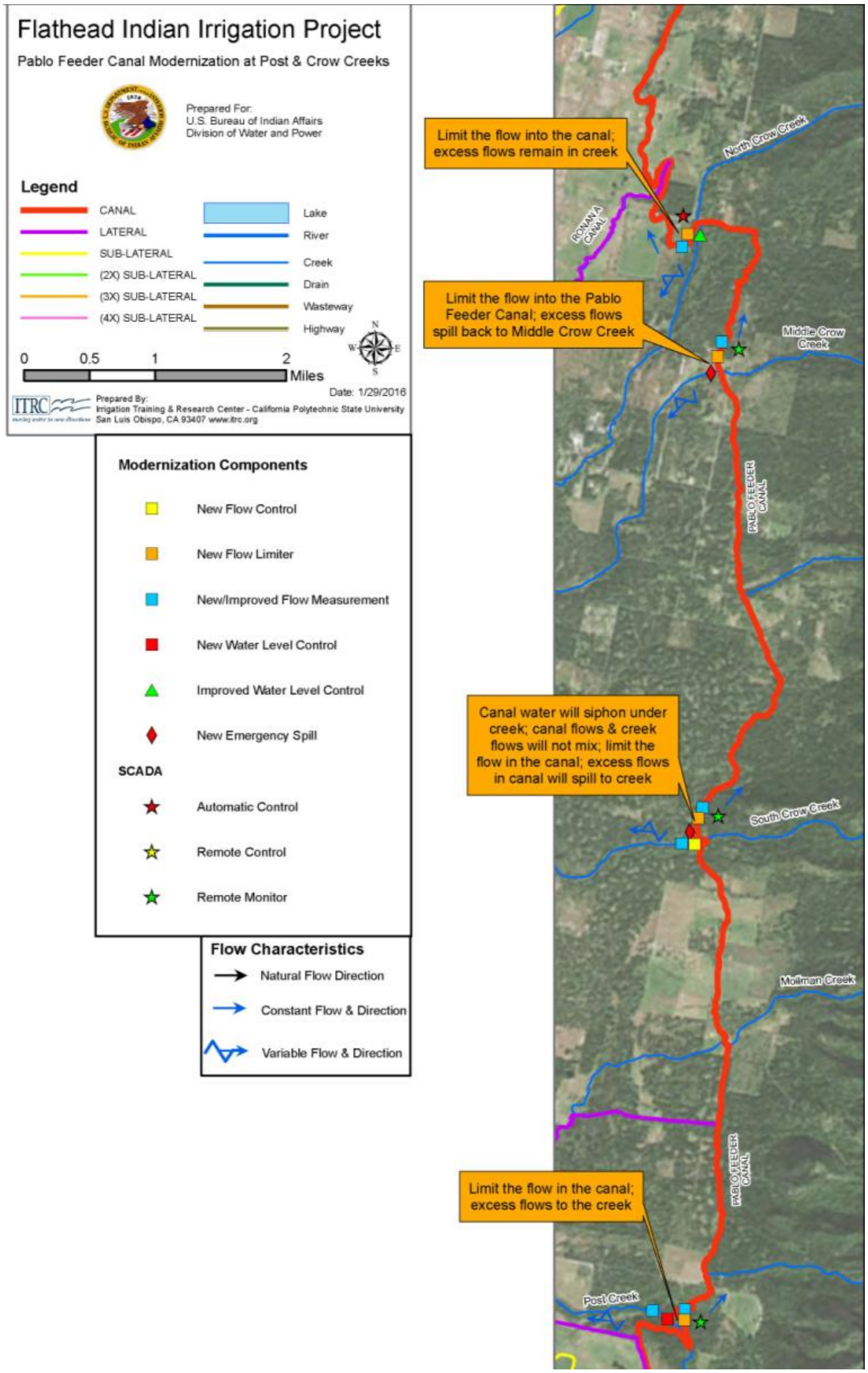

Figure 3. General modernization changes to the Pablo Feeder Canal at Post and Crow Creeks

Pablo Feeder Canal at Post Creek

Existing Conditions

Figure 4 shows the approximate location of the Pablo Feeder Canal at Post Creek.

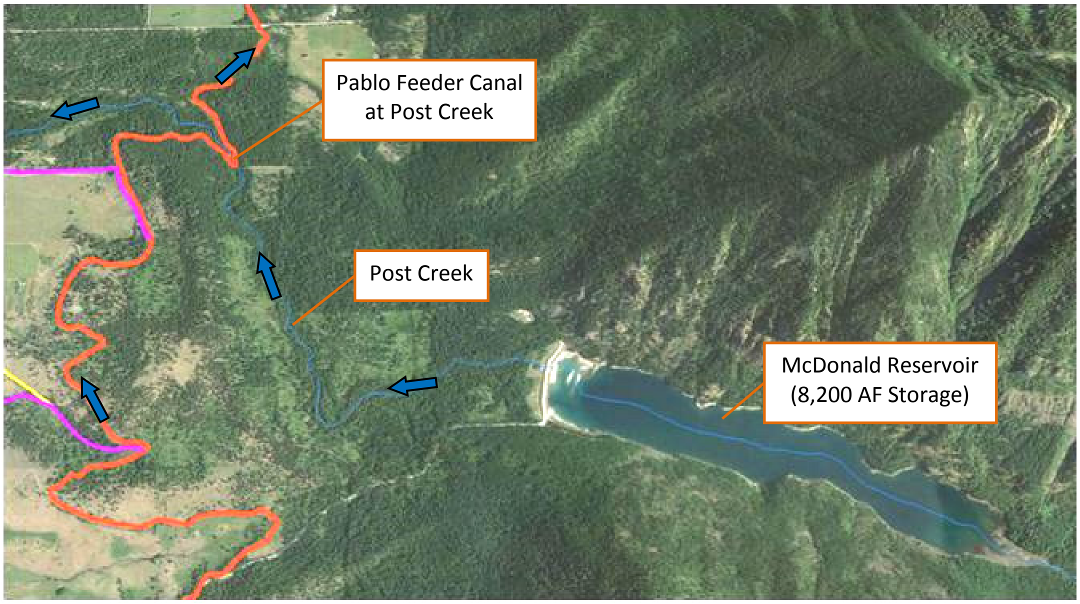

Figure 4. Pablo Feeder Canal at Post Creek

Figure 5 shows the conceptual drawing of the existing control of the Pablo Feeder Canal at Post Creek. Figure 6, Figure 7, and Figure 8 show photos of the existing structures. The existing control is as follows:

- Water in the Pablo Feeder Canal is diverted into a fairly new metal conveyance flume to cross over Post Creek.
- A weir for emergency spills is located in the Pablo Feeder Canal just a short distance downstream of the flume entrance. Any water that passes over the emergency weir flows to Post Creek.
- A rock dam in Post Creek raises the water upstream water level so that water can flow through the Post Creek diversion gates and into the Pablo Feeder Canal.
- A flow control structure on the side of Post Creek contains four manual sluice gates to divert water from Post Creek into the Pablo Feeder Canal.
- A small canal gate on the left-hand bank of the canal, downstream of the steel conveyance flume, can provide instream flows to Post Creek.

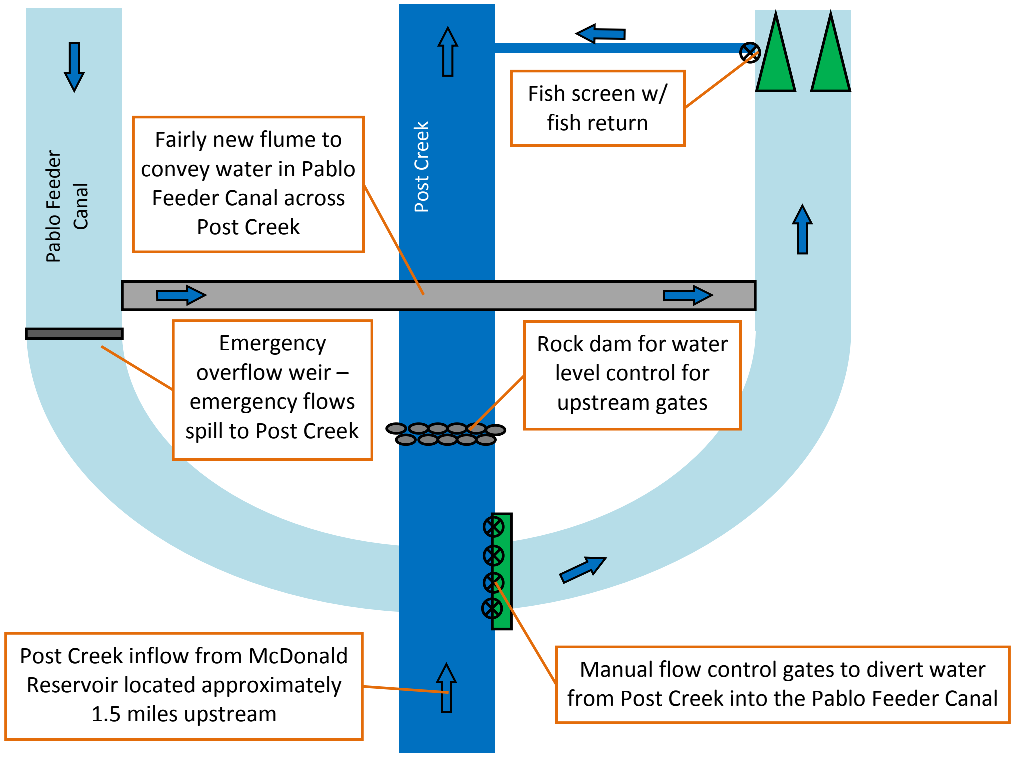

Figure 5. Existing control at the Pablo Feeder Canal and Post Creek (not to scale)

Figure 6. Pablo Feeder Canal flume entrance and emergency spill weir at Post Creek

Figure 7. Pablo Feeder Canal steel flume over Post Creek

Figure 8. Rock dam in Post Creek, and diversion gates to supply the Pablo Feeder Canal

Figure 9. Pablo Feeder Canal and small gate to maintain instream flows; located downstream of the steel conveyance flume

Figure 10. Fish screen in the Pablo Feeder Canal, downstream of Post Creek

Modernization Changes

Figure 11 illustrates the modernization changes at this site. The primary goals for the modernization changes for the Pablo Feeder Canal at Post Creek are:

1. Maximize the "restart" flow rate to the downstream portion of the Pablo Feeder Canal
2. Simplify the control and management for operators

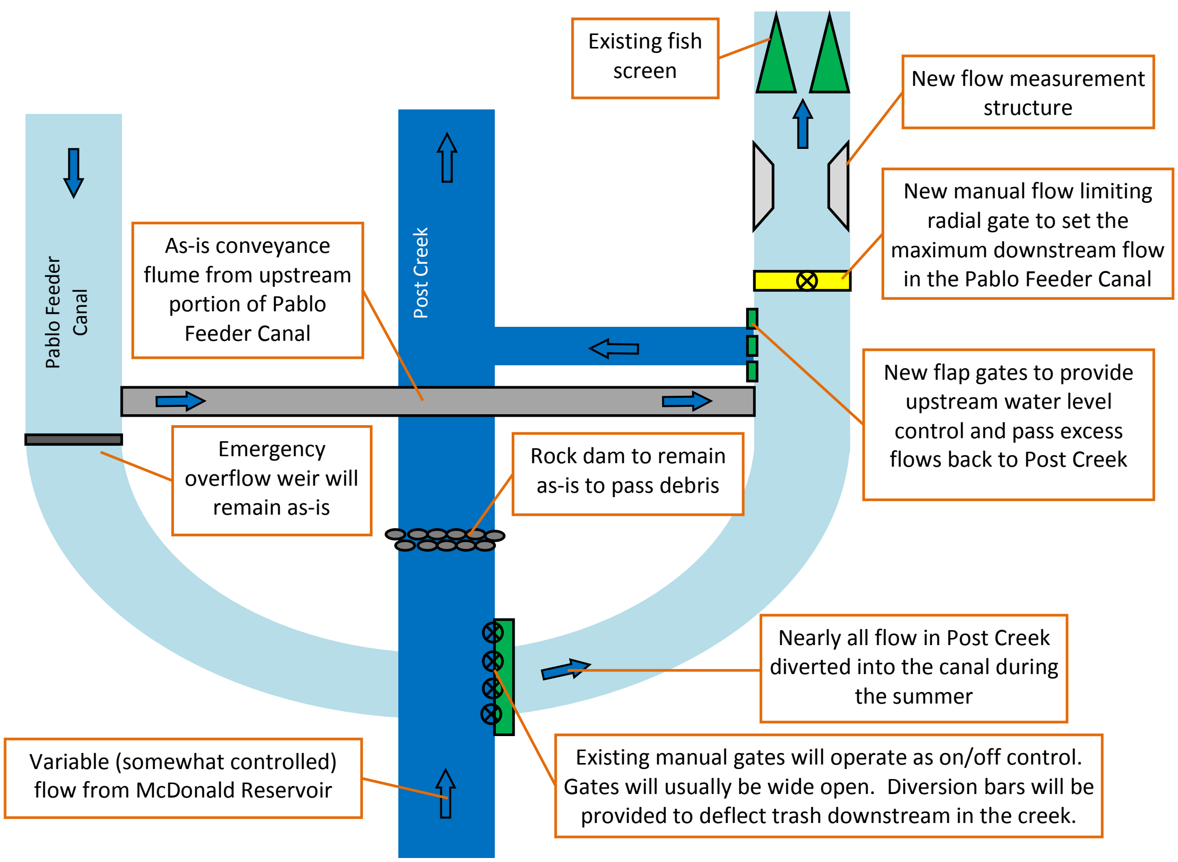

Figure 11. Modernization changes on the Pablo Feeder Canal at Post Creek (not to scale)

The modernization changes include:

1. The existing canal headgates in Post Creek will only function as on/off control. Usually all four canal gates will be wide open to pass nearly all of the flow in Post Creek into the canal.
2. A new trash-deflecting bar arrangement will be installed in the creek in front of the headgates.
3. A new flow limiting structure will be constructed in the Pablo Feeder Canal approximately 100 ft. downstream of the steel conveyance flume discharge. A manual radial gate will be set to pass the maximum safe flow rate to the downstream portion of the Pablo Feeder Canal.
4. Multiple flap gates will be installed in the left canal bank directly upstream of the new flow limiting structure to maintain a fairly constant upstream water level. All excess flows will spill back to Post Creek.
5. A new fish screen will be constructed downstream of the new flow limiting gate in the Pablo Feeder Canal.
6. A flow measurement structure will be constructed downstream of the flow limiting structure. The type of structure will depend on the available headloss. The flow rate through the new structure will be remotely monitored via SCADA.

The rock dam in Post Creek will remain as-is to divert water through the completely opened Post Creek headgates but to also pass debris in the creek downstream.

The debris racks that are recommended were not seen in the FIIP. Figure 12 provides some images of an example installation. Sometimes the bars extend further downstream, gradually sweeping past the gates. Because of the large, smooth openings between the horizontal pipes, sand does not accumulate behind them and there are only minor secondary currents to pull trash backwards behind the bars.

Figure 12. Views of horizontal trash deflector bars in a river

Pablo Feeder Canal at South Crow Creek

Existing Conditions

South Crow Creek collects runoff from the nearby mountains and discharges directly into the Pablo Feeder Canal. Figure 16 shows the existing canal structures at the confluence. A manual radial gate in poor condition is used to “restart” the downstream flow rate in the Pablo Feeder Canal. A three bay check structure (one bay has a canal gate installed to meet in-stream flows) is used to maintain the upstream water level at the confluence. The whole structure is scheduled to be replaced.

Figure 13. Google image of the bifurcation point of Pablo Feeder Canal and South Crow Creek

Figure 14. South Crow Creek as it approaches the Pablo Feeder Canal

Figure 15. Confluence of South Crow Creek (entering from the left) and the Pablo Feeder Canal (entering from the top). Open flashboard structure plus canal gate on the right-hand side is a continuation of the South Crow Creek.

Figure 16. Existing structures in Pablo Feeder Canal at South Crow Creek

Figure 17. Radial gate to control flow into the Pablo Feeder Canal at South Crow Creek

Figure 18. Drop into South Crow Creek at Pablo Feeder Canal bifurcation

Figure 19. Rated section in the Pablo Feeder Canal downstream of the bifurcation with South Crow Creek

The major problem with the current control structures is that during a storm event, up to 150 CFS can discharge into the canal from the creek. The current check structures are not capable of easily handling the sudden increase in variable canal flow. With the rise in the upstream canal water level, the flow rate through the existing radial gate to the downstream portion of the Pablo Feeder Canal can exceed the canal capacity. During storm events, operators have to travel to the site (often at night) to remove boards in the check structure to spill the excess water back into the downstream section of South Crow Creek.

The Pablo Feeder Canal at South Crow Creek is listed as one of the tribe's Water Rights Compact Rehabilitation and Betterment Projects. The goals for improved control and management at the site are:

- Not allow canal water and creek water to mix together
- Limit the downstream flow rate in the Pablo Feeder Canal to 350 CFS
- Automatically handle flow increases due to storm events
- Meet in-stream flow demands to South Crow Creek

Recommended Modernization Option

It is recommended that the modernization features at the Post Creek crossing of the Pablo Feeder Canal, including the steel flume to cross the creek at the bend, be replicated at this location with all new structures. It likely that the Tribes will want to install a new fish screen in the canal as well.

It appears that less headloss is available in the Pablo Feeder Canal at South Crow Creek, so careful attention must be paid to providing hydraulically smooth entrances to the flume; this is a factor that was not so important at the Post Creek crossing.

Pablo Feeder Canal at Middle Crow Creek

Middle Crow Creek has the smallest watershed of the three Crow Creeks and flows directly into the Pablo Feeder Canal. Additional stream flow from Lost Creek, located approximately 1.75 miles upstream of Middle Crow Creek, discharges into the Pablo Feeder Canal as well.

An existing two bay waste structure (see Figure 20) spills water back to Middle Crow Creek if the water level in the Pablo Feeder Canal rises too high. A manual canal gate is used to meet downstream in-stream flow requirements.

Figure 20. Existing spill structure in the Pablo Feeder Canal at Middle Crow Creek. Photo provided from HKM 2008 report.

With the inflow from the two creeks, the major concerns are:

- Exceeding the canal flow capacity during storm events
- Unsafe conditions for operators who must manually manipulate the existing waste structure to accommodate the storm flows entering the Pablo Feeder Canal

To address the major operational concerns for both normal operation and storm events, Figure 21 shows the conceptual changes that will be made in the Pablo Feeder Canal at Middle Crow Creek.

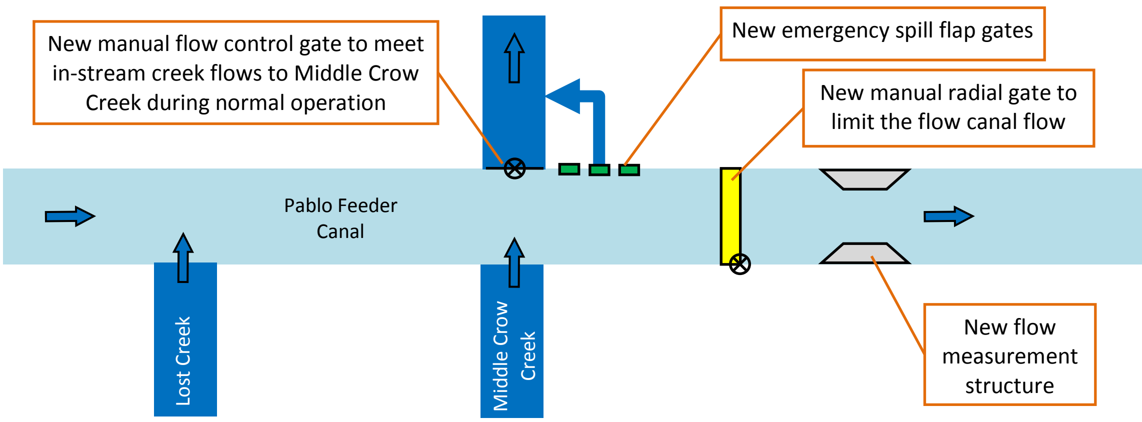

Figure 21. Conceptual control changes in the Pablo Feeder Canal at Middle Crow Creek (not to scale)

The control changes include:

1. A new manual radial gate will limit the flow rate to the downstream portion of the Pablo Feeder Canal. The radial gate will always be set to pass the maximum canal flow rate with an upstream water level that almost reaches the target water surface elevation of the ITRC Flap Gates.
2. The existing canal gate to Middle Crow Creek will be replaced with a new manual sluice gate to set a target flow rate to the downstream portion of the creek during normal operations.
3. Multiple flap gates will provide emergency water level control. All excess flows will spill back to Middle Crow Creek.
4. A new flow measurement structure will be constructed downstream of the flow limiting radial gate. The flow rate through the new measurement structure will be remotely monitored via SCADA.

Improved Control at Pablo Feeder Canal at North Crow Creek

North Crow Creek collects water from a large watershed and discharges directly into the Pablo Feeder Canal, forming a large pond. Figure 22 shows an aerial of the canal and creek confluence.

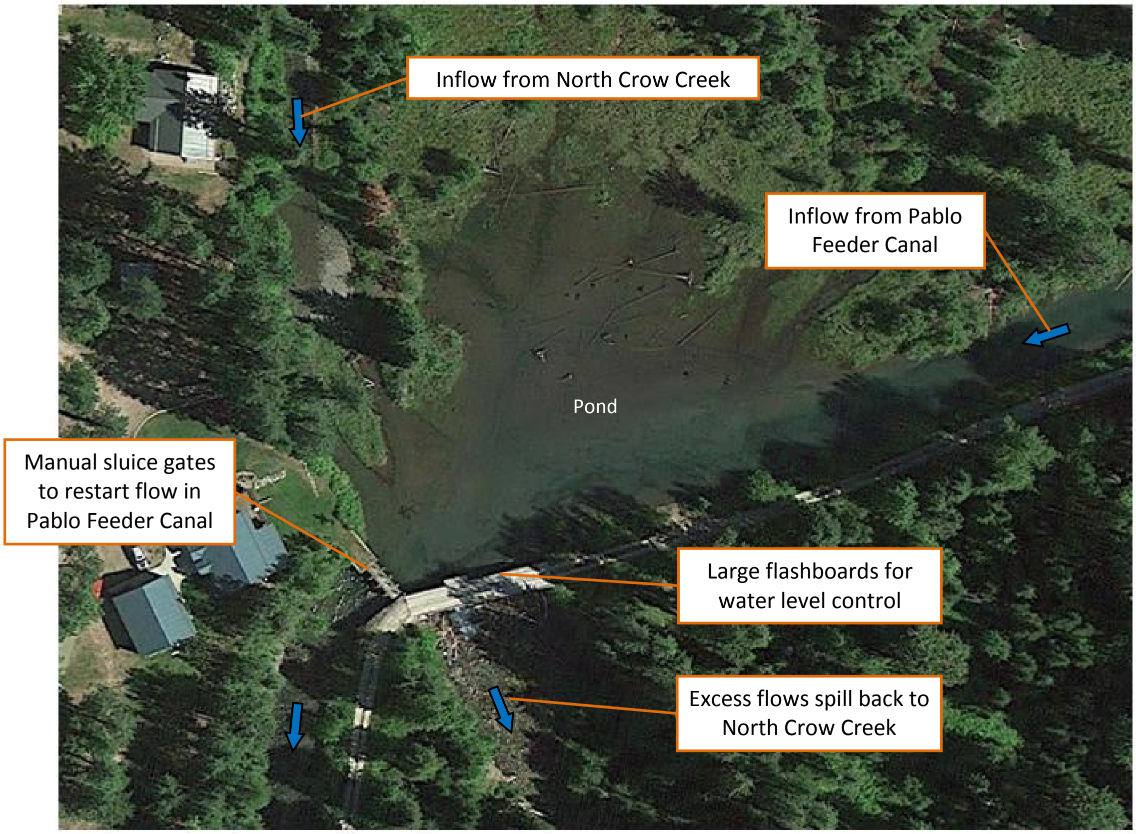

Figure 22. Aerial image of the Pablo Feeder Canal at North Crow Creek

A seven bay check structure (refer to Figure 23) is used to maintain the upstream water level in the large pond as well as spill all excess flow back to North Crow Creek.

- Each bay is approximately 10 ft. wide with large flashboard beams.
    - Three operators are needed to lift a single board out of the water during storm events.
    - A single 30” canal gate installed in one of the flashboard bays is used to divert water to meet downstream creek flow demands.
- Four manual 48” sluice gates shown in Figure 24 are used to restart the flow rate to the downstream portion of the Pablo Feeder Canal.

Figure 23. Seven bay check structure in North Crow Creek as the Pablo Feeder Canal passes through the pond

Figure 24. Existing manual flow control gates for the restart of the Pablo Feeder Canal at North Crow Creek

The major problems associated with the site include:

- Handling the large storm flows entering the canal from the creek
- Safety hazards to operators trying to manipulate the large flashboards in the waste structure during normal operations or storm events. Notice there are no safety rails installed for employees on the waste structure in Figure 23.
- Trying to maintain a constant flow rate downstream in the Pablo Feeder Canal
- Large amounts of debris such as tree logs and branches that flow down the creek to the structure

The modernization improvements for the Pablo Feeder Canal at North Crow Creek are shown in Figure 25.

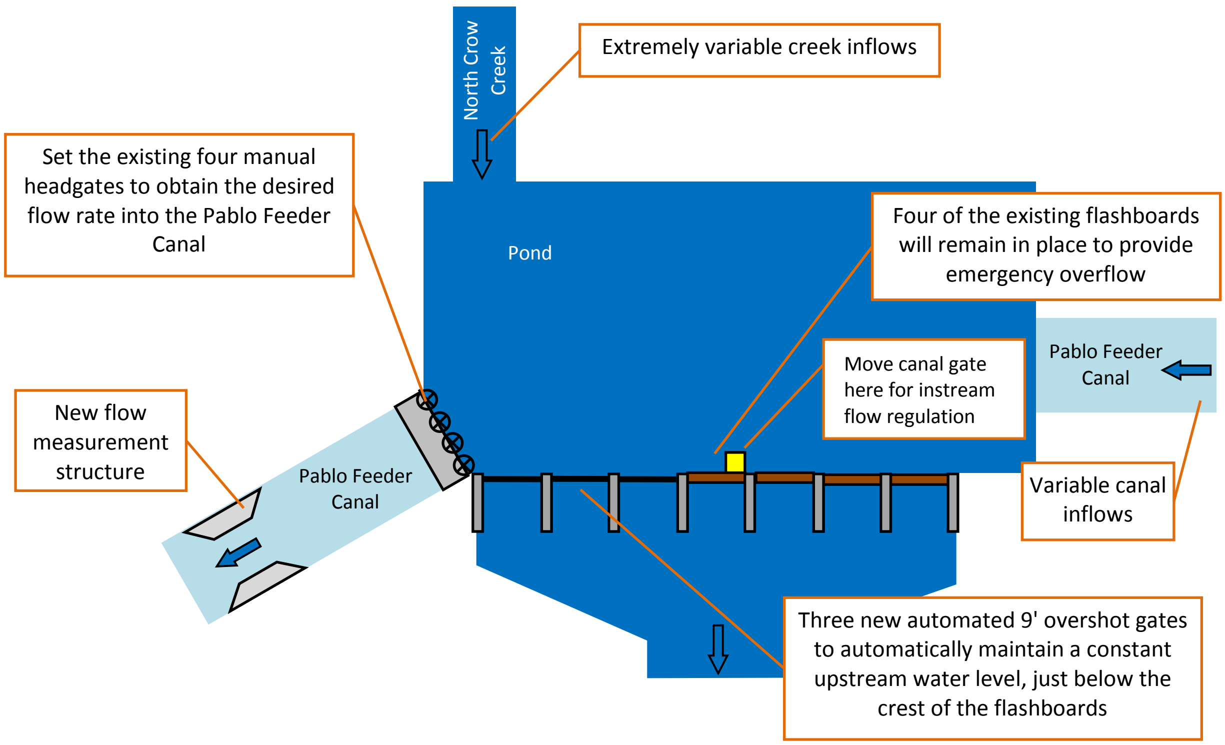

Figure 25. Conceptual modernization improvements for the Pablo Feeder Canal at North Crow Creek (not to scale)

Three new automated overshot gates will be installed in the three flashboards bays of the existing creek check structure. They will have local automation to provide upstream control, maintaining the pond at a constant level. The target level will be about 0.1' below the crest of the remaining (4) flashboards. This will accomplish the following:

1. Because the pond level will remain fairly constant, the flow into the Pablo Feeder Canal can be set to any desired target flow rate.
    a. During the summer, if the four Pablo Feeder Canal gates are set at the opening that will provide the maximum safe flow into the Pablo Feeder Canal, the overshot gates may be completely up (closed).
    b. Under that mode of operation, all flows, up to a maximum safe flow, will enter the Pablo Feeder Canal (not counting the flow through the canal gate in a flashboard structure for instream flows).
2. During storm flows, the gates will automatically lower (i.e., open) to pass the storm flows.

It is likely that two overshot gates, if completely opened, would pass approximately 600 CFS of flood flows. However, the dimensions were not carefully surveyed, and it is always a good idea to have some redundancy at an important site such as this. It is also possible that floating trash can foul one of the gate flow paths. Therefore, the final design will likely select 3 overshot gates.

Overshot gates, such as shown in Figure 26, are recommended because:

1. Much of the trash will be floating, and it will pass over a check structure more readily than it would pass under a sluice or radial gate design.
2. The overshot gate, hinged only at the bottom, can be completely lowered to help remove any bed load (gravel, rocks) that might accumulate upstream of it.

Figure 26. Example of an early automated overshot gate near Lethbridge, Canada

Figure 27. Hinged overshot gate in a new structure, almost completely open. Umatilla, Oregon

A Langemann gate would be an excellent design for this location for regular irrigation. However, the high storm flows are the major problem here, and with the storms comes a bed load problem. Also, the large floating trees are likely to damage anything that is not constructed in a very heavy duty manner.

Bottom-hinged overshot gates are available from a variety of vendors and are sometimes fabricated locally. The gates for this installation must be very heavy duty, and the cables must be shielded from the flow and debris.

ITRC can provide the control logic; some gate vendors also sell their gates with control logic. However, there are some control specifics that many vendors cannot match. Some specifics are:

- The control timestep must be 1 minute or less.
- Redundant gate position and water level sensors must be used, and must be incorporated properly into the control logic so that that system will operate if a sensor should fail.
- The control must be guaranteed to maintain the pool water level within +/- 0.1' of the target (to be designated as 0.1' below the crest of the flashboards), under a wide range of flow rate conditions until the gates are completely open.
- The selection of the actuators must be done in conjunction with the design of the control logic because the water level control criteria must be met for extreme cases of steep hydrographs. In other words, the gates will need to be moved very quickly but in a very stable manner. The special criteria for water level control during large storm events is that the upstream water level must be controlled within +/- 0.20'.

There is fairly extensive spalling on the concrete on the structures at this location. It was beyond the scope of this report to determine if that spalling has any negative structural impacts, or if it is more cosmetic and can be repaired.

Control Improvements near Kicking Horse Reservoir

Figure 28 shows the existing water distribution system near Kicking Horse Reservoir.

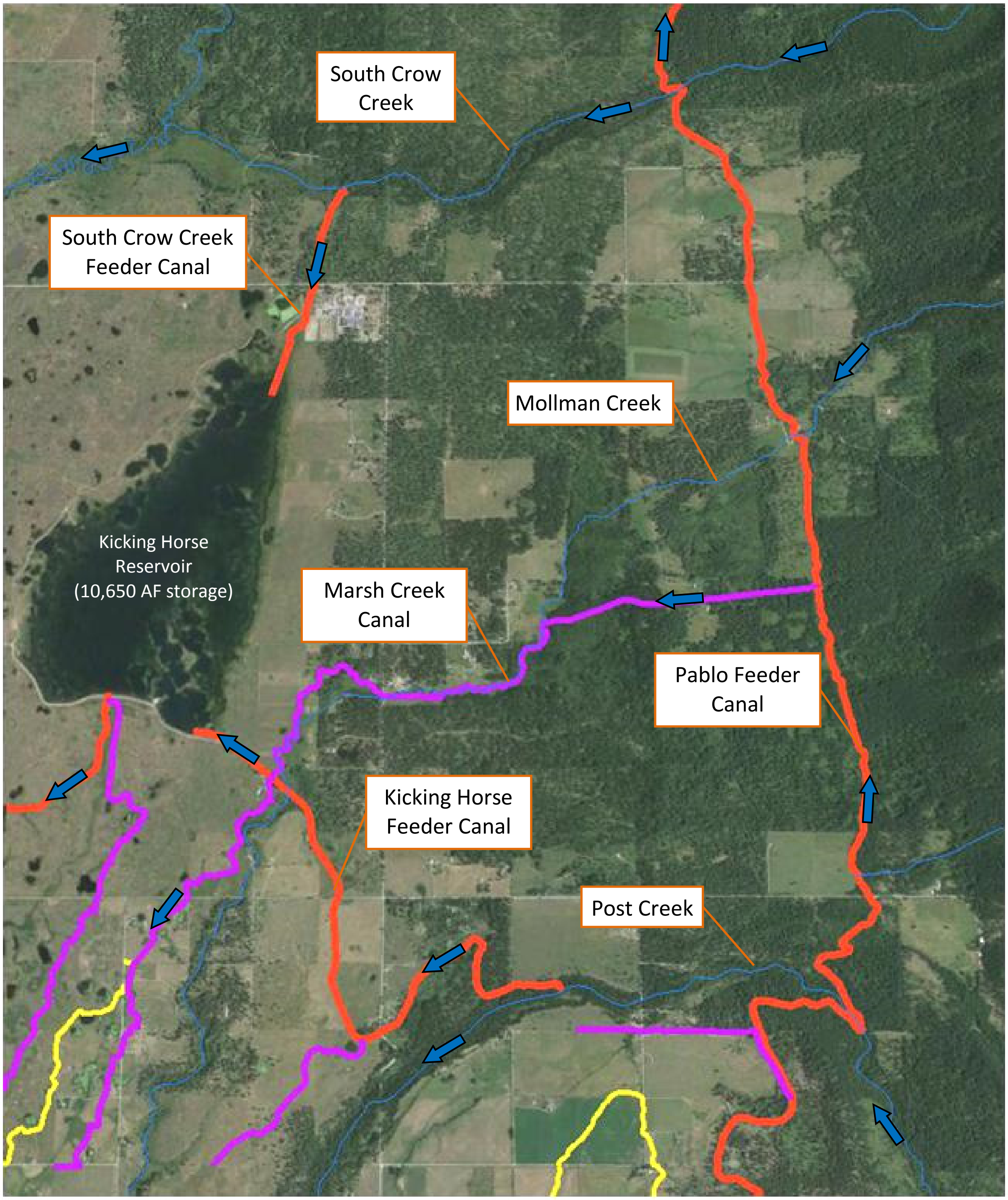

Figure 28. Existing water distribution system near Kicking Horse Reservoir

Kicking Horse Reservoir has a maximum storage volume of approximately 10,650 AF. The movement of water near Kicking Horse Reservoir is as follows:

- Variable flow rates travel down Post Creek as well as South Crow Creek from the Pablo Feeder Canal.
- Kicking Horse Reservoir has two inflow water sources:
  - Post Creek via the Kicking Horse Feeder
  - South Crow Creek via the South Crow Creek Feeder
- Kicking Horse Feeder also captures excess flows from the Marsh Creek Canal.
- Outflows from Kicking Horse Reservoir service the Post A Canal and Ninepipe Reservoir.

Overview of Modernization Changes near Kicking Horse Reservoir

The overall main goals for the modernization changes near the Kicking Horse Reservoir are:

- Divert all excess creek flows towards the reservoir to be utilized for irrigation in the Post Canal Unit.
- Easily manage large flow variations due to storm events.

Figure 29 shows the overall control and management changes near Kicking Horse Reservoir. The overall changes include:

1. The flow rate will be limited in the Pablo Feeder Canal at Post Creek as well as South Crow Creek. All excess flows will continue down the two creeks (see previous report sections).
2. The canal gates at the head of the Kicking Horse Feeder Canal will be automated to maintain a target downstream flow rate in Post Creek. All excess water will be diverted into the canal up to the maximum flow capacity.
3. A new flow measurement flume will be constructed near the end of the Kicking Horse Feeder Canal to remotely monitor the flow rate entering the reservoir.
4. A new flow control structure will "restart" the flow rate to the downstream portion of the South Crow Creek while a new water level control structure will divert all excess flows towards Kicking Horse Reservoir. Automated gates in the two new control structures will be remotely controlled to manage storm flows to show up at the site.
5. The discharge flow rate from Kicking Horse Reservoir will be remotely monitored.
6. Multiple existing check structures will be improved to provide better water level control.

Site-by-site features and recommended changes are described in the following sections.

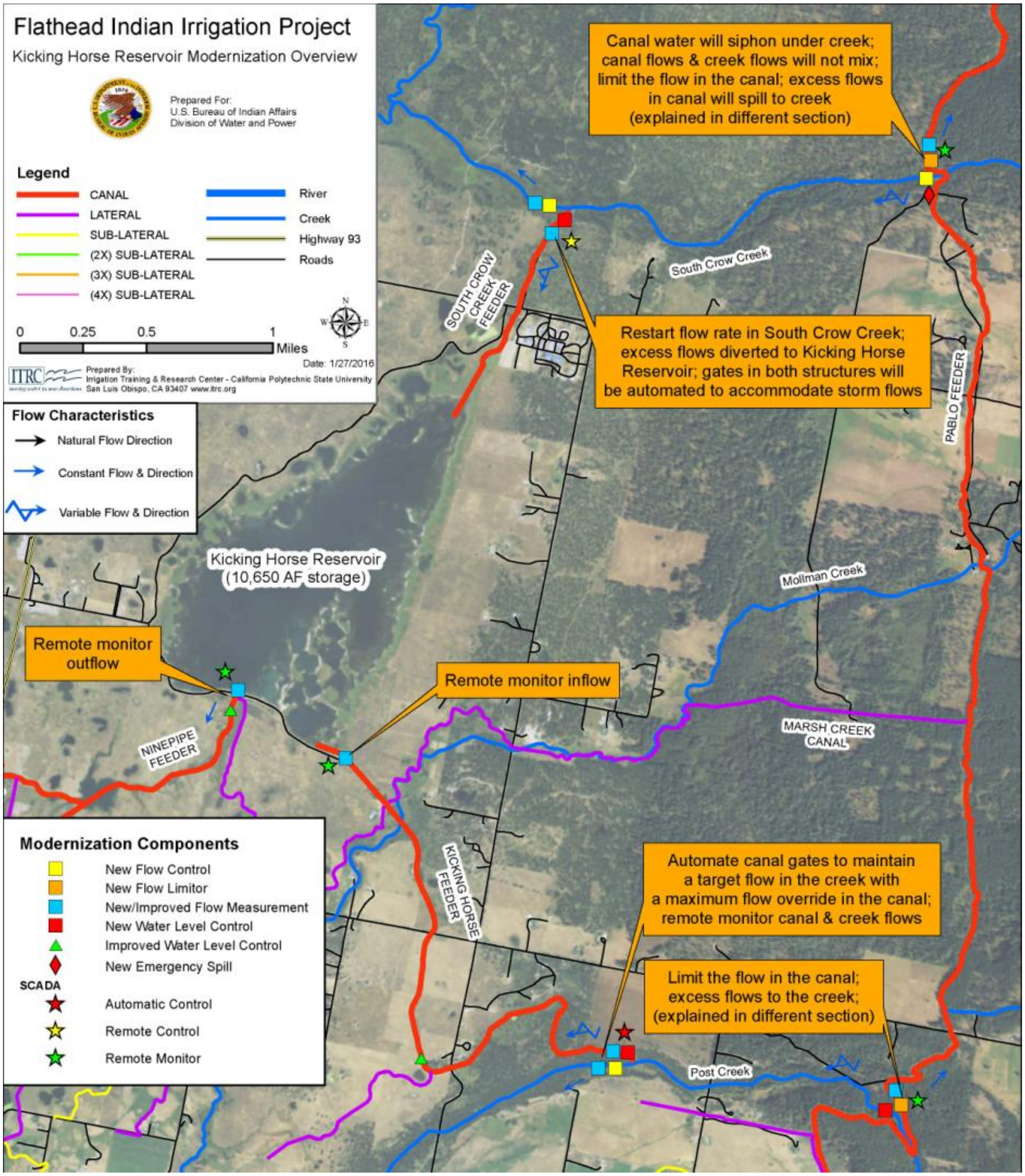

Figure 29. Inflow and outflow modernization changes to Kicking Horse Reservoir

Head of Kicking Horse Feeder Canal

Figure 30 shows the existing control at the head of the Kicking Horse Feeder Canal on Post Creek.

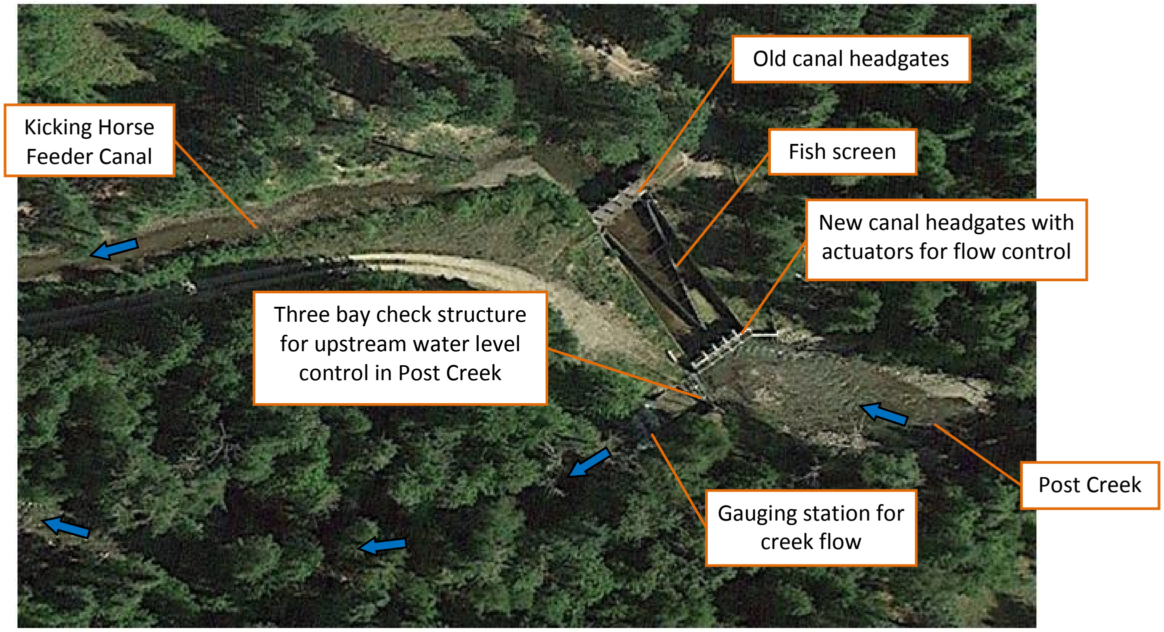

Figure 30. Existing control at the head of the Kicking Horse Feeder Canal on Post Creek

Figure 31 shows photos of the existing control structures at the canal and creek bifurcation. The existing control is as follows:

- A fairly new flow control structure has three sluice gates with electrical actuators to set a target flow rate into the Kicking Horse Feeder Canal. The actuators are not automated.
- A three bay flashboard check structure in Post Creek raises the upstream water level for the canal diversion.
- An inadequate gauging station for the downstream creek flows is located immediately after the check structure.
- Immediately downstream of the new flow control gates is a fish ladder and the old canal headgates.

Figure 31. New canal headgates (top left), fish screen and old headgates (top right), Post Creek check structure (bottom) at the head of the Kicking Horse Feeder Canal

Modernization Changes at head of Kicking Horse Feeder Canal

Modernization of the existing control at the head of the Kicking Horse Feeder Canal will accomplish the following:

- Only allow enough flow to remain in Post Creek to meet required in-stream demand flows
- Divert all excess flows (up to the maximum canal capacity) into the feeder canal to be captured and re-regulated at Kicking Horse Reservoir to be used in the Post Canal Unit
- Provide protection to the canal from high storm flows

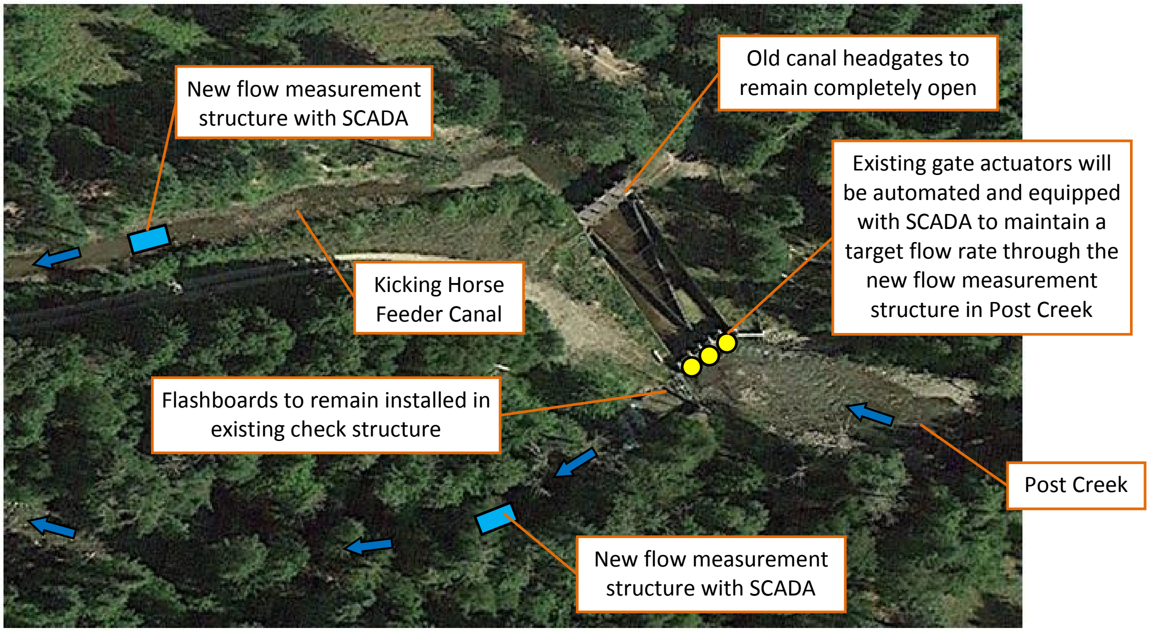

Figure 32. Modernization changes at the head of the Kicking Horse Feeder Canal on Post Creek

The new modernization components include the following:

1. All three canal headgates will be automated using the existing actuators to maintain a target flow rate to the downstream portion of Post Creek while simultaneously diverting the excess creek flow into the feeder canal.
2. A new flow measurement structure will be constructed in Post Creek.
   a. The creek target flow rate will be remotely set from the FIIP office, via SCADA. It can also be set on-site.
   b. The creek flow rate measurement reading will be hardwired back to a PLC at the automated canal headgates for continuous gate adjustments.
3. A new flow measurements structure will be constructed in the feeder canal approximately 250 ft. downstream of the old feeder canal headgates.
   a. The canal flow rate measurement reading through the structure will be hardwired back to the canal headgates to limit the flow rate into the feeder canal.
   b. A backup flow measurement scheme, using the head differential across the gates and the gate positions, will serve for redundancy in case the feeder canal flow measurement structure has problems.
   c. If the maximum canal capacity is exceeded, the control logic for the three headgates will switch to flow control to limit the flow into the feeder canal.
4. The flashboards will need to remain installed in the existing check structure to raise the water level enough for the canal headgates to operate.

Head of South Crow Creek Feeder Canal

Figure 33 and Figure 34 show the existing control at the head of the South Crow Creek Feeder Canal.

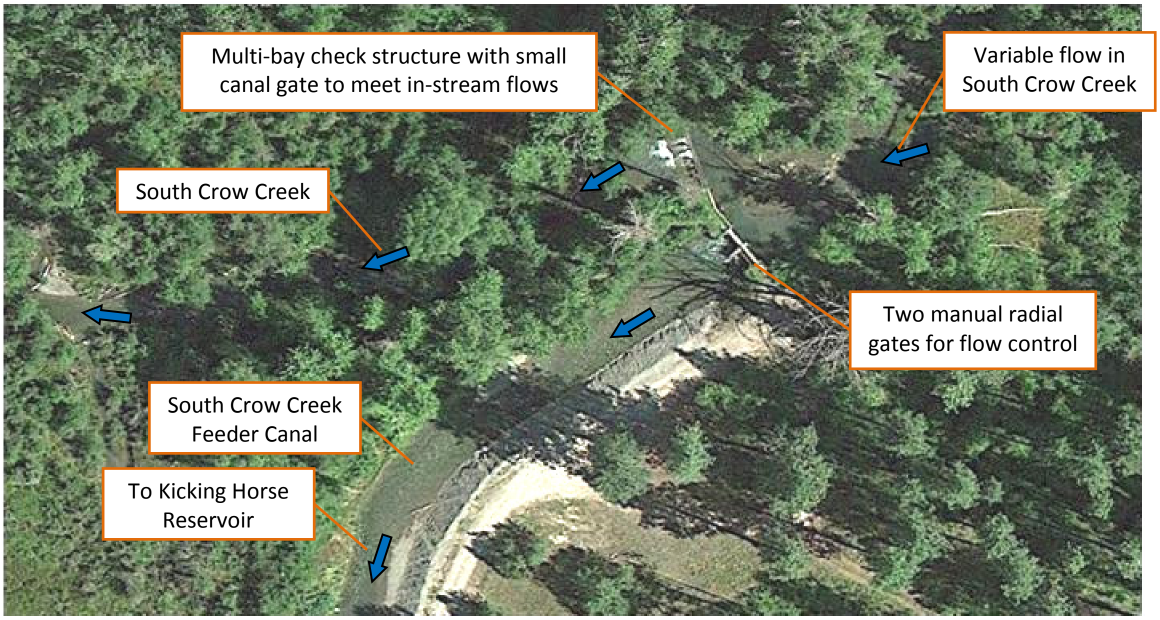

Figure 33. Aerial of the head of the South Crow Creek Feeder Canal

Figure 34. Control structures at the head of South Crow Creek Feeder Canal

Figure 35. South Crow Feeder Canal downstream of the headworks

Figure 36. View of headworks of South Crow Feeder Canal from downstream

The existing control is as follows:

- Two manual radial gates control the flow rate into the South Crow Creek Feeder Canal. One of the radial gates is broken and is not used.
- A multiple bay check structure provides upstream water level control in the creek. All excess flows remain in South Crow Creek.
- A small canal gate installed in one bay of the check structure is used to provide in-stream flows to South Crow Creek.
- A gauging station is located in the Feeder Canal approximately 850 ft. from the head for flow measurement. The stage readings are monitored via a GOES station and then converted to a flow measurement based on the site's stage-discharge relationship equation.

Modernization Changes at the Head of South Crow Creek Feeder Canal

The changes made at the head of the South Crow Creek Feeder Canal will:

- Route excess flows (up to 325 CFS) from South Crow Creek into the Feeder Canal to prolong storage of Kicking Horse Reservoir as well as other storage reservoirs upstream in the canal system.
- Provide easier control, management, and safety of large storm flows that must pass down the South Crow Creek (up to 400 CFS).

Figure 37 shows the conceptual modernization changes at the head of South Crow Creek Feeder Canal. It assumes that the existing structures will be demolished and replaced with new structures. *Because of this rather isolated location, the selection of structures/control does not incorporate any PLC, electronic/electrical automation.*

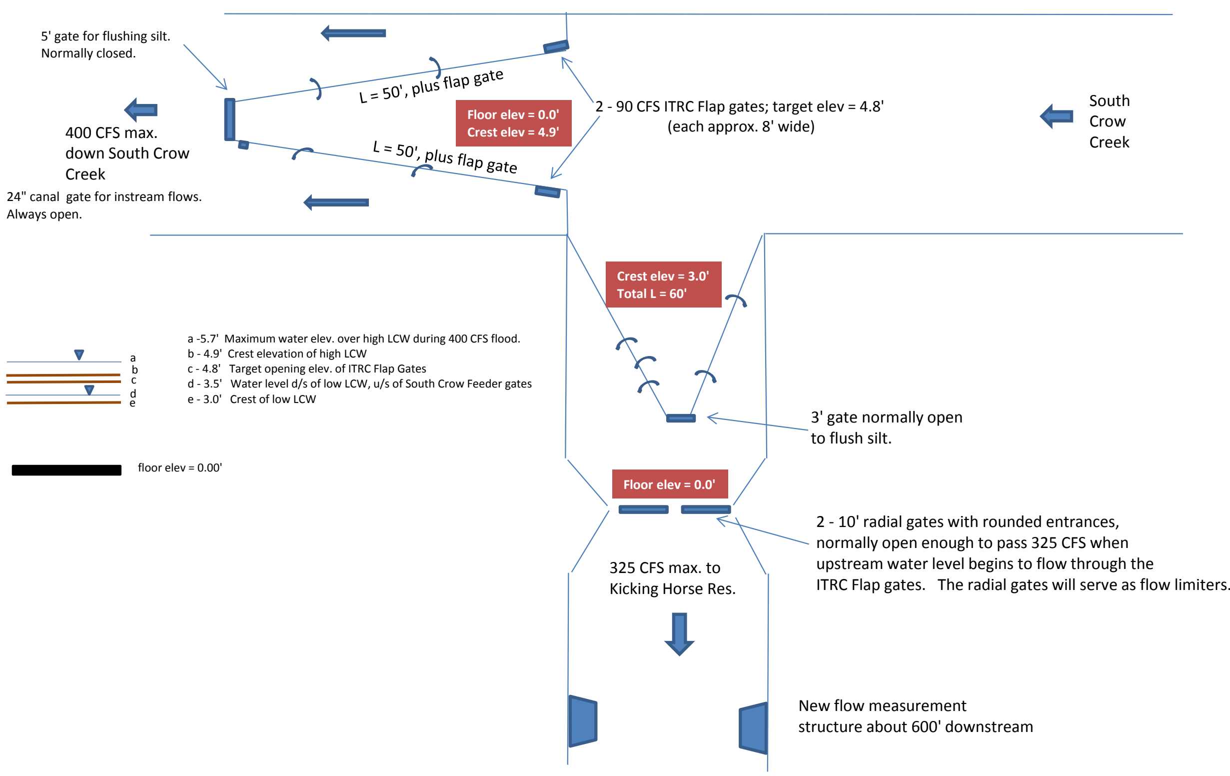

Figure 37. Conceptual modernization changes at the head of the South Crow Creek Feeder Canal (not to scale)

The operation of this system would be as follows:

1. A low (3' high) and relatively short, long-crested weir (LCW), located within the beginning of the Feeder Canal, will raise the water level in the South Crow Creek so that there is always pressure on a gate that will supply in-stream flows, yet not cause relatively large changes in pressure on the instream-flow control gate during typical operation.
2. A high LCW in South Crow Creek, plus two large ITRC Flap Gates, will cause all flow up to a maximum of 325 CFS to pass into the Feeder Canal. This high LCW will cause the water in South Crow Creek to rise over the low LCW.

3. Two large gates in the Feeder Canal, downstream of the low LCW, will be set to deliver a maximum of 325 CFS with an upstream water level that just begins to open the ITRC Flap Gates.
4. Any extra flow will first open the ITRC Flap Gates, and then begin to pass over the high LCW and will continue down the South Crow Creek. It recommended that horizontal trash bars be installed just upstream of the ITRC Flap Gates to deflect trash away from them.
5. Occasionally, sluice gates in both LCW structures will be opened to flush silt.

The structure should operate under a wide variety of flow conditions without human intervention except for checking for trash.

The design should allow for the eventual installation of a fish screen downstream of the new 2 - 10' wide radial gates. For the final design, the elevations and hydraulics will need to be checked to be certain that the high LCW and two ITRC Flap Gates in the South Crow Creek are high enough. It is likely that they will need to be raised by 1-2 feet to allow for losses through the fish screen, plus an eventual flume downstream in the Feeder Canal.

Flow Measurement at the End of the Kicking Horse Feeder Canal

A GOES gauging station is located in the Kicking Horse Feeder Canal just upstream of a chute drop to Kicking Horse Reservoir (see Figure 38).

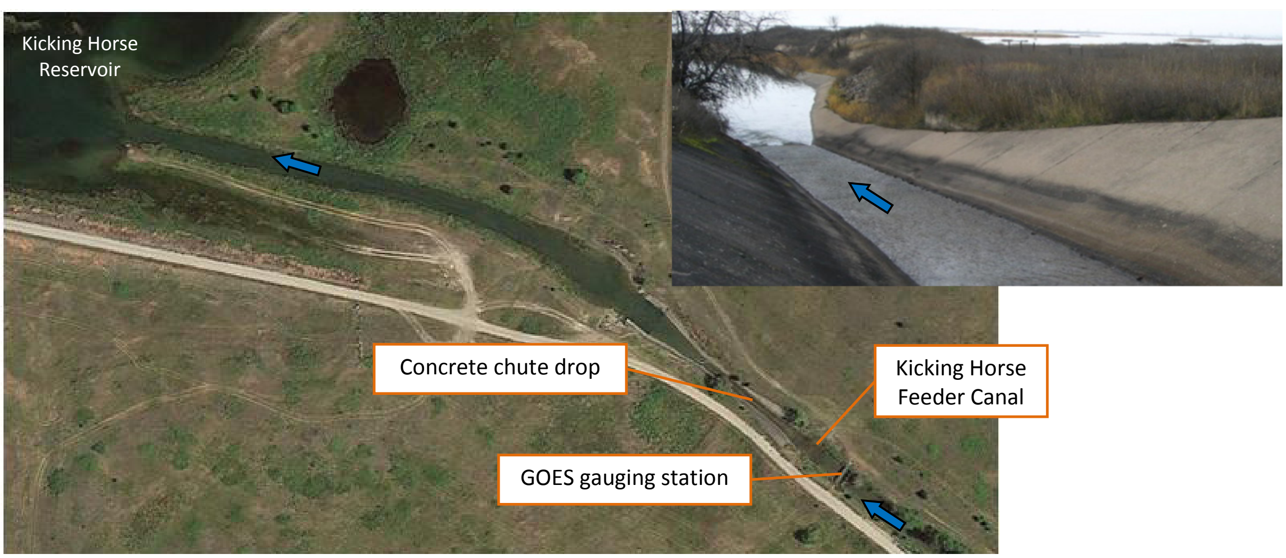

Figure 38. Gauging station and drop chute at the end of the Kicking Horse Feeder Canal

The physical condition of the GOES gauging site is unknown so no conclusion can be made about the accuracy of the flow measurement readings. If more accurate flow measurement is desired, a measurement flume could be constructed at the head of the chute drop as shown in Figure 39. The flow rate through the new flume would be remotely monitored by the new SCADA system.

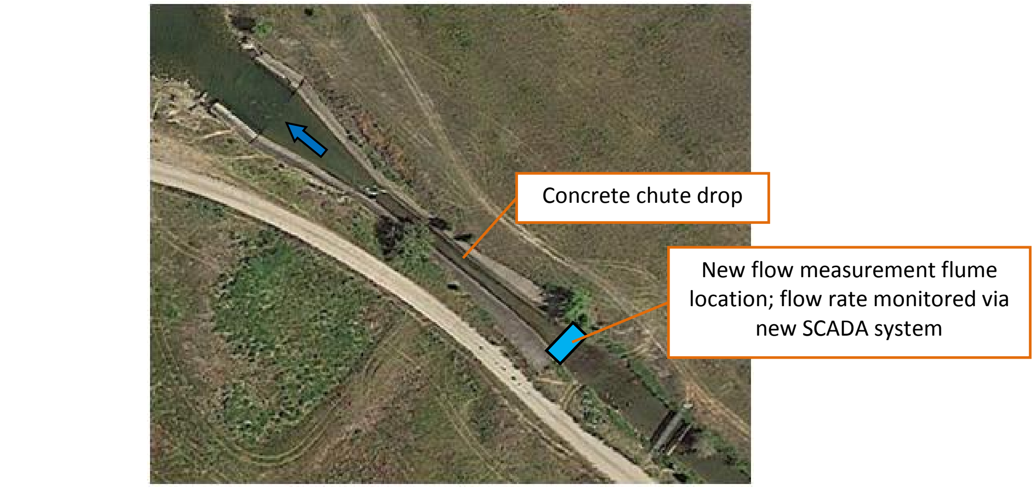

Figure 39. New flow measurement flume location at chute drop in Kicking Horse Feeder Canal

Improvements near the Kicking Horse Reservoir Discharge

Figure 40 shows the existing control near the discharge of Kicking Horse Reservoir.

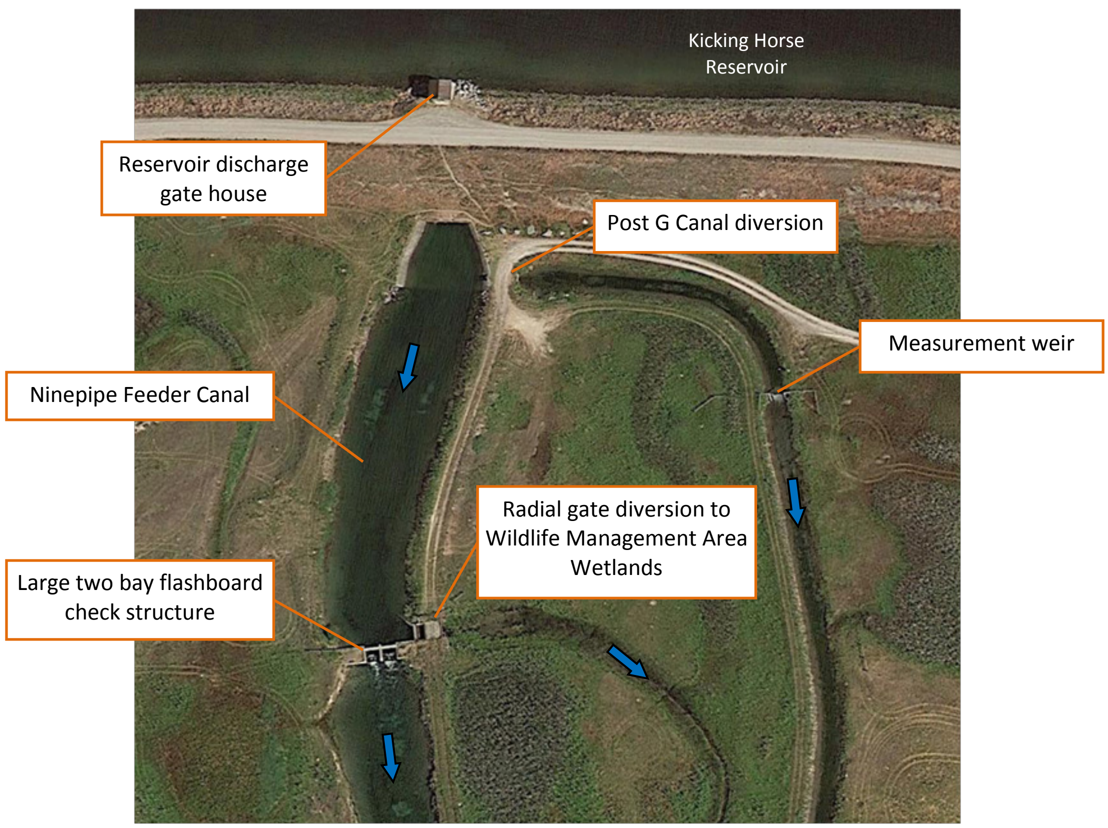

Figure 40. Existing control near the discharge of Kicking Horse Feeder Canal

The existing control is as follows:

- Water is released from Kicking Horse Reservoir into the Ninepipe Feeder Canal. It is unknown how the discharge flow rate is determined.
- A check structure with two individual 10 ft. wide flashboard bays provides upstream water level control for diversions to the Post G Canal and a Wildlife Management Area Wetlands.
- The Post G Canal diverts up to 25 CFS to service a large agricultural area in the Post Canal Unit. A measurement weir located downstream from the canal diversion is used to measure the flow rate.
- A radial gate on the left-hand side (convention = facing downstream) of the Ninepipe Feeder Canal, just upstream of the first Feeder Canal check structure (see Figure 41) controls the flow to the wildlife area. It is assumed that only a small continuous flow rate is diverted from the canal to the wildlife area.

Figure 41. Existing check structure downstream of Kicking Horse Reservoir in the Ninepipe Feeder Canal. Photo taken from HKM 2008 report.

Modernization Changes near the Discharge of Kicking Horse Reservoir

With this type of configuration, the typical operation is as follows:

1. Control the reservoir discharge gates to provide a total flow consisting of:

   Total flow = Flow to Wetlands
   + Flow to Post G Canal
   + Flow needed downstream in the Ninepipe Feeder Canal

2. There will only be three flow rate control points:
   a. Outlet from the reservoir
   b. Headgate of the Post G Canal (about 50 CFS)
   c. Headgate to the Wildlife Management Area Wetlands
3. The function of the first check structure in the Ninepipe Feeder Canal is not to control the flow down the Ninepipe Feeder Canal. Rather, it is a water level control structure that is intended to maintain a constant pressure on the headgates of the Post G and Wetlands discharges.

To accomplish this simple operation scenario, there are three missing parts that need to be added to the existing infrastructure. The changes are shown in Figure 42.

1. The Kicking Horse Reservoir discharge gate(s) will be rated for flow measurement.
   a. Operators will be able to set the target flow rate to the downstream canal system.
   b. The reservoir discharge flow will be remotely monitored via SCADA.

2. The existing check structure in the Ninepipe Feeder Canal can be modified to be a long-crested weir. It is recommended that a 100' long LCW be incorporated into one of the 10 ft. wide bays.
3. A flow measurement flume should be installed in the canal that supplies the Wildlife Management Area Wetlands.

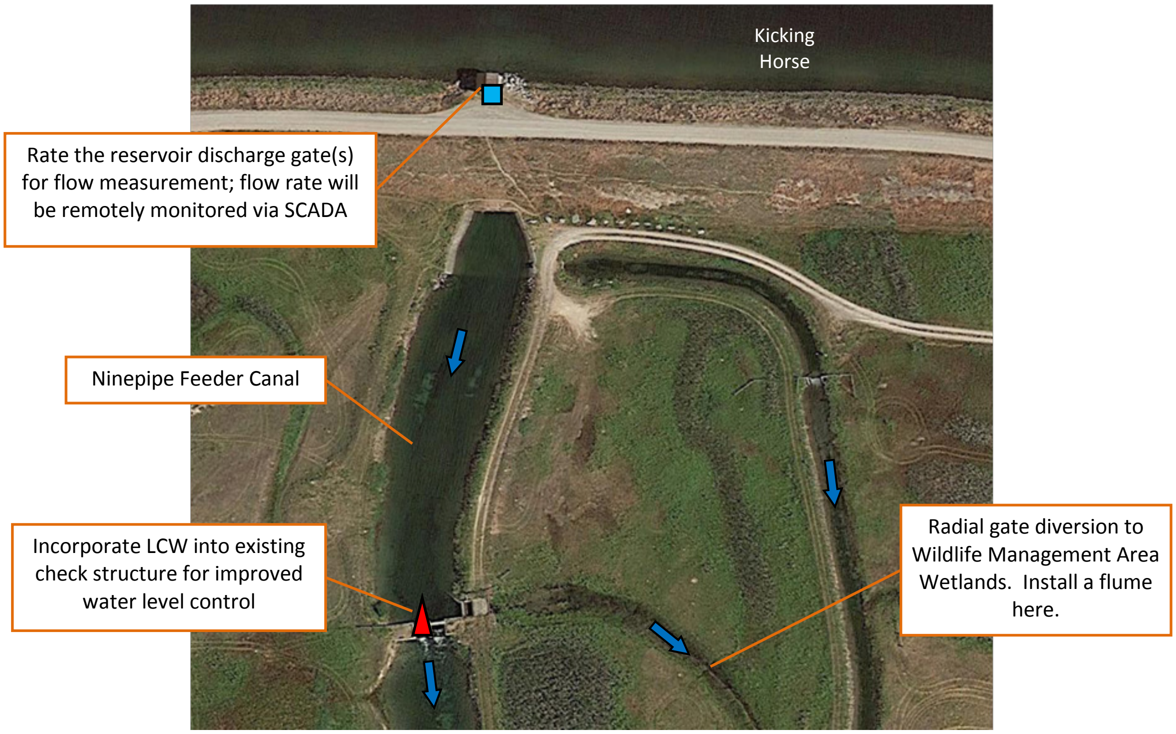

Figure 42. Modernization changes made at the discharge of Kicking Horse Reservoir

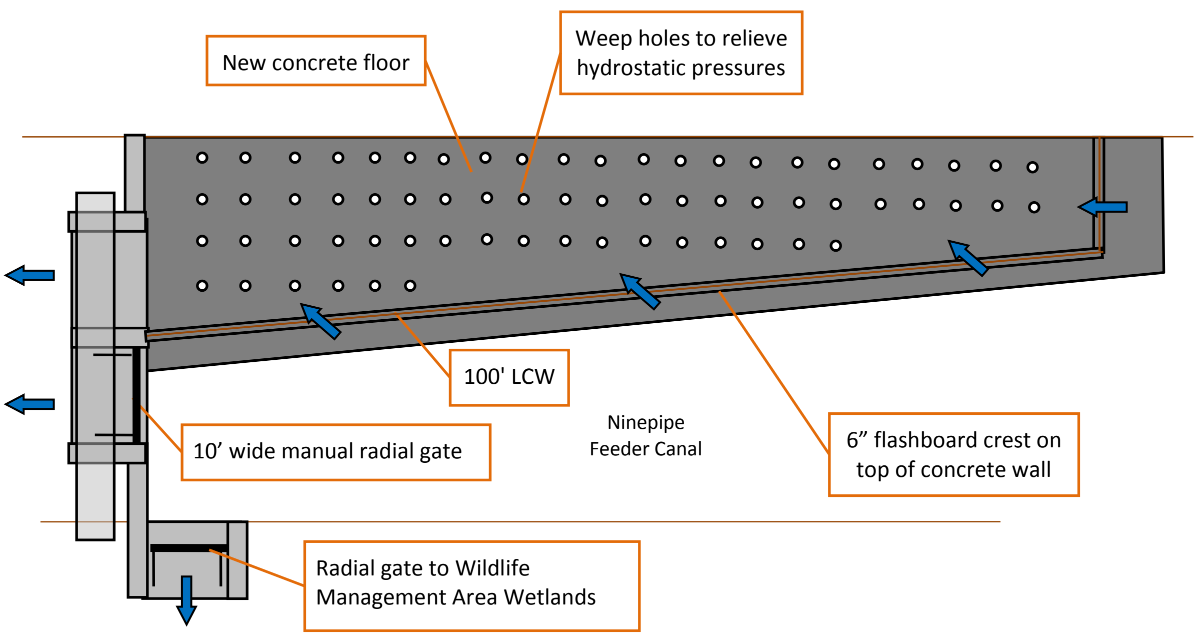

Figure 43. Conceptual plan view of new LCW design at the first Ninepipe Feeder Canal check structure

Control Improvements near Ninepipe Reservoir

Figure 44 shows the general canal layout near Ninepipe Reservoir. Ninepipe Reservoir has a maximum storage volume of approximately 15,000 AF. The major water movement to/from Ninepipe Reservoir is as follows:

- Water enters Ninepipe Reservoir from the East, via the Ninepipe Feeder Canal which is supplied by the Kicking Horse Reservoir (described previously).
- During times of water shortages, water is pumped from Crow Creek (north of Ninepipe Reservoir) into the Post P Canal and then diverted into the Ninepipe Reservoir.
- Releases from Ninepipe Reservoir feed directly into the Post C and D Canals by gravity, at the Ninepipe Reservoir dam.

In addition, there is an important bifurcation on Kicking Horse Reservoir. Just downstream of an intermediate and in-line pond (located about midway along the Ninepipe Feeder Canal), the Post A Canal is supplied. This intermediate and in-line pond is evidently not used for storage.

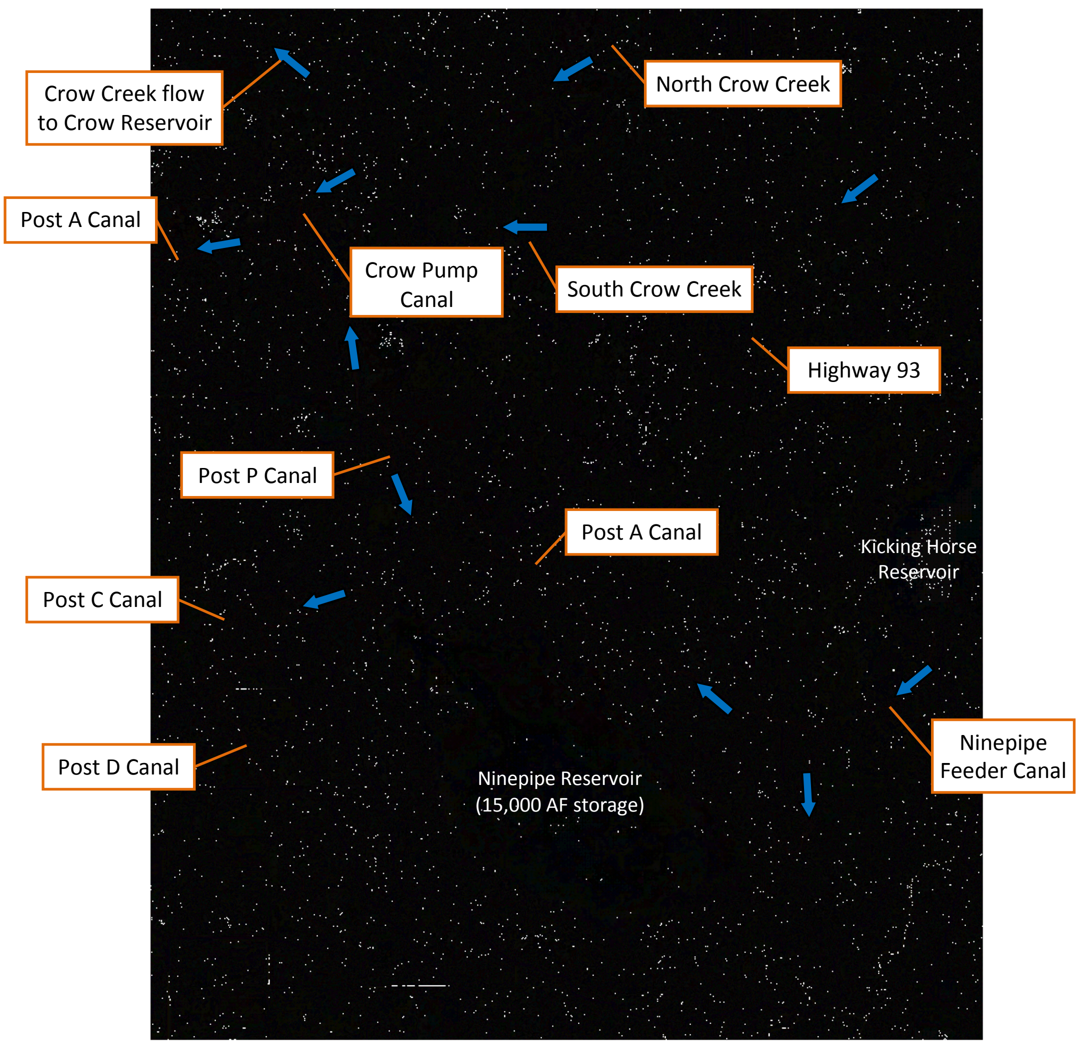

Figure 44. General canal layout near Ninepipe Reservoir

Overview of Modernization Changes near Ninepipe Reservoir

Figure 45 shows the general overview of the modernization changes near Ninepipe Reservoir.

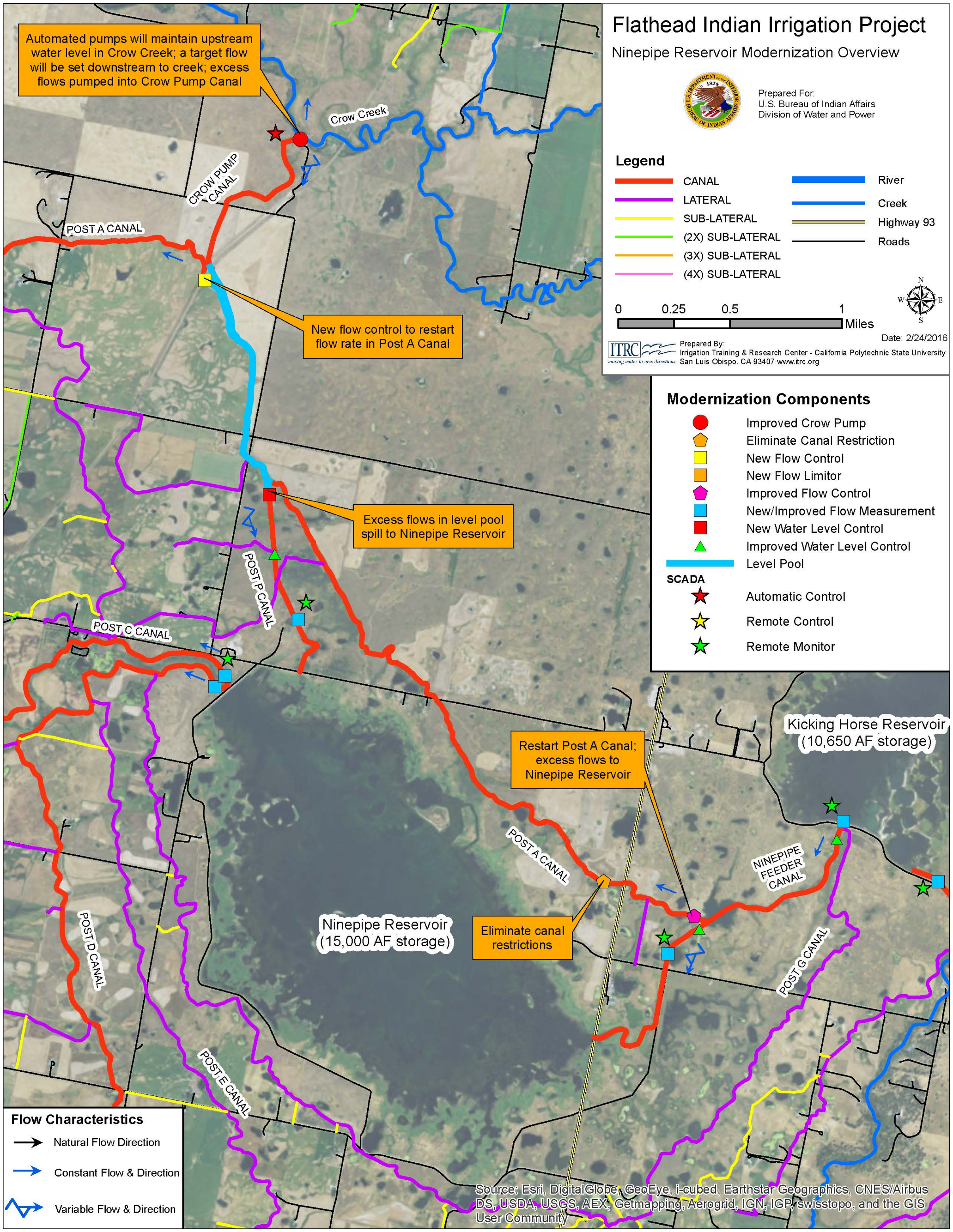

Figure 45. General overview of modernization changes near Ninepipe Reservoir

The general modernization changes near Ninepipe Reservoir include:

1. The structures at the discharge from the intermediate in-line pond of the Ninepipe Feeder Canal can be upgraded. This is not seen as having major importance, because discrepancies in flow rate will all eventually flow into Ninepipe Reservoir. However, if structures are replaced, this plan provides a visualization of how they should be upgraded.
2. Eliminate the existing canal restrictions in the Post A Canal.
3. Upgrade and automate the Crow Creek pump station to maintain the water level upstream of the diversion weir in Crow Creek.
    a. A target creek water level, upstream of a diversion weir, will maintain a constant pressure on a sluice gate in the diversion weir, ensuring a constant flow rate that will continue down Crow Creek as instream flow.
    b. All excess creek flow (up to the canal maximum) will be pumped into a new level pool in sections of the Post A and Post P Canals.
4. A new flow control structure in the Post A Canal, to the NW of Ninepipe Reservoir, will "restart" the downstream Post A Canal flow rate.
5. A new water level control structure will maintain a fairly constant water level in the new level pool while automatically spilling all excess canal flows to Ninepipe Reservoir.
6. Flow measurement will be improved at inlets and the outlet to Ninepipe Reservoir.

The following sections provide further explanation of modernization changes to be made at individual sites near Ninepipe Reservoir.

<u>Head of the Post A Canal</u>

Figure 46 shows the existing layout and control of the canal system near the head of the Post A Canal, located at the outlet of the intermediate in-line pond of the Ninepipe Feeder Canal. The existing control is as follows:

- Water released from Kicking Horse Reservoir into the Ninepipe Feeder Canal eventually flows into a large pond. That pond is not used for storage; its level remains fairly constant.
- An existing three bay check structure (see Figure 48) at the pond exit, at the head of the remainder of the Ninepipe Feeder Canal, maintains the upstream water level in the pond. Each bay is approximately 6 ft. wide and a large concrete chute drop is present on the downstream side of the check structure.
- The Post A Canal diverts approximately 30-50 CFS from the pond.
- Two flow restrictions in the Post A Canal downstream of Highway 93 limit the canal flow:
    - An abandoned check structure located approximately 500 ft. downstream of the highway causes approximately 0.15 ft. of headloss in the canal.
    - A farm road crossing culvert approximately 0.25 miles downstream of the highway causes approximately 0.5 ft. of headloss in the canal.

Figure 46. Existing control near the head of the Post A Canal

Figure 47. Outlets from Pond. Ninepipe Feeder Canal on bottom left. Post A Canal on upper left.

Figure 48. Structure at exit of pond and entrance to remainder of Ninepipe Feeder Canal. Photo taken from HKM 2008 report.

Figure 49. Structure at the head of the downstream section of the Kicking Horse Feeder Canal. View from downstream. Pond is seen upstream of the structure. Photo taken from HKM 2008 report.

Modernization Changes At/Near the Bifurcation of Post A Canal and Ninepipe Feeder Canal

The modernization changes shown in Figure 50 are recommended.

1. A new LCW will be incorporated into the existing check structure on the Ninepipe Feeder Canal as shown in Figure 51 to maintain a fairly constant upstream water level in the intermediate in-line pond. This will allow flow changes from Kicking Horse Reservoir to move more quickly to Ninepipe Reservoir. It will also stabilize the flow control into Post A Canal.
2. A flow measurement flume will be constructed just upstream of the concrete chute drop at Eagle Pass Trail. The flow rate to Ninepipe Reservoir from the Feeder Canal can be remotely monitored. This site has been selected because of good access from a paved road.
3. A new rectangular sluice gate can be installed at the head of Post A Canal for improved flow control and measurement. It should be installed in the middle of parallel walls, to create a suppressed condition, with a flat floor. It does not appear that there is sufficient head available for a flume for flow measurement.
4. Operations staff originally thought that the culvert of Post A Canal under Highway 93 restricted flow in Post A Canal. That is not the case; a quick survey of water surface elevations showed almost no drop from one side of the road to the other. To increase the flow rate capacity in the Post A Canal, the following modifications should be made on the west side of Highway 93:
    a. The abandoned check structure will be completely removed.
    b. The small road culvert crossing will be replaced with a larger culvert pipe to reduce the headloss through the pipe.

Figure 50. Improvements near bifurcation of Ninepipe Feeder Canal and head of the Post A Canal

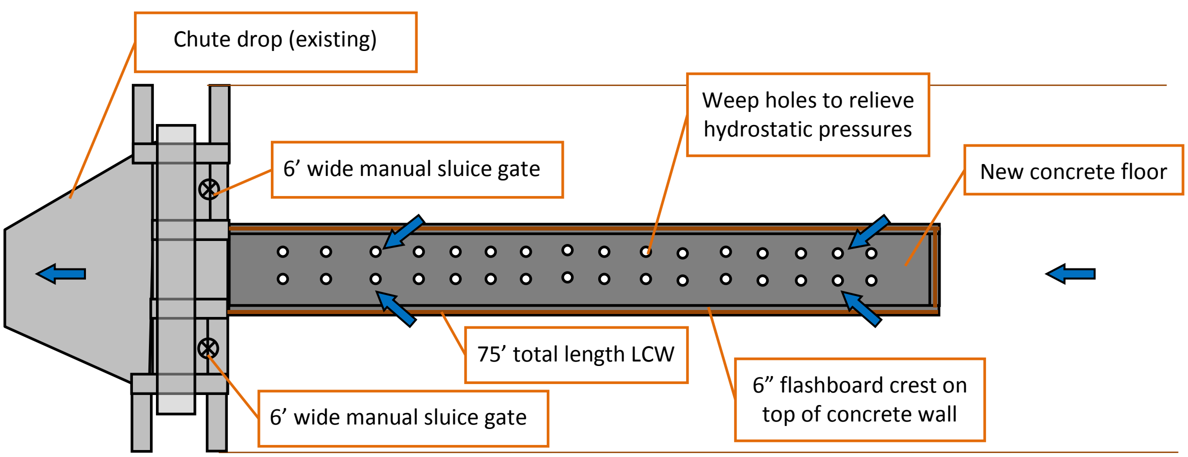

Figure 51. Conceptual plan view of new LCW structure in the Ninepipe Feeder Canal, at the outlet of the intermediate in-line pond (not to scale)

Existing Conditions: Post A and Post P Canals and Crow Creek Pump North Ninepipe Reservoir

Figure 52 and Figure 53 shows existing conditions to the north of Ninepipe Reservoir.

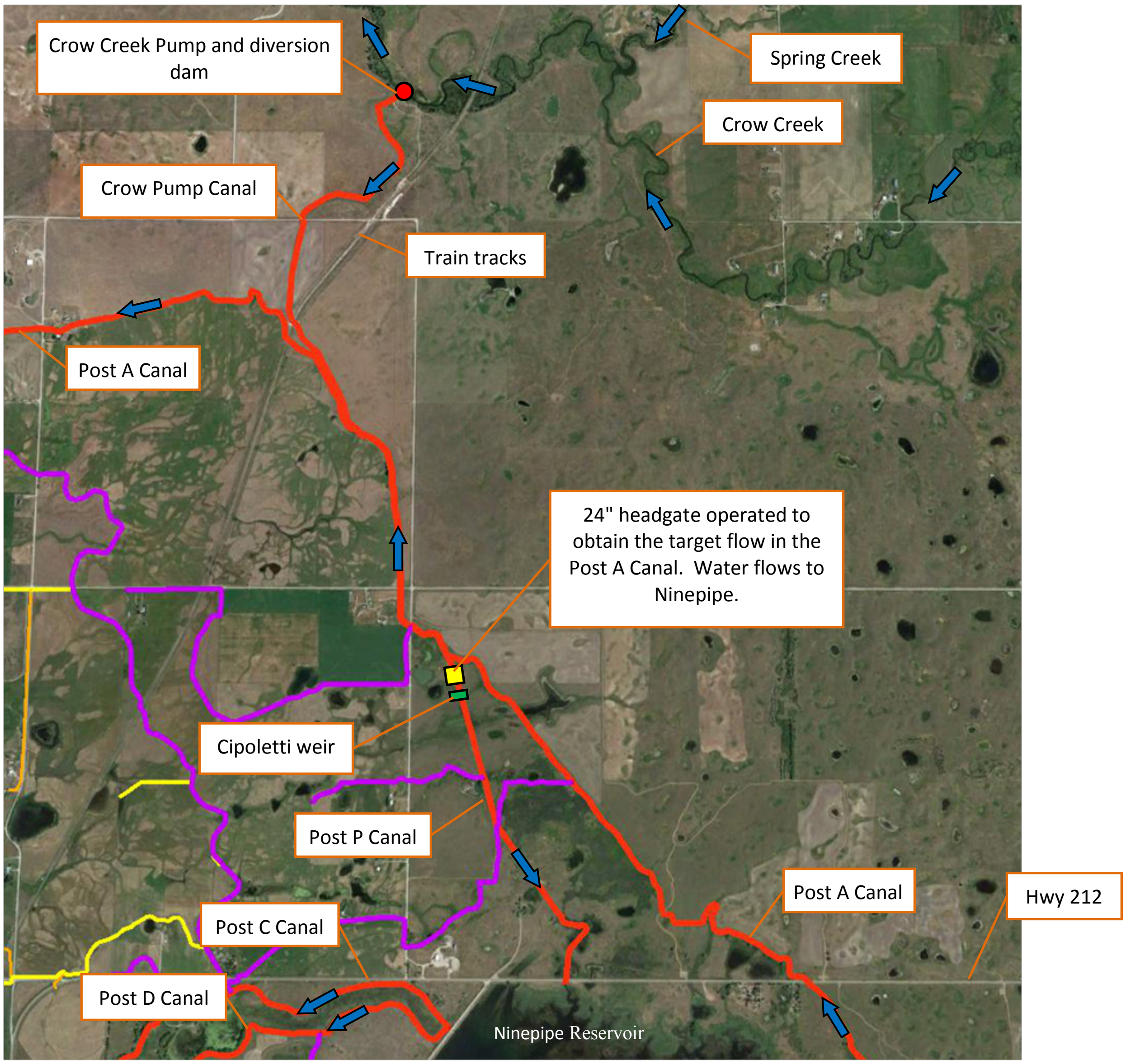

Figure 52. Existing control of the Crow Pump, Post A Canal, and Post P Canal north of Ninepipe Reservoir

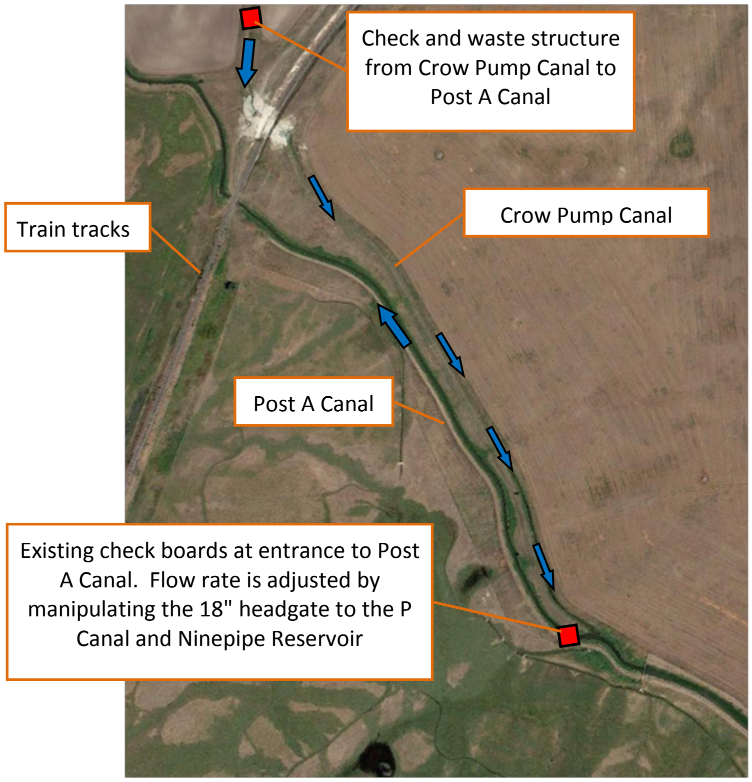

Figure 53. Existing control in the Post A and Crow Pump Canals near the train tracks

Existing control is as follows during normal operations (when the Crow Creek Pump is not operating):

- Water flows down the Post A Canal from the intermediate in-line pond on the Ninepipe Feeder canal. This is a long canal.
- A 24" headgate on the left-hand bank of the Post A Canal, at the head of the P Canal, is operated to obtain the target flow rate across a weir board check structure in the Post A Canal. That weir board check structure is just downstream of the Post A Canal and Crow Pump Canal bifurcation.
- A Cipoletti weir is located just downstream of the 24" headgate for the P Canal.
- Evidently the Crow Pump Canal does not need to be isolated, because the slope of the bottom of the canal is upward, as one proceeds north.

Existing control appears to be as follows when the Crow Creek Pump is operating:

- The Crow Creek Pump discharges into the Crow Pump Canal. This flows south and meets flows from the Post A Canal.
- The 24" headgate at the head of the Post P Canal is either set for a large flow rate to the Ninepipe Reservoir or is set completely wide open.
- A check and waste structure just north of the Crow Feeder Canal/Post A Canal bifurcation spills any excess flow to the Post A Canal.

Figure 54. Check and waste to Post A Canal (upper) from the Post Pump Canal. Post A Canal check structure just d/s of Post A Canal and Post Pump Canal bifurcation (bottom). Photos provided from HKM 2008 report.

Figure 55. 24" Control gate into Post P Canal, and Cipoletti weir downstream of that gate. Photos provided from HKM 2008 report.

Crow Creek Pump

The Crow Creek Pump and diversion are listed as one of the tribes' Water Rights Compact Rehabilitation and Betterment Projects.

Variable upstream creek flows, operational canal spills, and farmer field runoff are the three sources of water in Crow Creek (refer to Figure 56). It can be seen that many of these return flows converge at the Crow Creek Pumping Plant.

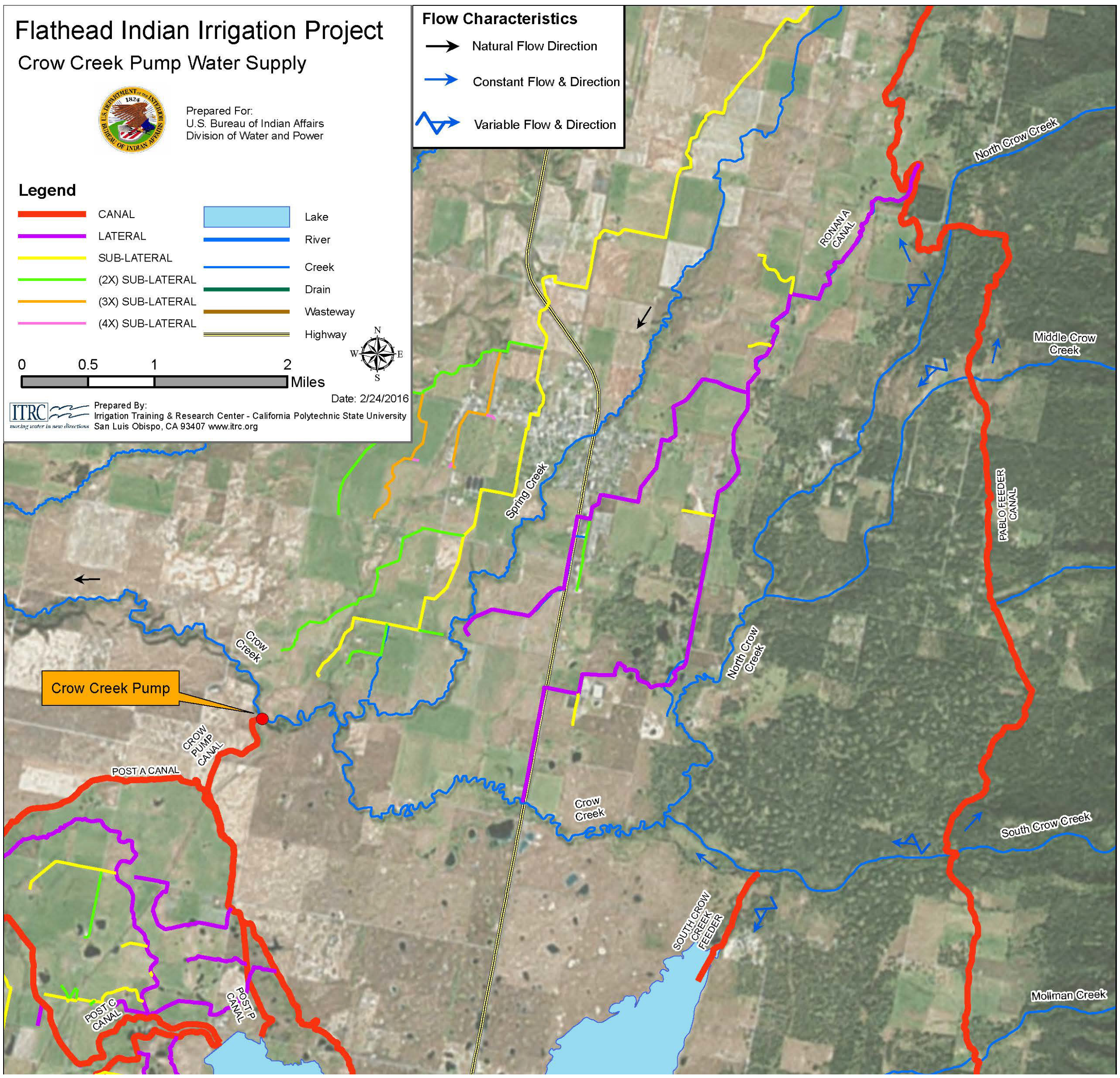

Figure 56. Upstream watershed for the Crow Creek Pumping Plant

The Crow Creek Pumping Plant (see Figure 57) consists of a diversion weir in Crow Creek, plus a pump house with one 150 HP pump. The maximum pump flow rate is about 20 CFS, with a static lift from Crow Creek to Post P Canal of approximately 43 feet. The pump is operated to supplement Ninepipe Reservoir and the lower Canal A when there is not an adequate supply available in Ninepipe Reservoir.

Figure 57. Crow Creek Pump and diversion weir. Photos taken from HKM 2008 report.

Modernization Changes

Figure 58 and Figure 59 shows the conceptual control changes to the Post A Canal, and Post P Canals, the Crow Pump Canal, and the Crow Creek Pumping Station north of Ninepipe Reservoir.

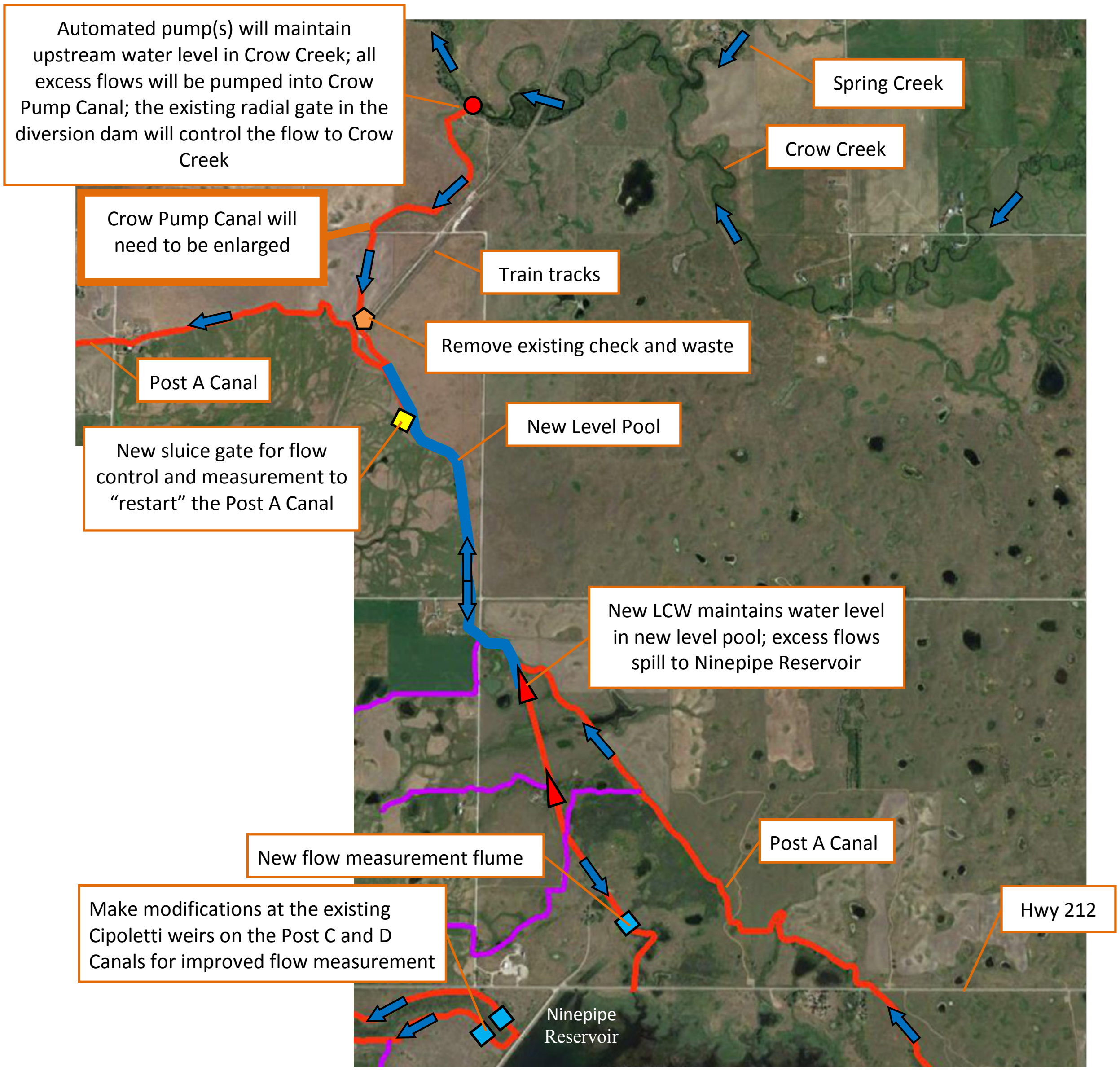

Figure 58. Control changes to the Post A and Post P Canals near Ninepipe Reservoir

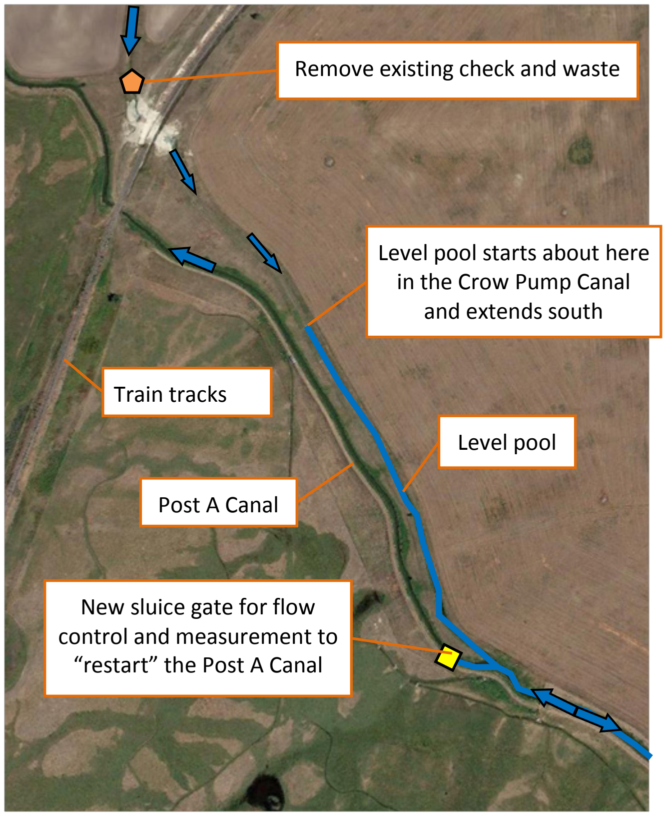

Figure 59. New "restart" point on the Post A Canal near the train tracks

The control changes include:

1. The Crow Pump Station will be modified as follows:
   a. The pump station will automatically maintain the water level in Crow Creek, just upstream of the diversion dam.
      i. It is likely that the existing pump will not be suitable for VFD operation.
      ii. Depending upon flow rate availability, it may be desirable to install an additional pump.
      iii. It appears that there is sufficient storage upstream of the diversion dam, and the in-stream flow control is good enough that the pumps can be automated as on/off (rather than with sophisticated VFD controls) using a PLC and redundant water level sensors.
   b. The existing radial gate in the creek diversion dam (refer back to Figure 57) will control the flow rate to the downstream portion of Crow Creek.
   c. All excess river flows up to the maximum canal capacity will be pumped up into a new level pool composed of the portions of the Post P and A Canals.
2. The modified pump station flow rate was selected considering the following:
   a. The existing flow rate is reported to be approximately 20 CFS.
   b. The new Hillside Reservoir operation will supply up to 55 CFS to the Moiese area; that water was previously supplied from the Crow Reservoir. Because Crow Creek supplies the Crow Reservoir, this modified pump station could pump the same (55 CFS) flow as an exchange.

   c. Historically, the flow over the Crow Creek weir, adjacent to the Crop Pump station, are in the 45-70 CFS range during most of the summer. In the years 2014 and 2015, the flows dropped closer to the 40-50 CFS range. Considering the recent flow rate history, a total pump flow rate of 50 CFS was selected.

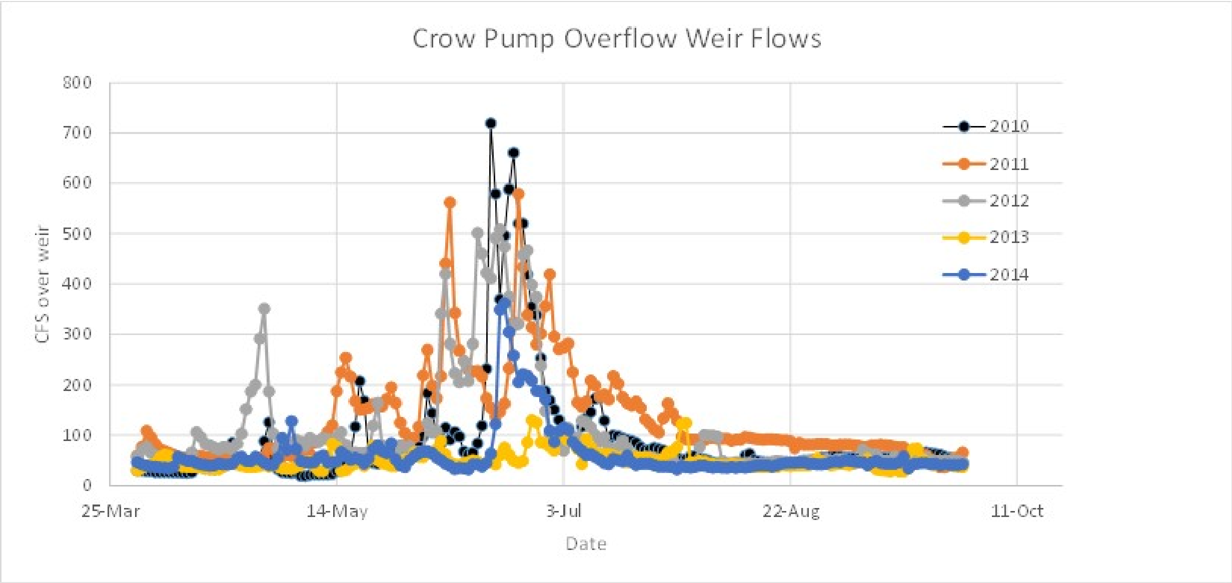

Figure 60. Historical flows over Crow Creek weir

3. It is likely that the existing 20 CFS pumping plant would remain in place.
4. The new pumps would have the following approximate characteristics:
   a. Two identical pumps:
      i. 15 CFS each
      ii. Inverter-duty motors
      iii. TDH = 49'
      iv. 100 HP motor on each; about 225 HP total input HP to motors
   b. VFD controls
   c. Automatic trash screen in front of new pump bays for these two pumps
   d. Pumps sequenced and with speed control to maintain a constant water level upstream of the weir.
   e. 30" steel discharge manifold pipe, with 30" buried PVC conveyance to the canal
5. Because the water level control does need to be precise, the built-in PLC of the VFD controller, using built-in PID logic, could be used to control the VFD speed. For simplicity and likely higher efficiency, it is recommended that the VFD pump be used first. If the available Crow Creek flow rate exceeds 20 CFS, the existing pump can be manually started. That pump should have an automatic shutoff in case the water level drops below some pre-set level.
6. ***The Crow Pump Canal will need to be upgraded to carry the additional flow rate. It is likely that the upstream banks (near the pumps) will need to be raised, to create the water surface slope necessary to overcome the canal friction and any culvert pressure losses. This modernization study did not examine the hydraulics of this requirement.***

7. A new flow control structure will be constructed at the existing check structure in the Post A Canal. The flashboards will be replaced with a sluice gate to provide flow control and measurement to "restart" the Post A Canal.
8. A new long-crested weir (LCW) structure will be constructed at the head of the Post P Canal to maintain a water level elevation in a new level pool. All excess flows from the level pool will spill to Ninepipe Reservoir. This water level control will provide excellent flow rate stabilization at the head of the downstream portion of the Post A Canal.
9. An existing check structure in the Post P Canal, at the head of a small lateral, will be modified to incorporate a LCW.
10. A new flow measurement flume will be constructed approximately 1,500 ft. upstream from the Highway 212 crossing to accurately measure the flow spilling to Ninepipe Reservoir. SCADA will be incorporated to remotely monitor the flume flow rate.
11. Modifications will be made at the two existing Cipoletti weirs in the Post C and D Canals downstream of the Ninepipe Reservoir discharge for improved flow measurement. The flow rates released into the two canals will be remotely monitored.

<u>Level Pool LCW Spill to Ninepipe Reservoir</u>

Figure 61 shows the location of the existing control gate in the Post A Canal to divert water into the Post P Canal and to Ninepipe Reservoir. This 24" canal gate is being used to control the water level in the Post A Canal, and the flow into the downstream section of the Post A Canal is being regulated by flashboards, which is the exact opposite of what is needed for simple operation.

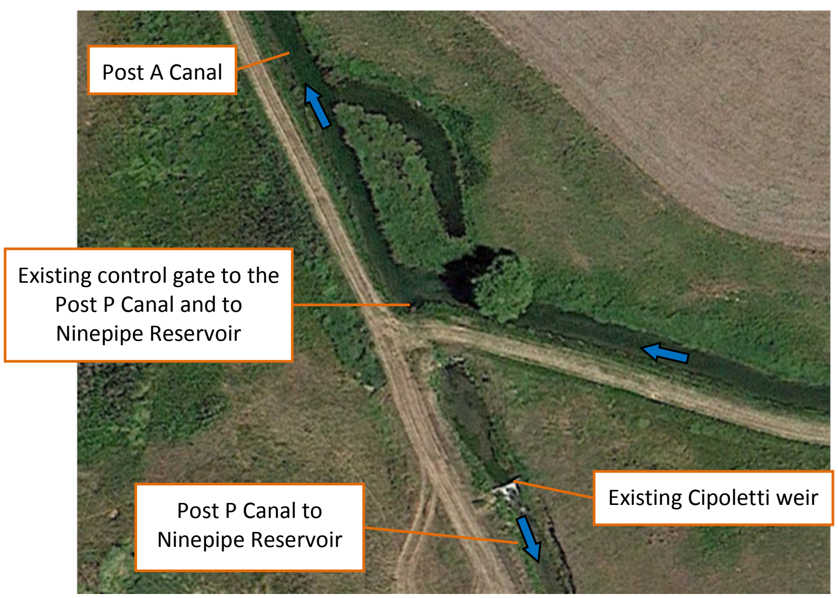

Figure 61. Existing diversion of the Post A Canal to southern portion of Post P Canal and Ninepipe Reservoir

Under the new control scheme, all excess canal flows will be diverted into Ninepipe Reservoir via the Post P Canal, using a new LCW at the head of the Post P Canal. Figure 62 shows the conceptual modernization changes.

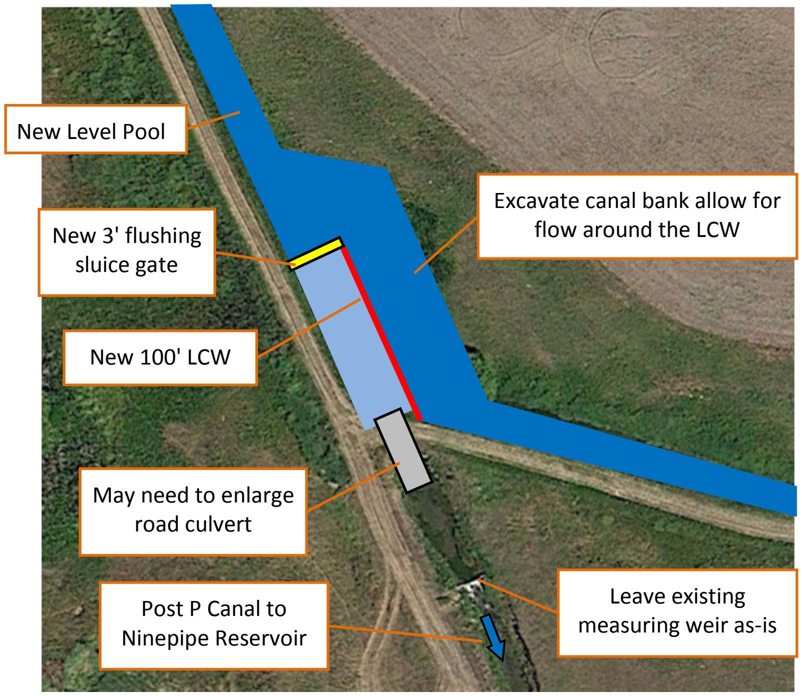

Figure 62. Conceptual plan view of new LCW structure in the Post A Canal (not to scale)

The modernization changes include:

1. Surveying will be needed to determine if any canal banks need to be raised between the bifurcation of Post A Canal/Crow Pump Canal, and the head of the Post P Canal. This section of canal will function as a level pool. Sometimes water will flow north; other times it will flow south. It must be level so that the water level into the head of the downstream portion of Post A Canal can be controlled by the LCW at the head of the Post P Canal.
2. A new LCW, at the head of the Post P Canal, will maintain the water level elevation in the new level pool.
3. A manual sluice gate installed at the head of the LCW will be used to pass a portion of the excess flow if needed, and to drain the level pool if desired. Usually it will be closed.
4. The existing road culvert may need to be enlarged to handle the increased flow rate heading into the Post P Canal.
5. The existing Cipoletti weir will remain as-is.

Flow Measurement Improvements at Head of Post C and D Canals

Ninepipe Reservoir discharges directly into the Post C and D Canals. Large Cipoletti weirs shown in Figure 63 are used to measure the discharge flow rate into each canal. According the flow rate record data, approximately 100 CFS is diverted into the Post C Canal while approximately 50 CFS is diverted into the Post D Canal.

Both flow rates are recorded and viewed by a GOES station. The sensor stilling wells are located right at the reservoir discharge headwall. In Figure 63 it appears the pressure sensor stilling wells are not located in the proper position. They could remain as-is if pipes were extended downstream from the stilling wells, to sense the water level closer to the weirs.

Figure 63. Existing Cipoletti weirs at the head of the Post C and D Canals at Ninepipe Reservoir

Not enough time was taken to fully evaluate the measurement accuracy of the two weirs but a few simple modifications shown in Figure 64 will help.

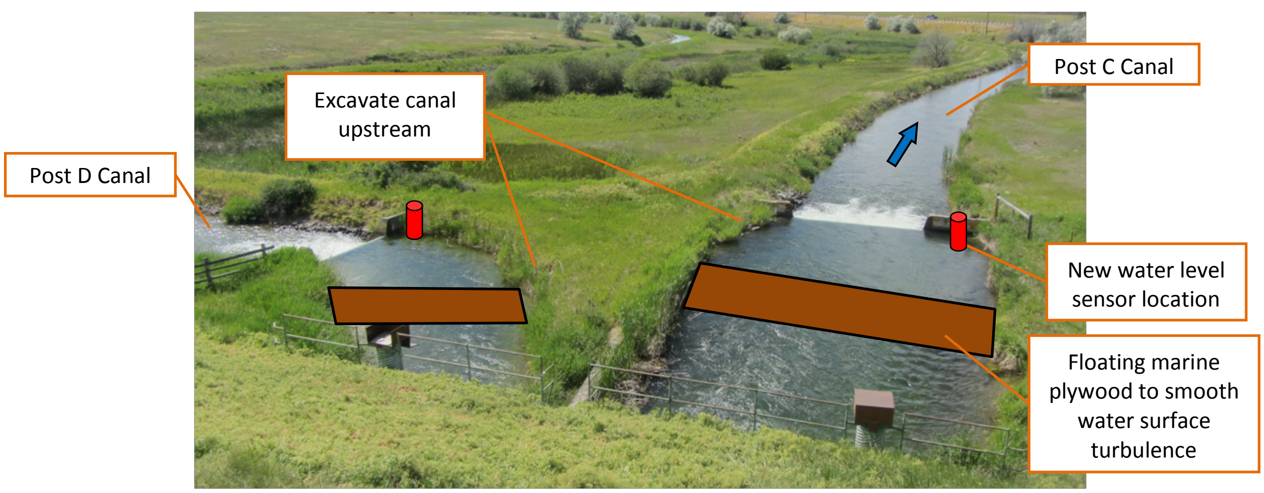

Figure 64. Modifications recommended for existing Cipoletti weirs at the head of the Post C and D Canals

The modifications include:

1. Parts of the canal banks will be excavated to improve the flow approach path to the Cipoletti weirs. The curve in the Post D Canal upstream affects the velocity profile of the water that can produce two different water level readings at the opposite ends of the weir.
2. The water level sensors will be moved from their current location to just to the side of the measurement weir where the water surface is smoother.
3. Marine plywood will be floated on the water surface upstream of the two weirs. The plywood will help reduce the water surface turbulence for more accurate sensor reading of the water level surface.
4. SCADA will be used to remotely monitor the flow rate over each Cipolleti weir. The flow rate measurement will be hardwired back to the Ninepipe Reservoir outlet house for the operator to see and adjust the manual gates accordingly.

In the future, if either Cipoletti weir needs to be replaced, Replogle flumes should be constructed in the locations shown in Figure 65 for accurate flow measurement.

Figure 65. Approximate location of possible new Replogle flumes at the head of the Post C and D Canals