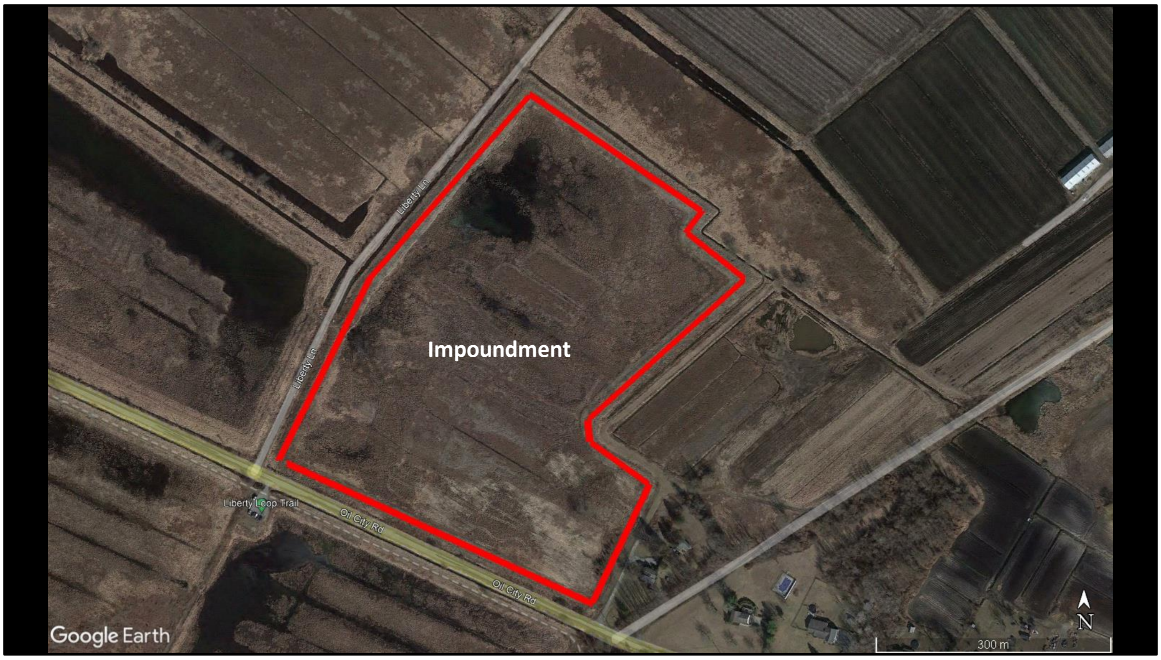
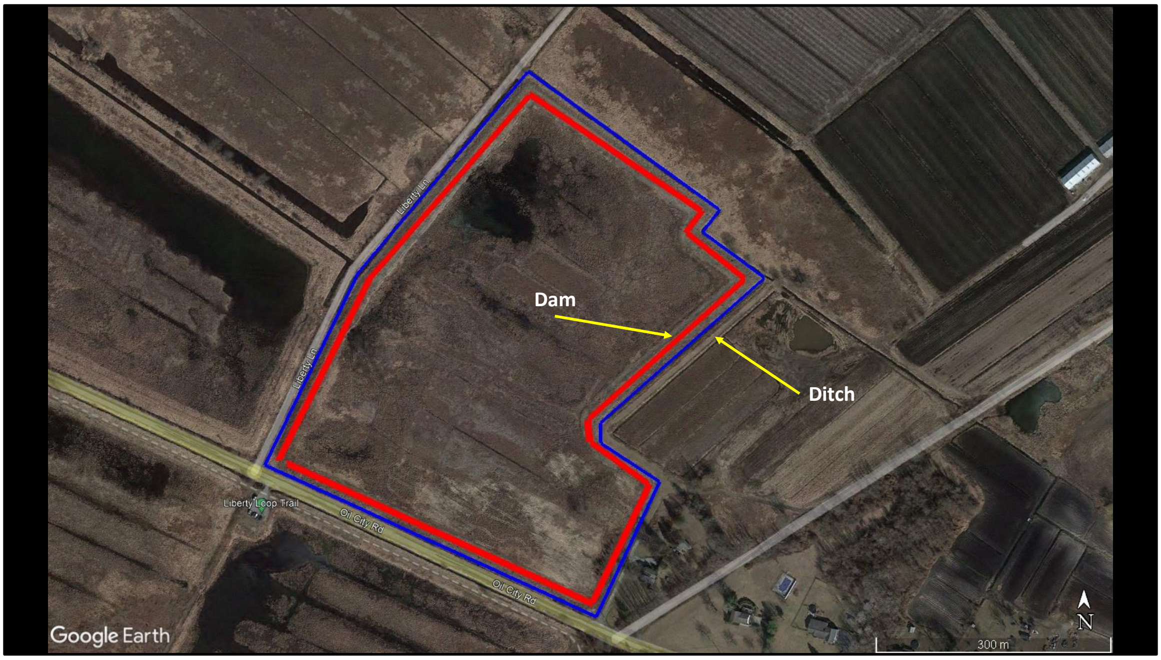
This presentation focuses on how wetlands, streams, and rivers are being restored from constructed impoundments on the Yaqan Nukiy Hunting Grounds near Creston, British Columbia, Canada. The project is receiving major funding from the Columbia Basin Trust, Fish and Wildlife Compensation Program, and the Aboriginal Fund for Species at Risk. The project is a partnership program involving the Yaqan Nukiy First Nations and the British Columbia Wildlife Federation. You'll see why after constructing over 1,400 dams, Tom Biebighauser now works to remove them.

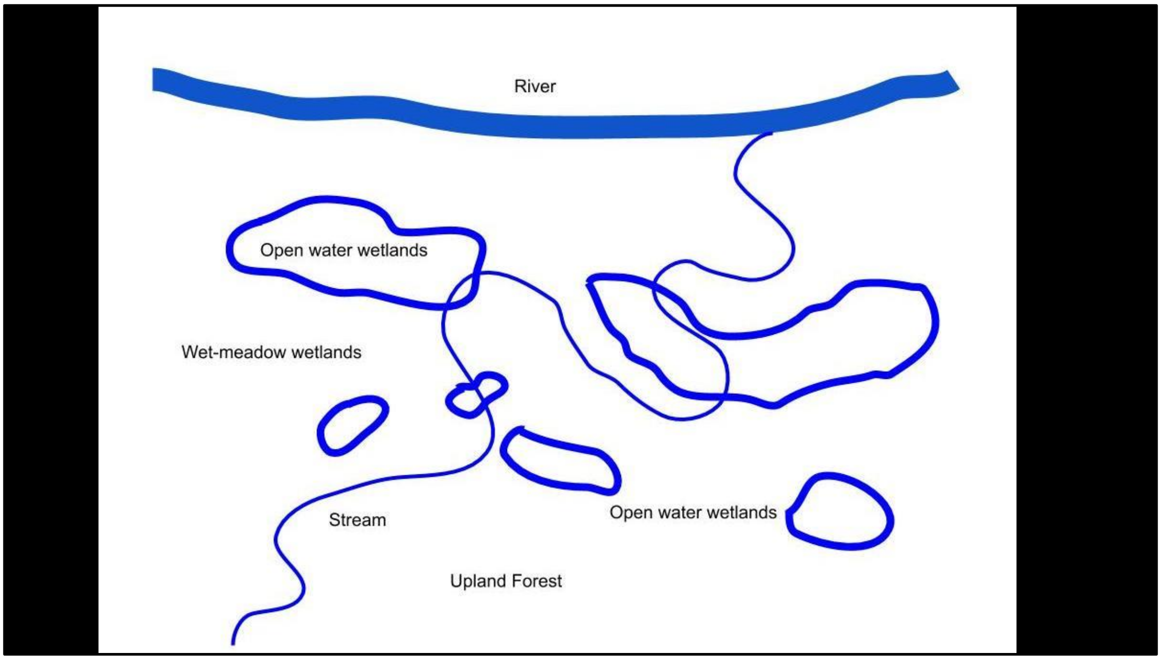


An impoundment is designed to create a large area of shallow water by building a dam around a level area of ground. The red-colored polygon outlines an impoundment constructed on the Wallkill National Wildlife Refuge in New York. The impoundment was built by constructing a dam around a large agricultural field. The field had been created over 100-years ago by draining and filling natural wetlands and streams. The impoundment is located on the floodplain of the Wallkill River. The red lines show the location of dikes or dams constructed to hold water in the impoundment, and to prevent floodwaters from the Wallkill River from entering the impoundment.

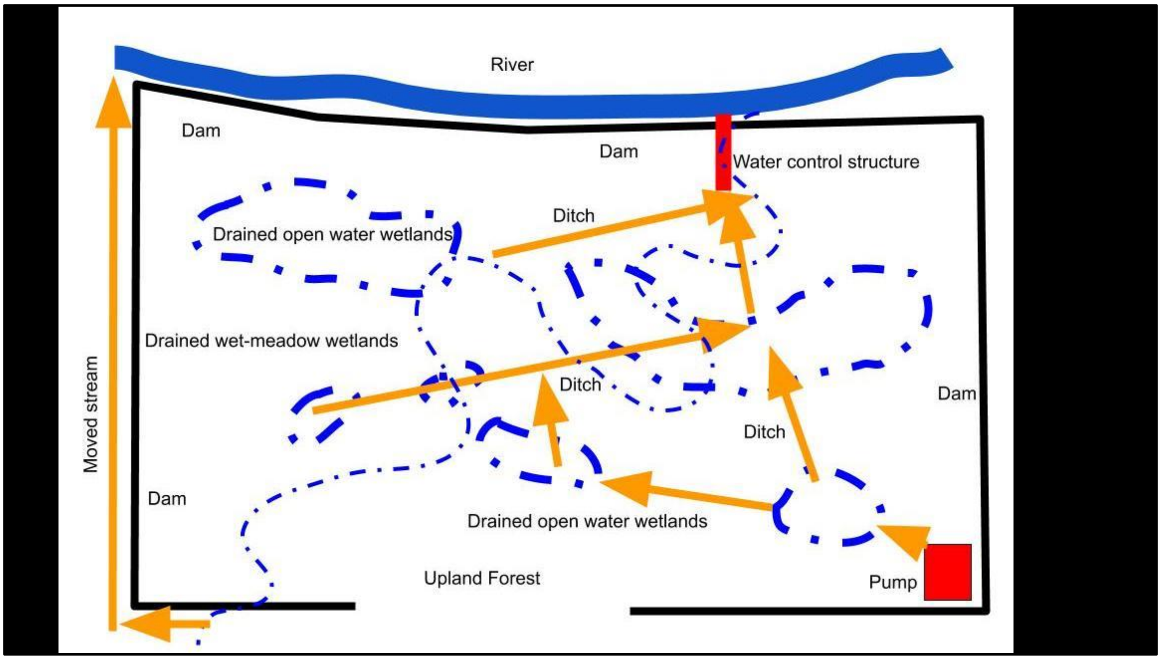
This impoundment like most others is dry most of the year. Water is pumped into the impoundment in the fall when budgets permit. Once filled, the impoundment dries quickly because the impoundment basin intercepts sand-texture soils.



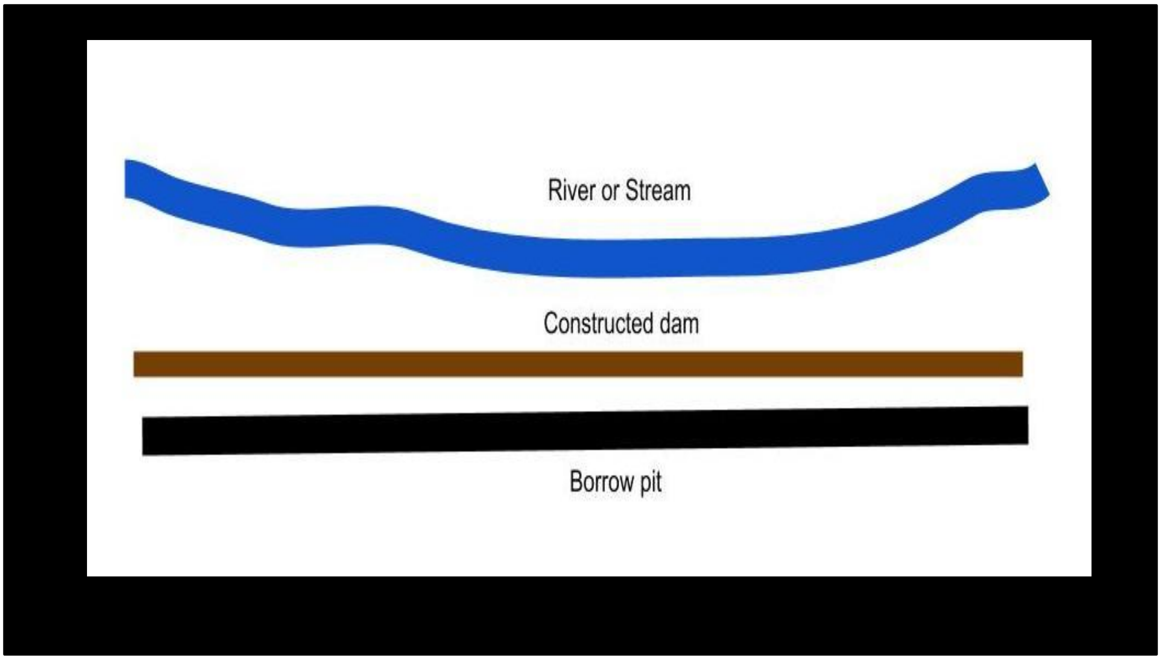
The blue lines show the locations of ditches that were dug around the perimeter of the impoundment. The U.S. Fish and Wildlife Service dug these ditches to prevent the constructed dams from flooding neighboring property. Unfortunately, these ditches are now draining water from the impoundment because they intercept a thick layer of sand underlying the impoundment. Please notice the pool of water in the upper corner of the impoundment. This area contains water because the builders dug deep at this location to obtain soil for building the dam. The deep depression intercepted groundwater. Often times the only water one sees in an impoundment is where soil was dug out to build a dam.



This drawing shows a typical floodplain prior to the construction of an impoundment. Impoundments are generally built on large areas of land along streams or rivers where slopes are less than 1-percent. Impoundments are designed to create large areas of water by inundating fields, natural wetlands, drained wetlands, streams, and forests. Engineers and Wildlife Biologists have been building impoundments for over 100-years because they were taught that impoundments provide better habitat for waterfowl compared to restoring natural wetlands.



This drawing shows the same floodplain after the impoundment is built. The stream has been moved to flow around the impoundment. Ditches have been dug to drain natural wetlands within the impoundment. A dam has been constructed around the impoundment. A water control structure and drainpipe were installed so that the impoundment may be drained. A drainpipe was installed where the natural stream once exited the area. The stream that once flowed through the area has been changed into a deep ditch so that water may be removed from the impoundment much like the drain in a bathtub. The impoundment can now be filled using a pump, well, or diversion from a stream or river.



The key component of an impoundment is the construction of a dam that can be over 2km long. The soil used to build the dam is often taken from the area immediately in front of the dam being built. The area where soil is removed is called the "borrow pit." Major steps in building an impoundment include the construction of a dam, installation of a water control structure, and installation of a pump. The dam is built to maintain water pumped into the impoundment and to prevent streams and rivers from flooding the area. The water control structure allows water to be removed from the impoundment.

Many of the dams built for impoundments were constructed using a dragline like the one shown here. The use of draglines explains why one often finds a deep borrow pits that look like ditches paralleling impoundment dams. The dragline has been replaced by the excavator for building impoundments today.

This photo shows a dam built for an impoundment. The dam is located along the banks of a river. The dam prevents floodwaters from entering the impoundment and is designed to maintain water pumped into the impoundment. These dams may also be called a berm, dike, or levee.

Dr. Frank Bellrose, famous waterfowl Biologist, introduced the concept of moist soil management the 1940's. Moist soil management involves removing water from an impoundment in the spring so that annual plants may grow, and then filling the impoundment in the fall to attract waterfowl for hunting season. Tens of thousands of impoundments have been built around the world so that moist soil management can be practiced.

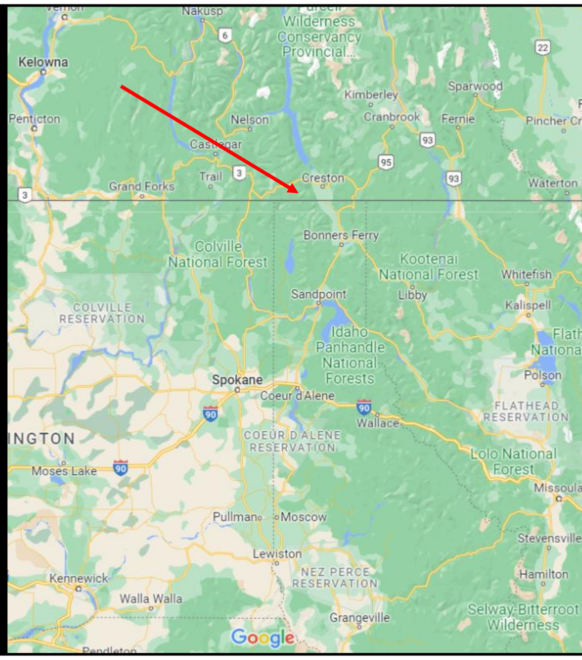
The Cane Creek Wildlife Management Area is part of the Patoka River National Wildlife Refuge near the Wabash River in Indiana. Like almost every other National Wildlife Refuge it contains large impoundments that don't hold water.

Wells with large pumps were installed at the Cane Ridge Wildlife Management Area in an effort to fill the impoundments with water.

The impoundments cannot be filled with water even the when large pumps are operated day and night

I carefully examined the impoundments and found that the dams were built on a foundation of sand, and that a layer of sand extended under the impoundment basins. The drainage ditches adjoining the impoundments intercepted the same layer of sand, and were draining the impoundments no matter how much water was pumped into them.

The cattails shown in this photo are growing in a natural wetland that was drained with ditches to create an impoundment on the Boundary Smith Creek Wildlife Management Area in Northern Idaho. The impoundment and drained natural wetlands now only contain water for short periods of time, only as long as water is pumped into the impoundment.



We’re now going to discuss how wetlands, streams, and rivers are being restored by decommissioning large constructed impoundments near Creston, British Columbia, Canada on First Nations lands. The Southern boundary of the Lower Kootenay Band Reserve is the Northern panhandle of Idaho along the Kootenay River.

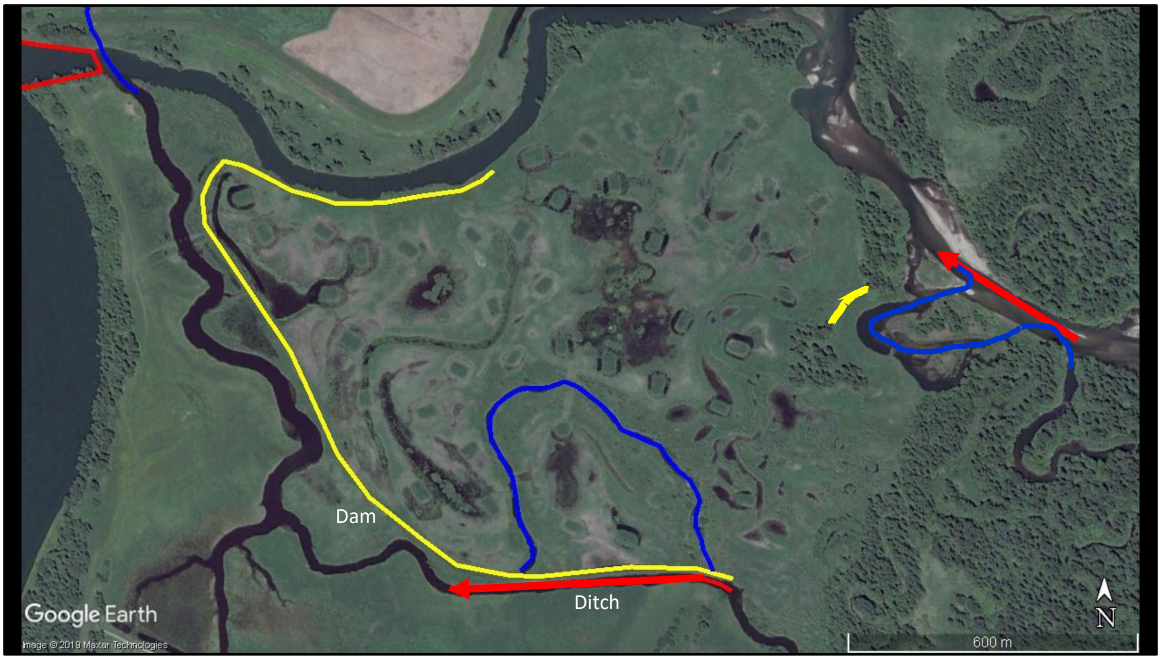
The redline shows the center of a ditch dug between two natural wetlands that were drained for the construction of an impoundment on the Lower Kootenay Band Reserve near Creston, British Columbia. The ditch was dug with a sinuous shape so it would appear like a stream. This type of ditch is called a "level ditch." Level ditches were designed to create narrow areas of open water within an impoundment. They are not supposed to drain water from an impoundment. However, this level ditch was dug on a slope, so it drains water from the natural wetlands it connects. The author has examined hundreds of level ditches that were dug in impoundments and has found that nearly all are draining water both from the natural wetlands that were drained to build the impoundment, and from the impoundment. The arrow points to one of the piles of soil left from digging the ditch.

The large dark areas are natural wetlands that were drained to build an impoundment on the Lower Kootenay Band Reserve in British Columbia, Canada. The squiggled lines are ditches dug between the natural wetlands within the impoundment. These so-called "level" ditches drained most of the water from the natural wetlands. The impoundment only contains water while water is being pumped into it from the Kootenay River. This is because the dams and the impoundment basin were built on a layer of sand.

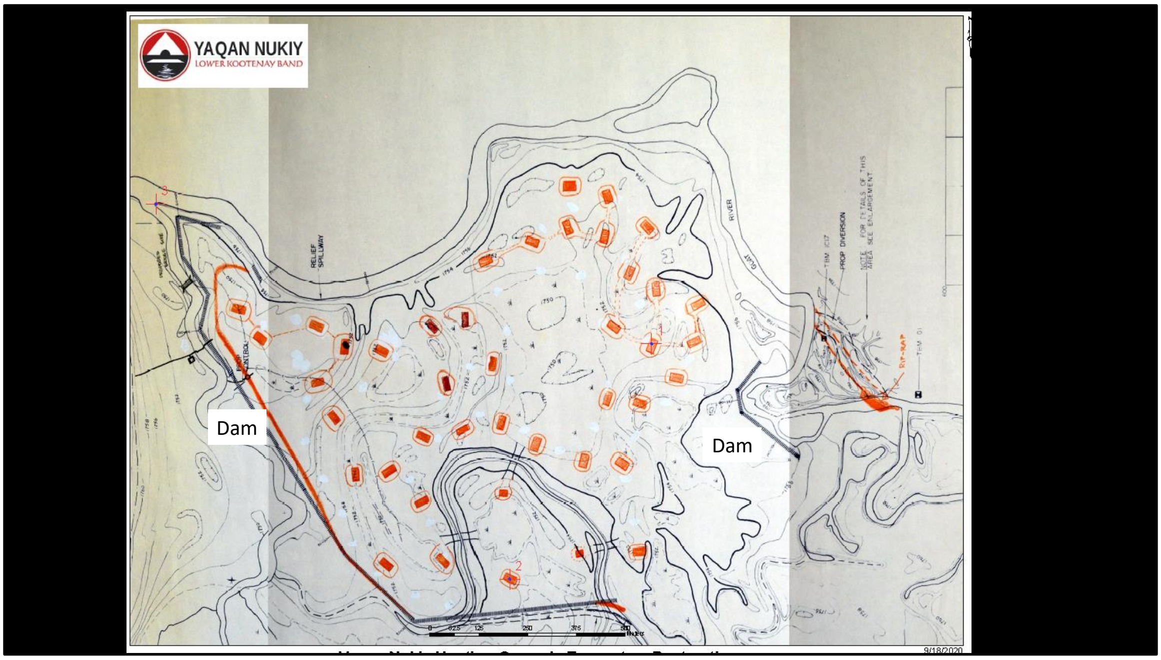
There are three main reasons why the ditches dug within the impoundment have drained the natural wetlands; 1) Each natural wetland is found on a slope, 2) The ditches were dug to cut through the natural rim of each wetland,, 3) The main dam constructed for the impoundment does not hold water.

This aerial photo taken in 2016 shows the Yaqan Nukiy Hunting Grounds. The land is part of the Lower Kootenay Band Reserve, located near Creston, British Columbia, Canada. The Hunting Grounds encompasses approximately 210-hectares (519-acres) of floodplain along the Kootenay River, Goat River, and Goat River South. The Hunting Grounds is of great traditional importance to the Yaqan Nukiy. All of the natural wetlands that were historically present on the Hunting Grounds were drained by Ducks Unlimited Canada when one large impoundment was constructed.

This image shows the Hunting Grounds as it appeared in 1929. Norm Allard, Community Planner for the Yaqan Nukiy, prepared this image by joining 4-separate aerial photos, that he also georeferenced. The black colored areas are deep water, the gray color is shallow water wetlands. The author used the Avenza Maps app to open the image in the field on his cell phone. This image also shows ditches that were dug to drain wetlands prior to 1929. The app and image were of great value in identifying the locations of wetlands, streams, and rivers that had been drained since 1929. The image and Avenza app were used to guide the marking of every wetland area, stream, and river to be restored using heavy equipment. The image was also of critical importance in guiding where soil should be spread, so that soil would not be placed in wetlands that had been historically drained.



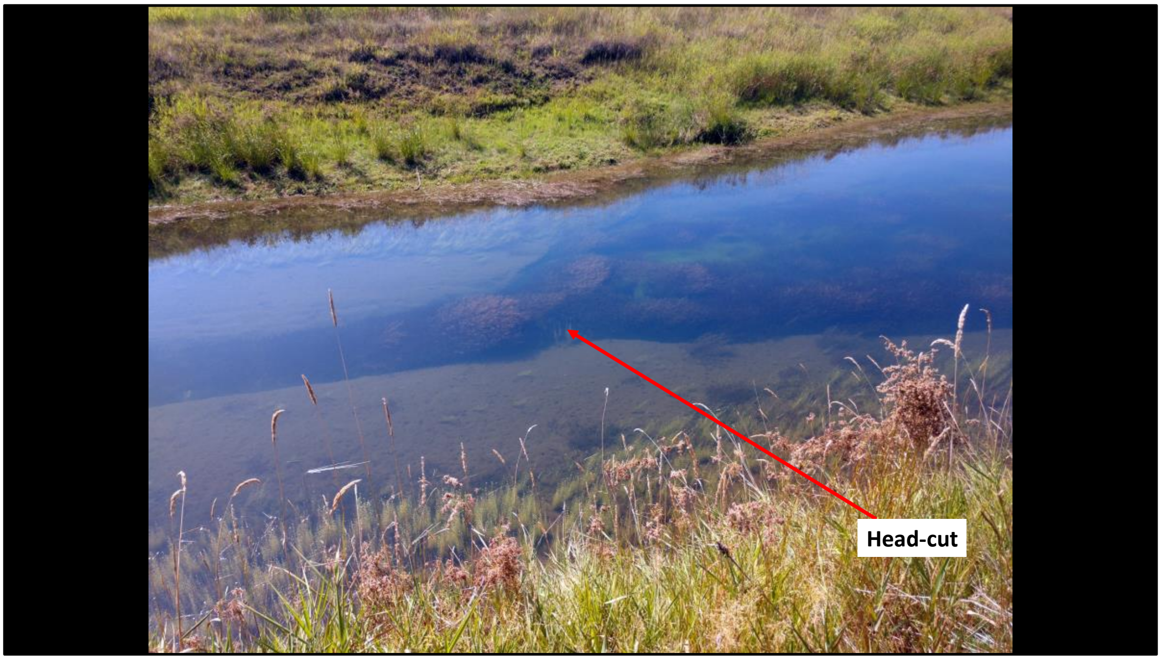
Ducks Unlimited Canada (DUC) began working on Lower Kootenay Band lands in the 1960's to build a number of large impoundments, including one surrounding the Yaqan Nukiy Hunting Grounds. The yellow lines in this photo show the locations of dams built to create the impoundment. The red lines shows where major ditches were dug to divert the Goat River and the Goat River South. The blue lines show sections of each river that were cutoff by the construction of the dams. Not shown are the hundreds of ditches dug at the same time to drain all of the natural wetlands within and surrounding the Hunting Grounds.



This Ducks Unlimited Canada Engineering Design for the Hunting Grounds shows where the diversion of rivers and construction of dams was planned. The orange colored rectangles show where large islands would be built in the natural wetlands being drained. The solid orange lines show where deep and wide ditches were dug to move rivers. The faint orange-colored dashed lines show where ditches were planned to drain water from the natural wetlands. We have since found that many more ditches were dug to drain the existing natural wetlands, and many more islands were built using the soil removed from digging the ditches. People thought the impoundment would provide better habitat for waterfowl than the natural wetlands and streams on the floodplain. They were wrong.

Ducks Unlimited Canada dug this deep ditch to cut off a natural loop in the Goat River South to build the impoundment dam The ditch intercepted a subsurface permeable layer so it also drained over 200-acres of natural wetlands adjacent to the Hunting Grounds. Broken concrete slabs were placed along the banks of the ditch to control erosion. Prior to the restoration of wetlands and streams within the Hunting Grounds people were not aware that the Goat River South was flowing in a constructed ditch.

This photo shows a diverted section of the Goat River South that was turned into a deep drainage ditch as part of impoundment construction on the Hunting Grounds. This ditch was dug through the center of major natural wetlands and streams, draining an estimated 200-acres of wetlands. The author has seen where numerous other rivers and streams were diverted to construct similar impoundments across North America. Engineers and Biologists with Ducks Unlimited Canada believed that the constructed impoundments would provide better habitat for ducks than the diversity of natural wetlands on the Hunting Grounds.



This photo shows a head-cut advancing in the ditched portion of the Goat River South. The head-cut was caused by the construction of the ditch. The head-cut is causing a deepening and widening of the ditch, and is lowering the elevation of groundwater over the Hunting Grounds.

This photo shows the longest dam that was built for the Hunting Grounds impoundment. The dams averaged 1.7-meters high. The dam did not hold water as planned because it was built on a permeable foundation of sand and organic soils. Here are some possible reasons the dam was built:

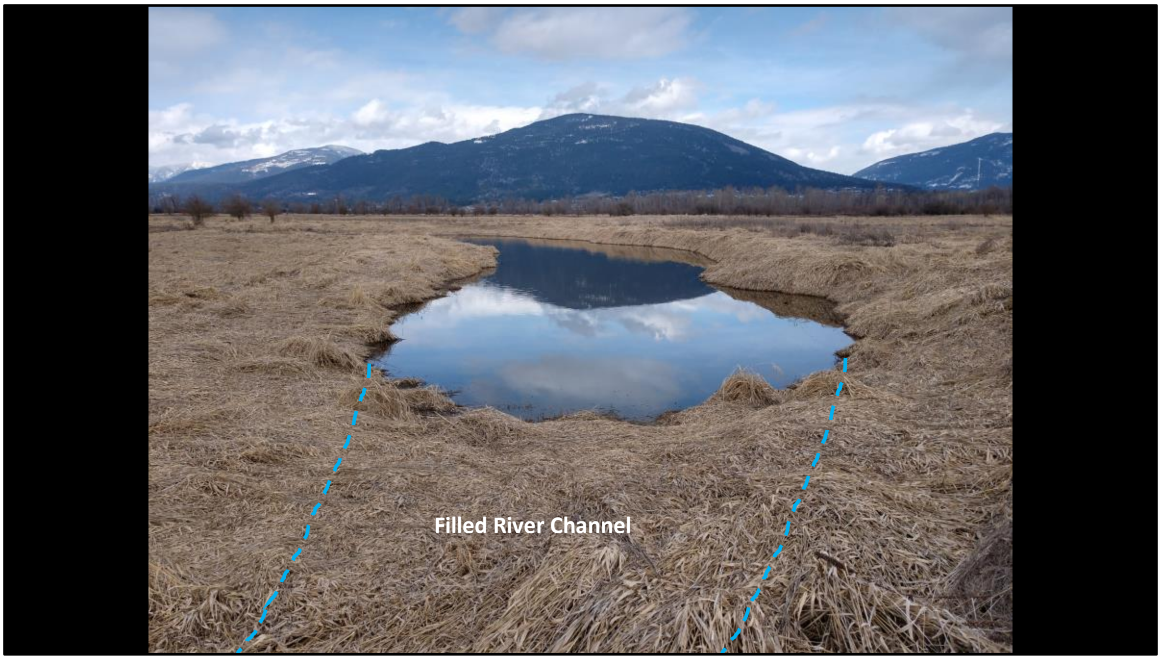
- Prevent the Goat River and Goat River South from flooding the Hunting Grounds.
- Hold water pumped into the impoundment from the Kootenay River
- Dry large areas for farming.
- Reduce the possibility of duck nests being flooded.

The author has examined hundreds of constructed impoundments across North America and in New Zealand and has found that the majority do not hold water as planned.

The red arrow points to a section of dam built for the Hunting Grounds Impoundment along the moved and channeled Goat River South. Upon close examination we observed water flowing under the dam and into the ditched Goat River South via a thick layer of sand.

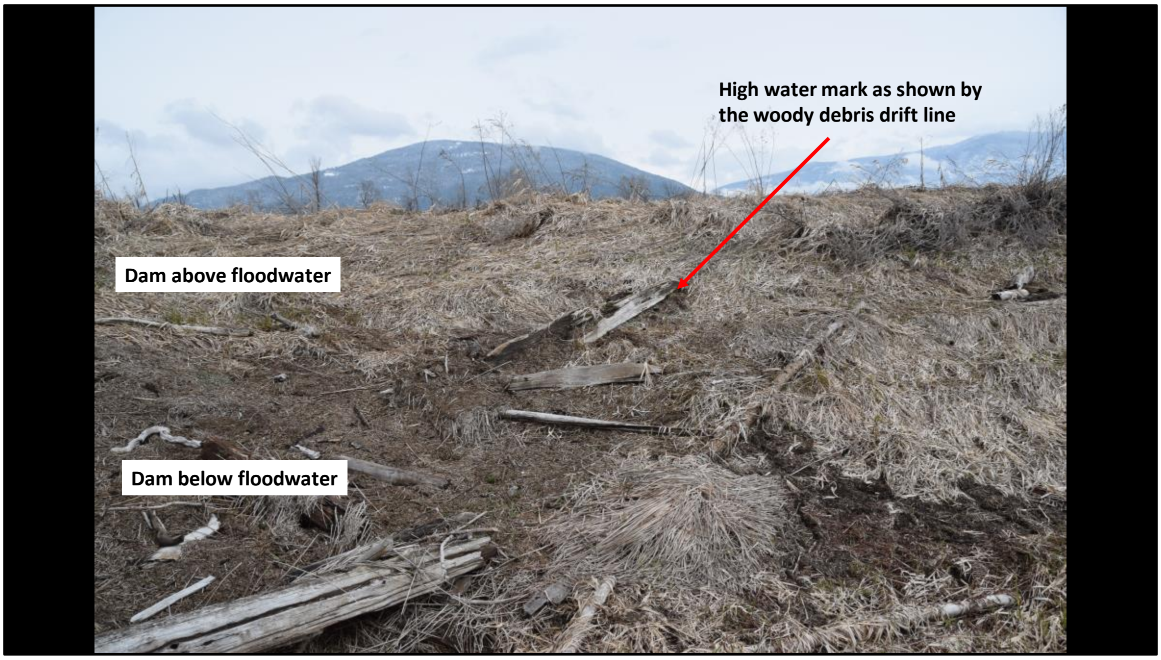
Large woody debris was no longer be deposited on the Hunting Grounds following construction of the large impoundment. This is one of the few logs remaining on the Hunting Grounds after 40-years of artificial flood control caused by the construction of the impoundment dam. The annual addition of wood to natural wetlands on floodplains is of critical importance to turtles for basking, waterfowl for loafing, and fish for hiding.

The only places holding water within and near the Hunting Grounds following construction of the impoundment were the deep and narrow borrow pits dug in the natural wetlands that had been drained with ditches. The borrow pits had exposed the groundwater in the drained wetlands.



This photo was taken while I was standing in a section of the Goat River South that had been filled with soil. The soil for filling the river channel was obtained from digging the deep ditch to divert the river. The water shown in this photo is the downstream loop of the Goat River South that was cut off by the construction of the impoundment dam, and by digging the ditch to divert the river. The large amounts of soil generated from digging ditches to drain wetlands within the impoundment was used to fill the cut-off channel of the Goat River South at 6-different locations.

Norman Allard Jr., Community Planner with the Lower Kootenay Band, stands on a section of dam built to prevent floodwaters from the Goat River from entering the Hunting Grounds impoundment Norm is standing within a historic inlet where floodwaters from the Goat River once flowed naturally onto the Hunting Grounds. Inlets often occur in outside bends of a river. The presence of eroding banks and large woody debris deposited are also signs of an inlet. The red arrows show the location of three inlets along the Goat River, all had been blocked by the construction of the impoundment dam.



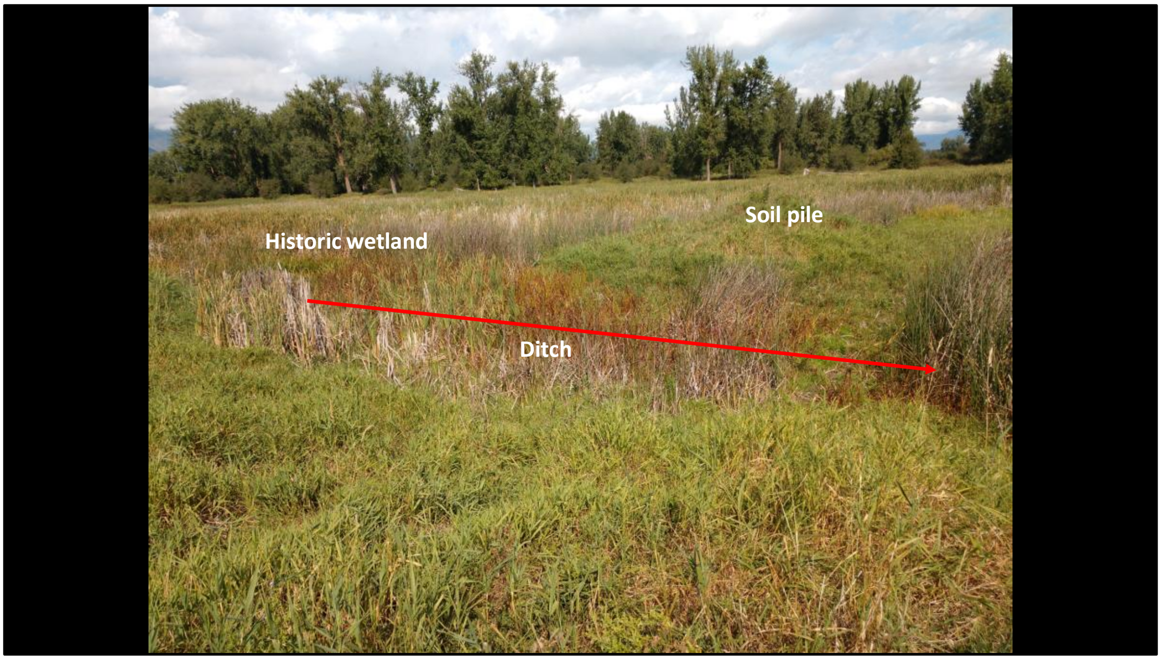
This photo shows the river side of a dam constructed for the impoundment. The photo was taken while standing on the edge of the Goat River South, looking into the Hunting Grounds. The high- water mark from the Goat River South can be seen by the drift line of wood and fine organics (red arrow). The impoundment dam prevented floodwaters woody debris, and fish from entering the Hunting Grounds. The elevation of the drift line served as an important guide in removing the dam. Floodwaters and woody debris may again enter the Hunting Grounds if the dam was lowered to an elevation below the high-water mark as shown by the woody debris.

This water control structure installed for the Hunting Grounds Impoundment was no longer functioning, having been damaged by ice. The water control structure was installed so that water could be removed in the Spring for farming and closed to contain water pumped into the impoundment for duck hunting. The structure was installed in an natural outlet for the Hunting Grounds Floodplain that had been deepened into a ditch so that the entire Hunting Grounds could be drained in the spring for moist soil management.

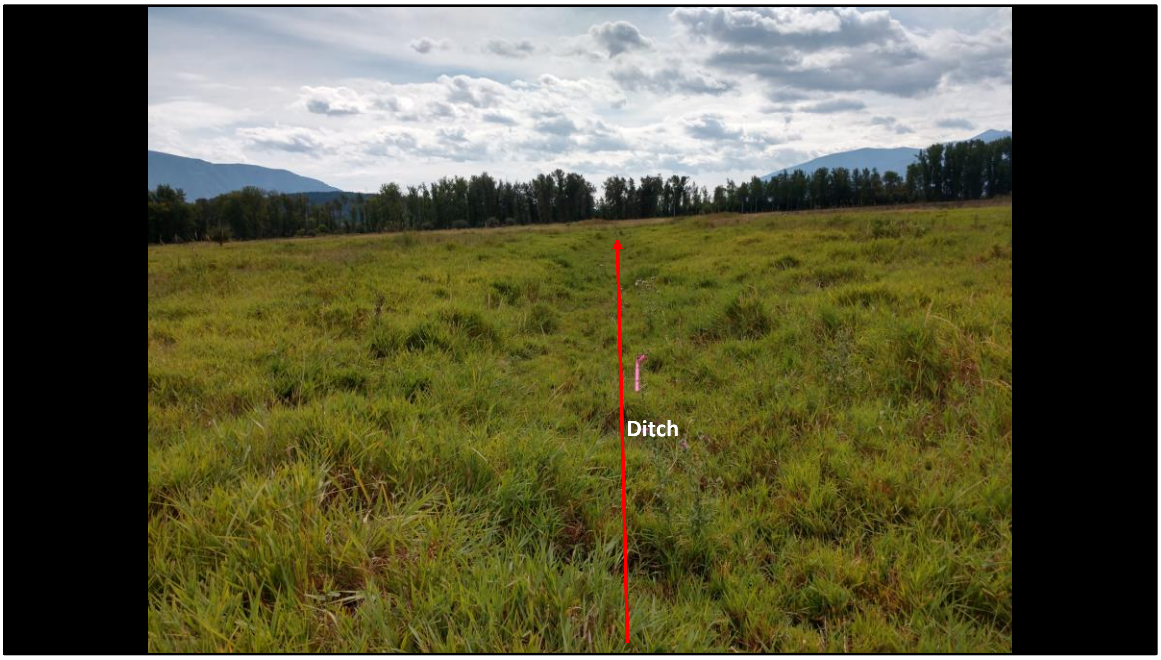
Here's a natural ephemeral wetland near the Hunting Grounds that was not drained. This wetland was located outside of the impoundment. Note the willows growing on higher ground around the edge of the natural wetland. All of the natural wetlands within the Hunting Grounds impoundment were drained using ditches, and then filled with soil.

This photo shows one of many natural wetlands drained when the Hunting Grounds impoundment was built. Willows surrounding dry basins that are now dominated by reed canary grass show where natural wetland were drained when the impoundment was built.

This photo shows a ditch dug to drain a natural wetland within the Hunting Grounds prior to 1929.



This photo shows one of the many natural wetlands that were drained as part of impoundment construction. The pile of soil was made from digging the ditch that drained the wetland.

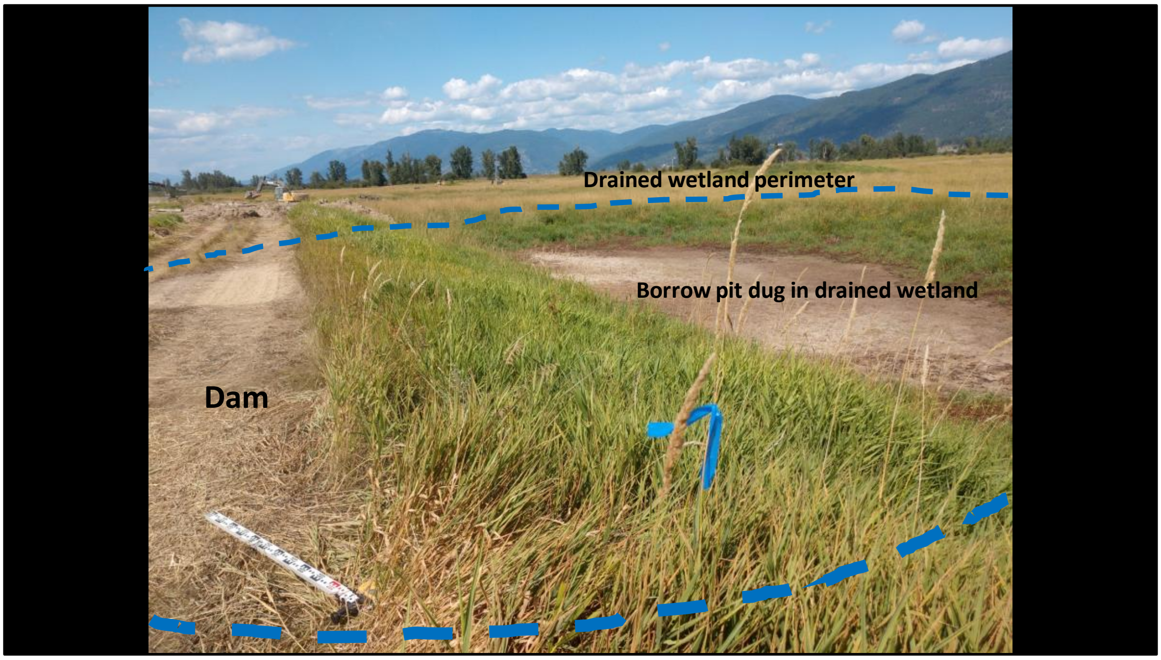


The red line shows the location of a ditch dug to drain a large natural wetland as part of impoundment construction. The pink colored ribbon was used to show heavy equipment operators where to fill the ditch to restore the wetland.

This photo shows a historic river channel on the Hunting Grounds. Note its wide width and low banks. These river channels were dried when the impoundment was built.

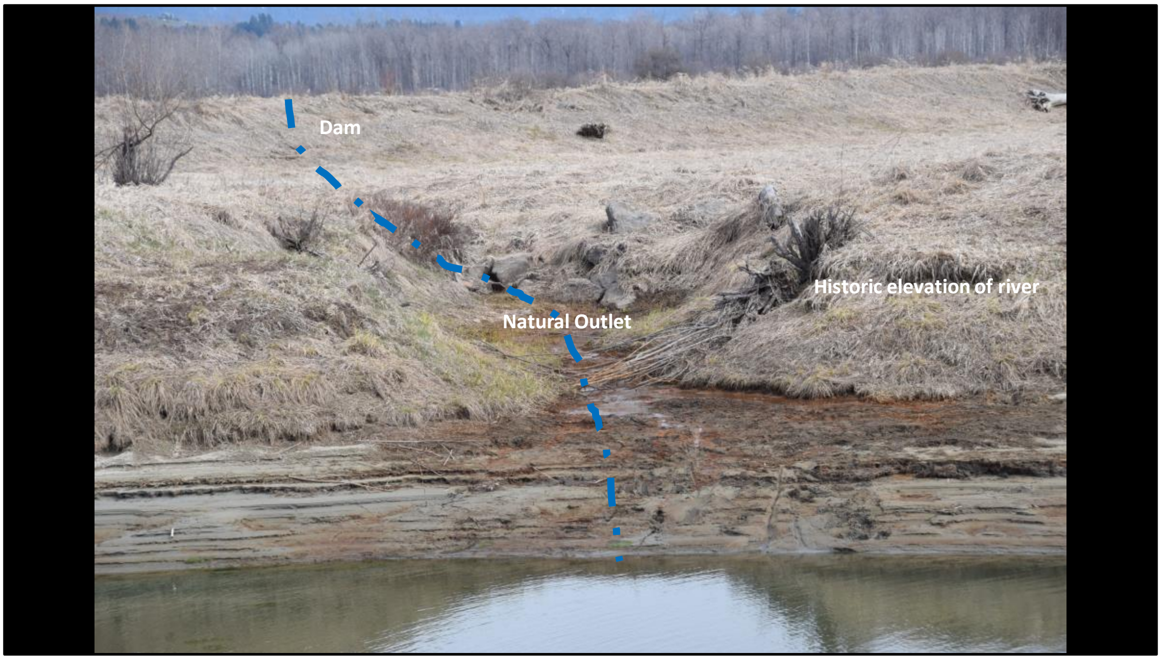
This photo shows one of many piles of soil shaped in the Hunting Grounds impoundment. We've been told these were built to provide waterfowl with islands for nesting. The piles were not used for nesting because the impoundment did not hold water as planned.

The piles of soil or “nesting islands” were huge. By walking around examining the area we discovered that the majority of the islands were built using the soil removed from digging ditches to drain natural wetlands within the impoundment. Some of the islands were built on the edges of natural wetlands that were drained while others were used to fill natural wetlands. The actions completed on the Hunting Grounds and other impoundments on the Lower Kootenay Band Reserve show there was a systematic and purposeful effort to destroy all natural wetlands and streams within the impoundment.



Here's a section of impoundment dam that was built over a natural wetland. The dashed blue line shows the perimeter of the historic wetland that was destroyed by filling and draining..

The Hunting Grounds is dominated by reed canary grass. Reed canary grass thrives in drained wetlands. We found a direct correlation between drained wetlands and dense reed canary grass.



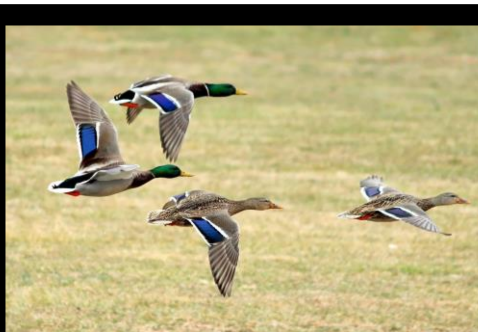
This dashed blue-line shows the location of a natural river outlet from the Hunting Grounds that was filled and blocked by the construction of the impoundment dam. The short valley section is characteristic of natural outlets along rivers. Historically the elevation of water in the Goat River South was about the same as where the willows are growing. The elevation of water in the river has dropped because of head-cuts caused by the shortening of the Goat River in the 1930's, and the ditching of the Goat River South. Large boulders were placed in the outlet, most likely to control erosion during construction of the impoundment.

The dashed red line shows a dam that was built by Ducks Unlimited Canada to prevent the Goat River from flooding the Hunting Grounds. The dam was so wide and sloped that it was difficult to determine it had been constructed. The center of the dam is shown by the dashed red line. The Goat River was also diverted so that floodwaters would not flow over the dam constructed for the impoundment.

Here is a major bend in the Goat River that was cut-off when the river was diverted. The water in the channel is groundwater that is being drained from the Hunting Grounds. The natural bend in the river was cut-off to prevent the Hunting Grounds Impoundment from flooding. The moving and channeling of rivers and streams to construct impoundments is common practice across North America.

This historic river channel was cut off by the construction of the impoundment dam.

A major restoration project was planned by the Lower Kootenay Band for the Hunting Grounds. Named the *Yaqan Nukiy Hunting Grounds Ecosystem Restoration Project* actions were identified to restore floodplains, wetlands, streams, and rivers damaged by the construction of impoundments, dams, ditches, and installation of pipes and pumps. The project was designed to increase wildlife and fish populations on the traditional Yaqan Nukiy Hunting Grounds in partnership with the Columbia Basin Trust, British Columbia Ministry of Forests, Lands and Natural Resource Operations and Rural Development, Aboriginal Fund for Species at Risk, British Columbia Wildlife Federation, and the Fish and Wildlife Compensation Program.



Mallard

Wood Duck

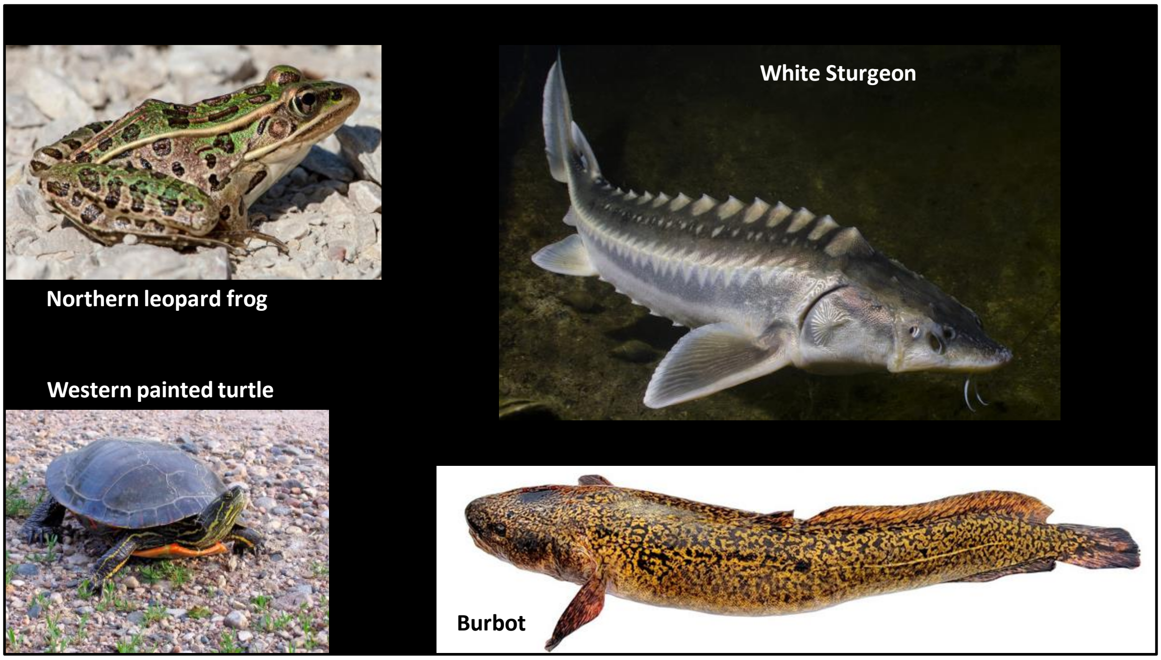
Sandhill Crane

Burbot

White Sturgeon

Western painted turtle

Yaqan Nukiy Elders shared with the authors that the Hunting Grounds was named because one could always find animals to hunt in the area. However, this changed after the impoundments were built. The *Yaqan Nukiy Hunting Grounds Ecosystem Restoration Project* was designed to improve habitat for a diversity of wildlife, fish, and plant species. The plan was to restore wetlands, streams, and rivers destroyed by the construction of the impoundment, and to reconnect the historic floodplain with adjoining rivers.



The project would be completed to specifically improve habitat for these Species at Risk

Unfortunately, many people think all you have to do to restore a floodplain is to breach a dam. They are wrong! Breaching a dam and doing nothing else to restore the floodplain triggers catastrophic erosion resulting in the drainage of wetlands and streams in the entire valley.

A significant accomplishment of the Hunting Grounds Project involved the removal of 1.9km of constructed dam averaging 1.7 meters high. This photo shows a section of the dam, and the inside slope of the dam. The dam and the impoundment basin were dominated by reed canary grass. Orange colored plastic flagging was used to mark the width and elevation of soil to be removed from the dam for the project. A laser level and survey rod were used to guide the placement of the orange flagging, providing a rapid and low-cost way of guiding the excavator operators in the removal of the dam.

The excavator operator used the orange plastic flags as a guide to create temporary benches along the inside and outside slopes of the dam to be removed. The elevation of each bench equaled the final elevation of the dam to be removed.. The temporary benches served as a visual guide, allowing the operator to rapidly remove sections of the dam approximately 30-meters long before checking elevations using a laser level.

Two excavators and a dozer were used to remove the entire length of the dam to restore floodwater access to the floodplain.

This photo shows where a section of dam is being removed. The bench was created by removing the inside slope of the dam. The orange flags were tied to reed canary grass above the desired final elevation of the dam to be removed.

Wire flags were also placed to show the elevation of the dam to be removed.

Here the excavator removes a center section of dam.

Here the soil that was in the dam has been placed in parallel ridges by the excavators. These ridges of soil will be spread by the dozer..

The dozer spreads the soil piled by the excavators. The dozer is doing this faster and at a lower cost compared to using dump trucks or a scraper.

Here the dozer is spreading the soil removed from the dam in thin layers. The 1929 aerial photo image prepared by Norm Allard was used to show heavy equipment operators where soil could be spread. The importance of directing where soil is spread cannot be overemphasized. Heavy equipment operators are trained to spread soil in low areas. We found that all of the low areas used to be wetlands.

Elevations are taken regularly using a laser level as the dam is removed. This is critical as floodwaters may not enter the restored floodplain if high sections of the dam are left, and the wetlands being restored will be drained if the dam is lowered too much.

Here is a partially removed dam showing some of the many holes found in the dam.

Muskrat burrows were found along the length of the dam that was removed. These burrows were difficult to find and prevented the dams from holding water.

This photo shows the foundation of the dam after a section was removed. The dam was built on a thick layer of organic soil. Water was leaking under the dam through this organic layer. The engineering drawings showed that the dam was to be built on a foundation of clay. Many of the dams removed by the author to date have been built on foundations of permeable sand, and organic soils. It would have been very expensive for the contractor to build the dams as designed by the engineer.

The impoundment dam was built of a mixture of topsoil, silt, silty clay, and sand that was permeable. The hand shows topsoil in the dam being removed. Water leaks through dams unless they are made from soil high in clay that is compacted in layers under suitable moisture content.

Trees like the one shown were found under the dam, also explaining why the impoundment did not hold water. The author has observed that most dams built for impoundments fail to contain water because they are constructed over permeable substrates.

Here’s a section of dam that has been removed. The orange flag served as a guide for removing the dam.

Woody debris uncovered during the removal of the dam was saved and placed by the excavator.

The excavator is used to loosen soils and remove heavy equipment tracks following removal of the dam.

Here’s a section of dam that was removed. The rough and loosen technique was used to control erosion and to create a substrate for plant germination and growth.

This photo shows another section of dam that was removed.

This photo shows a section of dam that was removed near water standing in the borrow pit. Soil was purposely not placed in the water. The water is present where soil was removed years ago to build the dam. Logs were placed in the water to provide the Western painted turtle with basking sites, and waterfowl with loafing sites.

Small ephemeral wetlands were built on the same location where the dam had been removed.

One of the main actions taken to restore the Hunting Grounds was to return annual flooding from the Kootenay River, Goat River and the Goat River South. The annual flooding would fill wetlands and streams and provide the rare burbot and white sturgeon with foraging and breeding habitat. The historic location of each inlet and outlet were identified using aerial photos and from an on the ground examination of the area. Here Norm Allard uses a GNSS unit to determine the elevation of a historic inlet so that annual floodwaters can be made to return to the Hunting Grounds. Restored wetlands that are annually inundated by floodwaters can be expected to become perennial, while wetlands that are not inundated will be ephemeral.

Here the excavator is being used to restore a natural inlet that will carry floodwaters from the Goat River into the Hunting Grounds. The inlet is being restored at the upper edge of the Hunting Grounds so that floodwaters may flow downhill and inundate the restored wetlands and streams Note the soil that was used to build the dam is brown in color, the gray-colored soil is from a wetland that was filled when the dam was built. Tom Biebighauser was onsite 100-percent of the time supervising construction. Norm Allard was onsite daily working with Tom to design and direct the project.

The width of the inlet was made to match the width of natural stream channels that had been cutoff by the dam surrounding the Hunting Grounds. The elevation of the restored inlet was set so that floodwaters from the Goat River would flow into the Hunting Grounds every year. The elevation of outlets was set so that floodwaters would fill restored wetlands and streams, and remain in these features when floodwaters receded.

The restored inlet was shaped to be level in cross-section, and along its length. This was done so there would be a sheet-pattern flow of water over the inlet, and no erosion.

A dozer was used to spread the soil removed from building the inlet. The center of the inlet being restored is shown by the dashed blue line.

The banks of the restored inlet are sloped after the channel is dug.

Gravel was uncovered during construction of the inlet. This gravel was brought in years ago so that trucks transporting soil to build the impoundment dam would not get stuck driving across the drained and filled wetlands.

This photo shows the finished entrance to the inlet. The Goat River will now inundate the Hunting Grounds when the elevation of the river rises only 25cm. The elevation of the inlet is critical to the success of the project. If set too high floodwater will not enter the floodplain. If set too low the inlet can also act like a drain to remove water from the restored floodplain.

Here is where another inlet was restored to provide a way for floodwaters to enter the Hunting Grounds. The inlets were shaped to resemble wide stream channels with low banks that were dry most of the year.

Sedges and cottonwood trees are growing in this restored inlet one-year following construction. There is no erosion because the stream channel was built wide and level with low sloping banks.

Ted Krane, one of the excavator operators, said that this was the most important project he has helped build in over 40-years of operating heavy equipment. He was excited that the wetlands and streams being restored that would provide habitat for the burbot as he used to fish for burbot as a child.

Outlets were restored to serve as spillways where floodwaters could leave the Hunting Grounds without causing erosion. The outlets are short sections of stream that flow under flood conditions. The elevation of the outlet is set so that floodwaters that fill restored wetlands and streams will not drain out when floodwaters recede. Here the excavator begins construction of an outlet by digging a trench through the dam. The trench is placed on a gradual slope of one-half of one-percent. The elevation of the outlet is critical to the success of the project. If set too low the outlet will act like a ditch to quickly drain floodwaters from the restored floodplain.

The narrow trench is widened so that water may flow over the outlet in a sheet-like pattern. **The elevation of the outlet is set to be approximately 20cm lower than the elevation of the restored inlets. <u>The outlet was not placed where the drainpipe had been removed</u>**. This is because a deep ditch had been dug to drain the impoundment when the drainpipe was installed, and building an outlet at this location would have been too low and on too steep a slope, causing major erosion and further drainage of the Hunting Grounds.

The outlet is widened and made with gradual sloping banks. The location of this outlet is the same as where an outlet was visible on the 1929 aerial photo.

Gradual slopes are placed on the banks of the outlet.

Water will leave the Hunting Grounds by flowing out this restored outlet into the Goat River South. The historic connection was visible as a narrow valley along the Goat River South (red arrow). The construction of the impoundment dam had obliterated the stream that had been the historic outlet.

Measures were taken to prevent head-cuts from forming in the outlet, as these could drain the restored floodplain. To prevent head-cuts from forming in the outlet the channel was built wide and was placed on a gradual slope. Frequent elevations were taken, and rock was embedded in the ground to armor steeper slopes.

Rock is used to armor the steep slope where water flows from the restored outlet into the Goat River South. The rock is embedded into the ground to control erosion and to prevent head-cuts from forming. The current elevation of the Goat River South is much lower than it was historically, explaining why the slope between the outlet and the Goat River South was so steep.

Here is how the rock-armored outlet appears one-year after construction. No erosion is occurring.

Here Norm Allard uses a Trimble GNSS Unit to check elevations in an outlet constructed the year before. The outlet area where the dam was removed is now growing a diversity of aquatic plants.

Fish and woody debris that were blocked by the impoundment dam now have access to the restored floodplain which is the Hunting Grounds.

Pipes installed for the impoundment were removed as part of the restoration project. Here a drainpipe and water control structure are being removed.

The pipe that moved water from a pump to the impoundment was also removed.

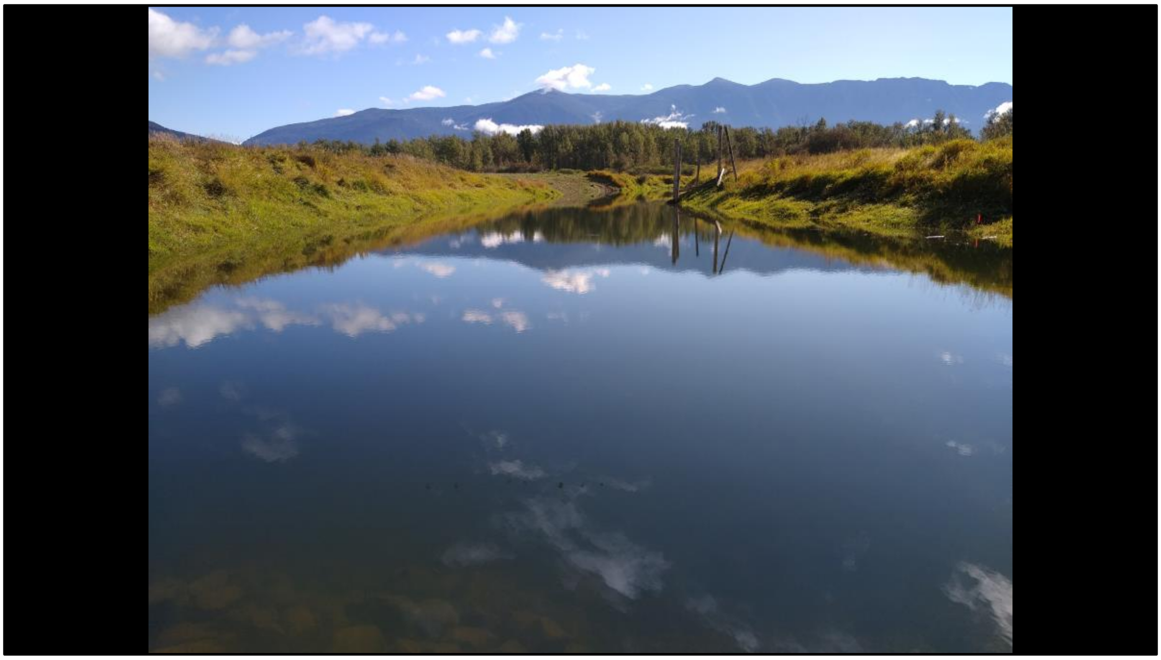
A wide and deep trench was dug perpendicular to where each pipe passed under the dam. This allowed us to locate where other pipes had been buried in the dam.

The trench was dug perpendicular to the pipes being removed, extending down through the dam into a thick layer of clay. The trench showed where the dam had been built over topsoil and sand, explaining why the dams did not hold water. Soil high in clay was placed in the trench and compacted in layers to prevent water from flowing where the pipe was removed.

Here the soil that was used to block the natural channel of the Goat River South is being removed by using a John Deere 210G Excavator.

A 1.15 km loop in the Goat River South that was separated from the river was reconnected by removing 4-dams that were built to block the entrance and exit of the river loop. The dashed lines show the location of one of the dams that was removed. Here the excavator is building a riffle to transition higher water in the restored loop into the ditched section of the river that is at a lower elevation.

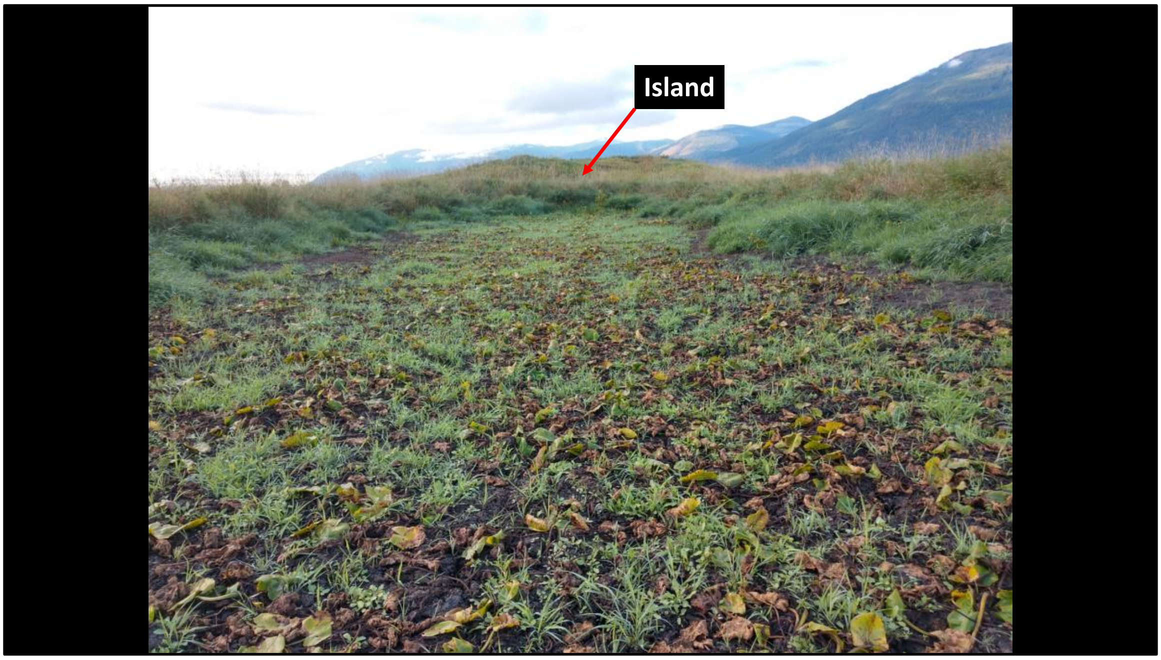
Rock was used to build two riffles in the Goat River South. The upstream riffle directed water from the ditched section into the restored loop of the river. The downstream riffle returned water from the restored loop where water the water level was higher into the dug ditch where water levels were lower.



The constructed downstream riffle raised the elevation of the ditched section of river by approximately 1-meter.

The loop in the Goat River South had been cut off to facilitate the construction of a dam for the impoundment. The cut-off loop was reconnected to the river and the original depth of water in the loop was also restored. The higher water level will help to restore groundwater elevations over the Hunting Grounds.

The restored loop of the Goat River South now provides habitat to the Western Painted Turtle, white sturgeon, and the burbot.



Numerous large mounds of soil were formed across the landscape of the Hunting Grounds, supposedly to provide nesting sites for waterfowl. The impoundment surrounding each nesting island remained dry because the dam for the impoundment did not hold water, and the natural wetlands had been drained as part of impoundment construction. The large island shown was built in the center of a natural abandoned channel of the Goat River.

Here the dozer operator removes one of the large mounds of soil. The soil from the mound was used to fill drainage ditches and to restore the rims of the many natural wetlands that were drained.

Care was taken not to fill historic wetlands with soil removed from leveling the islands. The 1929 aerial photo proved to be invaluable in quickly identifying where historic wetlands were located.

The Caterpillar D6R LGP dozer was able to remove an average of two large islands in a 10-hour day.

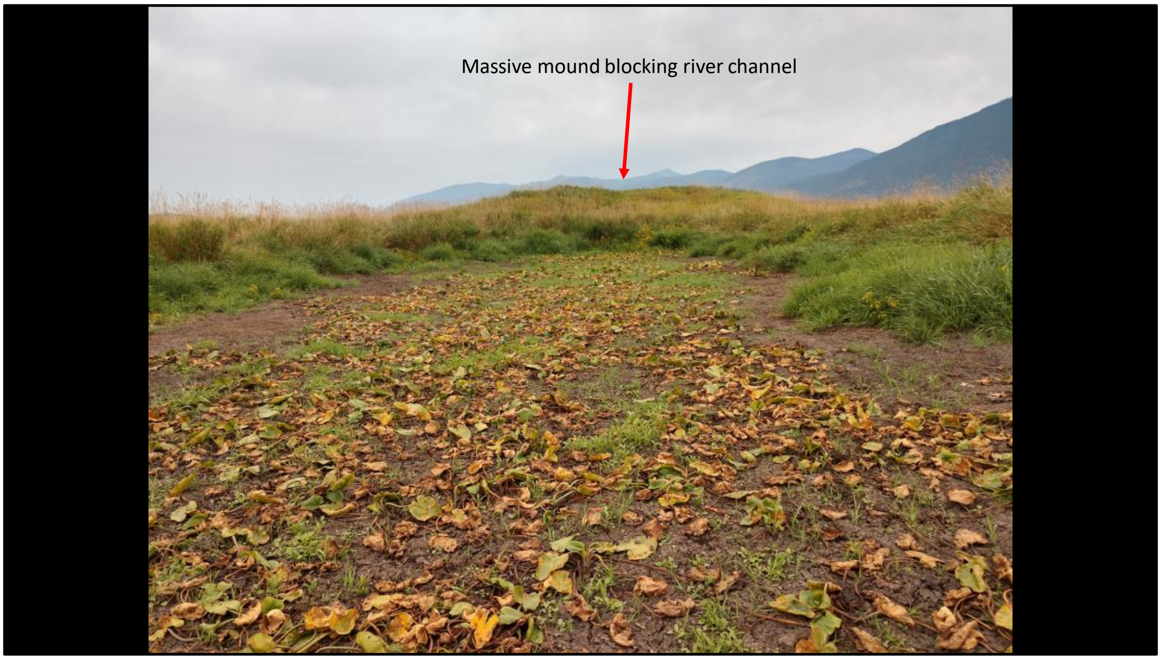
The smaller piles of soil leftover from digging narrow ditches were removed in one-hour or less.

Wetlands were then built where the islands had been located. This is one of many of the small wetlands restored where nesting islands were removed.

Wet-meadow wetlands were formed by shaping shallow depressions on the locations where large mounds (islands) were removed.

A diversity of aquatic plants are growing where a large mound of soil was removed one-year earlier. The sedges are being used for food by grizzly bear and elk.

This wet-meadow wetland was restored following the removal of a nesting island.



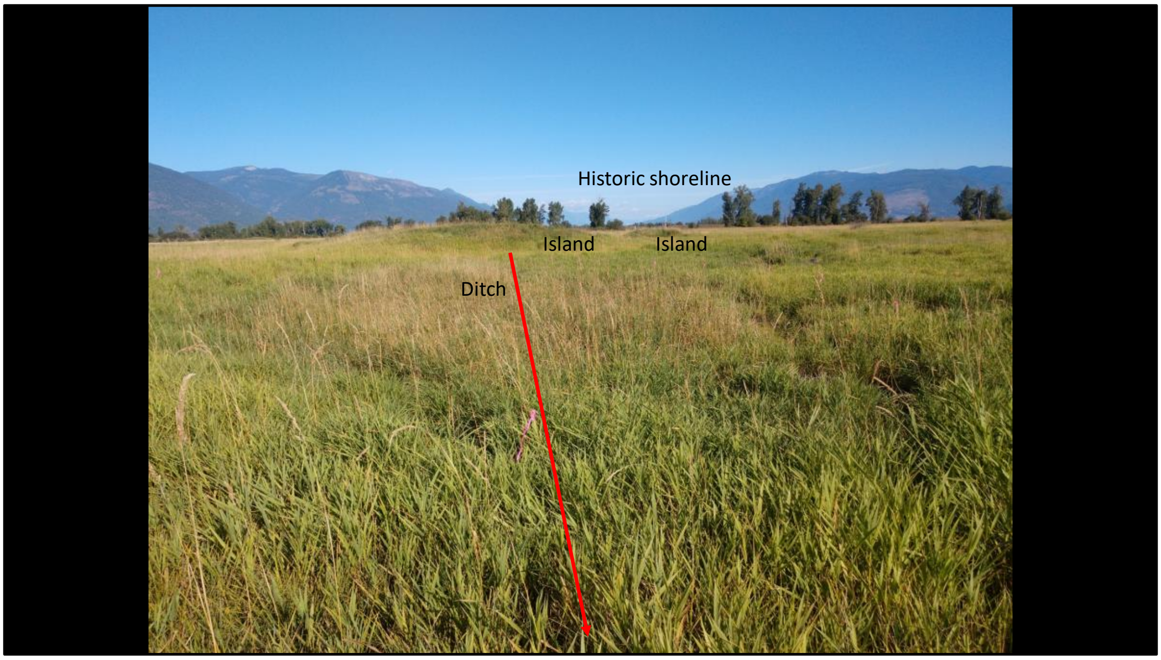
This massive mound of soil had been placed in the center of a natural river oxbow to block the channel.

Here is how the blocked river channel appears one-year after the removal of the mound and reconnection with floodwaters.

Here is another river channel that was restored.

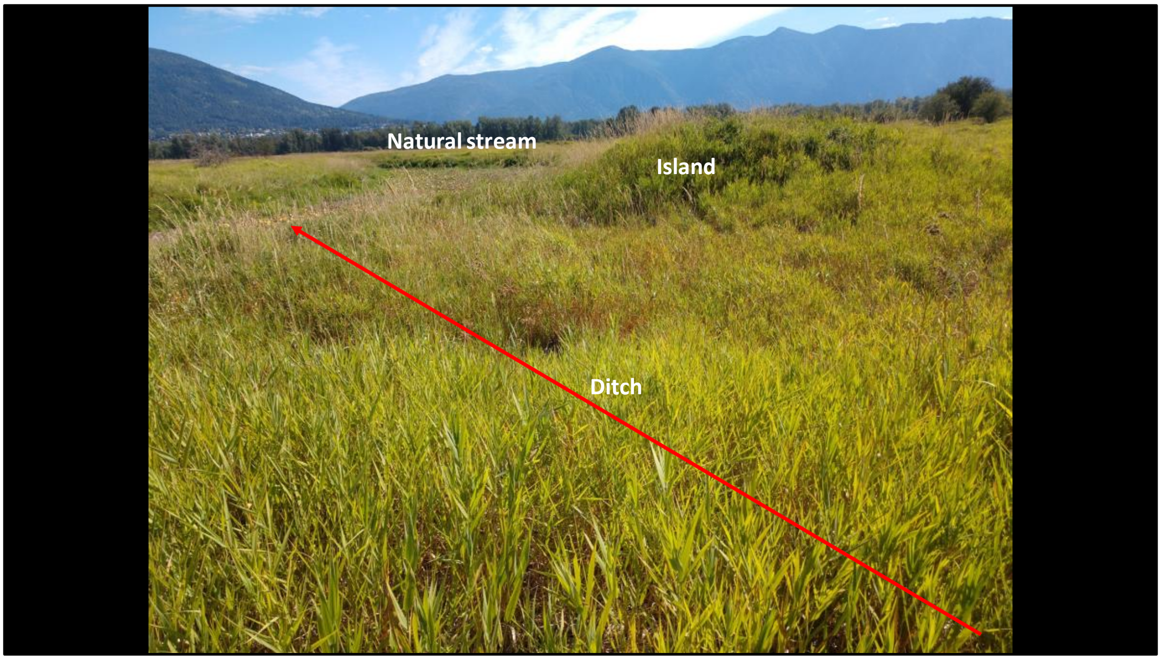
Tall and dense growths of reed canary grass were found growing in wetlands that had been drained. Dry, shallow basins containing reed-canary grass provided strong indication of drained wetlands.

Norm Allard is standing in the bottom of a ditch dug to drain a natural wetland for construction of the impoundment. The ditch appears deepest where he is standing because it is passing thru the natural rim of the drained wetland. Notice the tall and dense reed canary grass in the drained wetland. We identified ditches that were dug to drain every natural wetland within the Hunting Grounds as part of Impoundment Construction.



The red line shows the location of a ditch dug to drain another large natural wetland for the impoundment. The large islands were constructed within the drained natural wetland using soil removed from digging the ditches. The shoreline of the historic wetland is shown by the tall cottonwood trees in the background. The detailed Lidar images we had were of limited value because tall reed canary grass masked the presence of ditches.

This is a ditch within a ditch. The narrow ditch was dug by a beaver in the bottom of a wide ditch dug by humans to drain a natural wetland for the impoundment. We found that beaver often dug canals along the length of human dug ditches. The deeper beaver dug channels resulted in further drying of wetlands drained by humans.



We found the best way to identify drained wetlands was to examine areas on the ground. This red line shows the center of a ditch that was dug to drain a natural wetland for the impoundment. The ditch drained water into a natural stream channel. Ditches were identified by the presence of islands, straight lines, and low places or notches along the banks of streams which had also been drained.

Colored plastic ribbons were used to show heavy equipment operators the center location of ditches to be filled.

The orange plastic flags show the excavator operator where to build a groundwater dam in order to disable the ditch shown by the dashed line..

Here the excavator operator begins the restoration of a drained wetland by removing vegetation and topsoil from a ditch to be filled.

Plants and topsoil are removed from an area approximately 10-meters either side of the center of the ditch.

Reed canary grass and its roots are removed and buried from each wetland area being restored. The topsoil was also removed and not placed in the restored wetland because of the reed canary grass seed it contained.

The excavator has removed the reed canary grass and topsoil from one side of the ditch to be filled. This is two-ditches in one. The narrow beaver-dug canal is in the center of a much wider ditch dug by humans.

The next step in restoring the wetland involves building a groundwater dam at right angles across the ditch. The ditch is shown by the red arrow. The purpose of the groundwater dam is to control the flow of water in soil beneath the ditch, and the flow of water in the filled ditch. The groundwater dam is built where the natural rim or dam of the historic wetland was located.

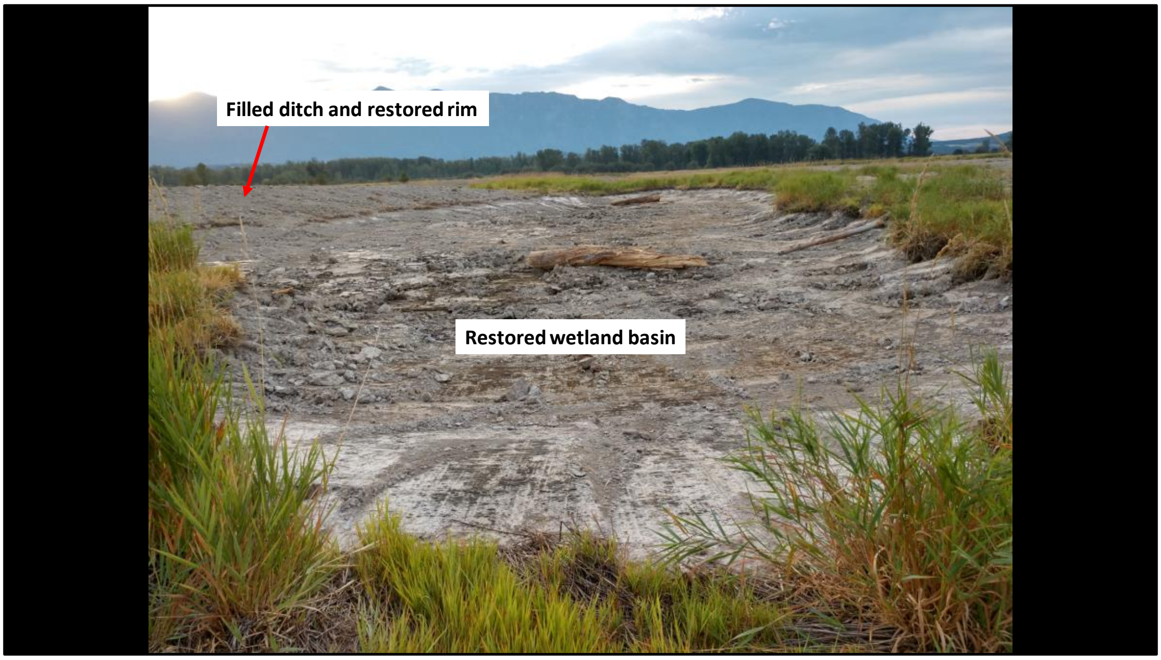
The pink wire flags show the operator where to begin and end digging the trench for the groundwater dam. The trench is dug deep into a dense layer of clay. Note the roots that were severed by digging the core trench.

Soil that is high in clay is placed in the core trench in 15cm thick layers, with each layer being compacted using the bucket on the excavator.

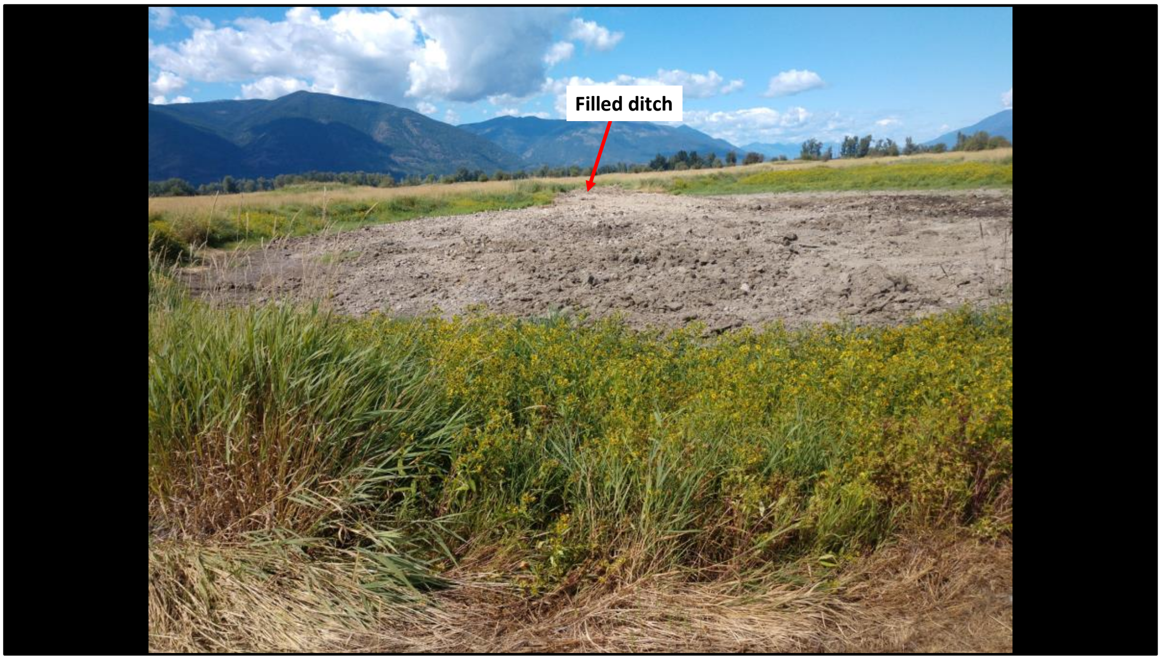
It takes time to fill the core trench with clay, and to compact each layer of clay. The clay used to fill the trench is obtained from the basin of the wetland being restored.

Here the excavator operator uses the weight of the machine to compact the upper layers of clay placed in the trench.

The dozer is used to move soil high in clay towards the excavator. The dozer also shapes a naturally appearing basin and rim for the wetland while supplying the excavator with the soil needed to fill the ditch. It is very important that one excavates basins if you want water to remain after floodwaters recede. This is because the elevation of the inlet is only 20cm higher than the outlet. When floodwaters recede a layer of water only 20cm deep will remain unless there are depressions on the floodplain.



The ditch has been filled and the natural rim surrounding the wetland basin has been restored.



This photo shows a natural wetland restored within the impoundment. The yellow flower is called Bidens that was saved to provide habitat for pollinators.

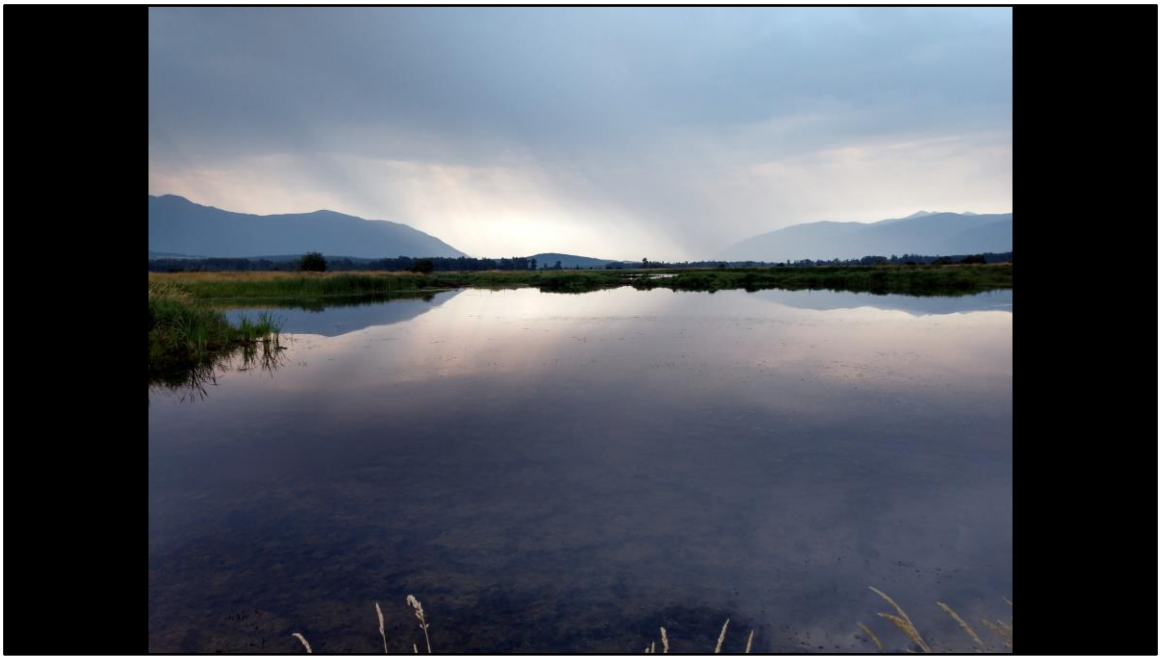
The borrow pits where soil was removed to fill the ditches were also shaped into wetlands. This small wetland that was made from a borrow pit is one-year old.

Large woody debris was placed in restored wetlands and streams to provide the Western painted turtle with basking sites, waterfowl with loafing areas, and the Great Blue Heron with perches.

Woody debris was placed in and around the restored wetlands to provide wildlife and fish with places to hide.

The large woody debris will provide fish with cover when the wetland fills.

Large woody debris was also placed in the restored loop of the Goat River South. There were 8-Western Painted Turtles basking on these logs before the photo was taken.



Some of the wetlands restored on the Hunting Grounds were made large and deep. These wetlands contain water year around because they are periodically inundated by floodwaters from adjoining rivers. Burbot and White Sturgeon, both Species at Risk, are being stocked in these perennial water wetlands.

Many wetlands were restored at higher elevations on the floodplain so they would not be inundated by floodwater. These wetlands, called ephemeral wetlands, dry annually. Ephemeral wetlands provide important habitat to waterfowl, amphibians, and crustaceans, because they do not support fish.

The restored wetlands that are not periodically inundated by floodwaters dry by late summer. These ephemeral wetlands provide outstanding habitat for migrating ducks, geese, and swans.

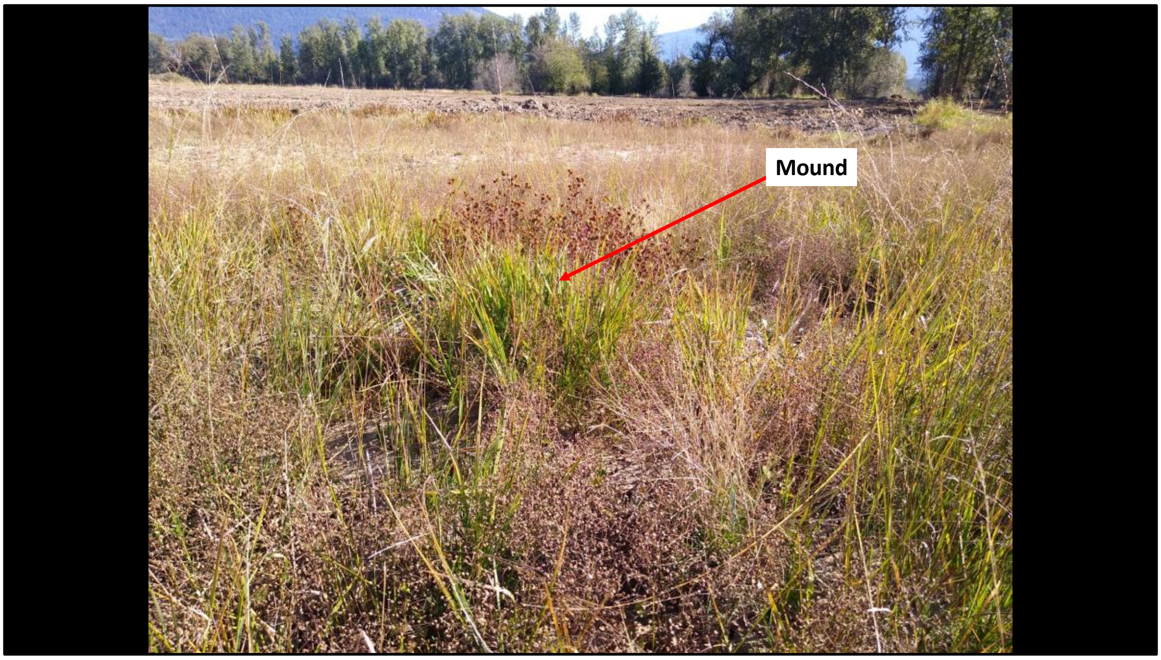
Sandy-loam texture soil removed during wetland restoration was shaped into above ground islands and ridges in well-drained and sunlit locations to provide the Western painted turtle with nesting sites. Note the logs placed in the background to provide turtles with basking sites.

The roots and rhizomes of water lilies unearthed during construction showed that the dry basins historically contained water. These were replanted on site in the restored wetlands and streams.

Water lilies are flourishing in the restored streams and wetlands where they laid dormant for 60-years.

Restored wetland basins were shaped with pits, mounds, and ridges to provide conditions for the establishment of a diversity of plants. The pits and mounds in the basins varied up to 2-meters in elevation. Excavator bucket marks were hidden, and loose soil was spread in the wetland basins. Cattails or reed canary grass are not able to dominate a wetland built using these techniques.

The pit and mound topography restored in and around the wetlands will provide conditions for a diversity of native plants to become established, and prevent any one species of plant from dominating the basin.



Note how the mound placed in this restored wetland is growing sedges and bidens in only one year. The lower elevations in the basin are supporting water plantain.

A diversity of native plants are growing in this two-year old restored wetland. These aquatic plants grew naturally without seeding or planting.

A diversity of aquatic plants have colonized this perennial water wetland within one-year of restoration.

One-year ago this drained wetland was dominated by reed-canary grass. The wetland was restored by removing reed canary grass and its roots, disabling ditches, and by restoring the contours of the natural wetland basin. We have been successful at replacing dense reed canary grass with a diversity of native aquatic plants by using this technique.

The restored wetlands are quite diverse. This restored wetland is growing burreed, rushes, and willow.

Sedge dominates this restored wet-meadow wetland on the Hunting Grounds. Sedges are important food for elk in the fall and winter.

One can see where elk are feeding on the sedges growing in the restored wetlands.

This restored wetland is growing wool-grass (Scirpus cyperinus)

This restored wetland is growing bullrushes.

Here is one of many wetlands restored on the Hunting Grounds one-year after construction. This site was dominated by a large mound of soil and by a dense growth of reed canary grass. The wetland filled when the Kootenay and Goat Rivers flooded the Hunting Grounds in the Spring of 2020. Restored wetlands that were hydrologically connected with floodwaters contained water throughout the severe drought experienced in 2021 while wetlands not inundated by floodwaters dried.

The restored wetlands contain shallow water and a diversity of plants.

The Hunting Grounds Ecosystem Restoration Project restored over 60-natural wetlands, 8-streams, and sections of 3-rivers by removing dams, filling ditches, and by recontouring wetlands and streams.

The Hunting Grounds project restored natural ephemeral streams that had been cut-off from rivers and impacted by the construction of impoundment dams.

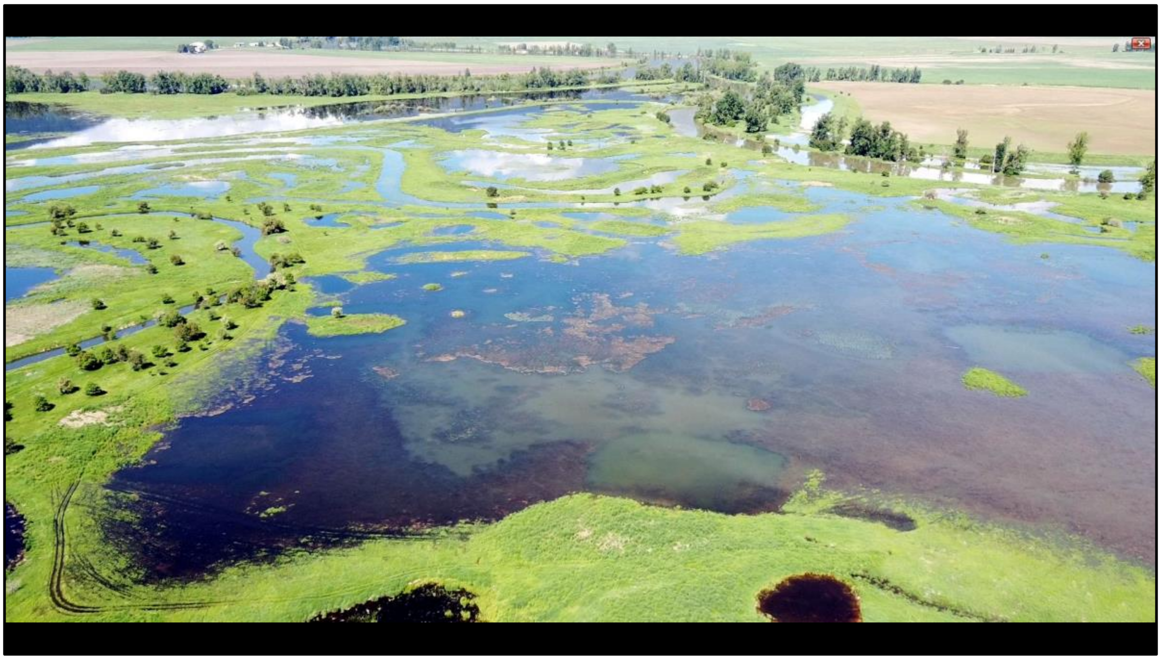
The restored ephemeral streams are rare habitats in agricultural regions. As most have been changed into ditches.

The Hunting Grounds Project restored seasonal wetlands that now support a diversity of wildflowers used by pollinators.

Bidens can be found growing in the moist soils of wetlands restored on higher ground that are not inundated by floodwaters.

The restored wetlands are supporting a diversity of plants and animals within one-year of construction. The tracks in this photo are from a grizzly bear and her cub that were feeding on cattails.

I would like to thank the Yaqan Nukiy for taking the lead in restoring wetlands, rivers, and streams from constructed impoundments.



This photo taken by Norm Allard shows the Hunting Grounds on June 6, 2022 reconnected with floodwaters from the Goat River, Goat River South, and the Kootenay River.

Returning annual flooding to the Hunting Grounds has produced wetlands that contain water in drought.

This aerial photo shows the Hunting Grounds prior to restoration in 2015.

This photo shows the Hunting Grounds reconnected with floodwaters in 2021.

Naturally appearing and functioning wetlands, streams, and rivers may be restored from constructed impoundments.

The Yaqan Nukiy Hunting Grounds Ecosystem Restoration Project is a success. The project reconnected over 519-acres of floodplain containing restored wetlands and streams with the Kootenay River, Goat River, and the Goat River South. The project showed that artificial impoundments constructed years ago may be restored to a diversity of naturally appearing and functioning wetlands, streams, and rivers that provide habitat for waterfowl and Species at Risk. Please contact Tom Biebighauser if you would like help planning similar projects in your area.