Wetland Restoration Pilot Project at Florissant Fossil Beds National Monument

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Introduction

Designated as a National Monument in 1969 in order to protect its fossil beds, Florissant Fossil Beds National Monument (FLFO) was homesteaded in the 1870's and used as cattle ranches for the following century. The land homesteaded for ranching contained large natural ground water fed meadows dominated by sedges and rushes. To irrigate the uplands during summer months to produce hay for cattle forage, as well as to create ponds for livestock watering, multiple small dams and reservoirs were constructed. By the time this land was set aside to become a national monument, 8 dams had been constructed throughout the valley. Many of the dams no longer hold back any water as the water has created channels through the wet meadow around the dams, where no channels had previously existed. Because of these hydrologic modifications, each channel has continued to incise, with some sections more than 2m below its historic level. Channelization within the wet meadow, along with the continuous incising and headcutting, has significantly lowered the water table, allowing upland exotic plants to invade, and putting the native wet meadow vegetation at risk.

Many of these channels have been created adjacent to the Hornbeck Homestead (475393 E, 4308569 N), one of the most important visitor use and history demonstration sites at FLFO. Because the meadow has been drained and heavily invaded by exotic vegetation the present day condition of the Hornbeck site does not reflect either the natural or early homesteader condition of the area. As the channels continue to headcut further up the valley as well as incising deeper into the meadow, the present study was implemented to understand the current hydrologic regime of the meadow, the impacts of the channels on the hydrologic regime, and how the meadow can be restored to its historic condition.

Methods

Historical Photo Analysis

Available rectified aerial photos were obtained for FLFO for the years of 1938, 1956, 1975, and 2010. All visible channels and dams were delineated for each image in ArcMap 10.1. to identify changes in land use and management.

Hydrologic Monitoring

In an effort to understand the current hydrologic regime within the valley, and the impact of channelization on the adjacent wet meadow, 46 groundwater monitoring wells were installed within the study area (Figure 1). Wells were installed along four primary transects perpendicular to the incised channels. One well was located in each channel, with wells installed along the transect at increasing distances from the channels, such that the density of wells was greatest near each channel. Two wells were also installed uphill of all channels to identify a suspected water source from the hillside. One meadow, uphill of all channels and dams was identified as a reference meadow. Four wells were installed within this meadow for an understanding of the hydrologic regime in the absence of channels or dams.

Wells were hand auger to approximately 1 m depth, cased with 3.8 cm schedule 40 PVC pipe with holes drilled approximately every 5 cm, and then backfilled with native soil. Both the top and bottom of the well were capped, with a hole drilled in the bottom cap to ensure water drainage from the well if the water table dropped below the casing. Water depth in each well was measured approximately weekly by FLFO park staff from July through October 2012. One pressure transducer (In-Situ Inc., Rugged Troll 100) was installed into sixdifferent monitoring wells, each in a different part of the valley. Pressure transducers were hung with braided copper wire near the bottom of the casing to record hourly water table depths. One barometric pressure logger (In-Situ Inc., Baro Troll 100) was hung in a tree near the center of the valley to account for barometric pressure variations recorded by the water pressure transducers.

Stable Isotopes

Water samples for stable oxygen isotope analysis were collected in polyethylene bottles from 14 wells as well as rain events in July 2012. Wells were chosen specifically to identify presumed water inflow sources to the meadow. Water was collected from each well using a well bailer. Rain was collected over the month by placing a funnel into a 1 gallon plastic jug, which was then dug into the ground to insure its stability. To limit evaporative enrichment of the collected rainwater, mineral oil was poured into the jug prior to the collection of rain. This layer of oil would float on top of any collected water, thus limiting the amount of evaporation from the sample. The jug was collected at the end of July and its rain water decanted into two sample bottles. After collection, each bottle was sealed with a screw cap and parafilm, and stored in a 37° F refrigerator until processed. All samples were processed within one month of collection.

The stable oxygen isotope ratio ($\delta^{18}O$) of all water samples was determined by CO2 equilibration using a VG Microgas Injector coupled to a VG Optima Isotope Ratio Mass Spectrometer (Natural Resource Ecology Laboratory, Colorado State University, Fort Collins). $\delta^{18}O$ results are reported as parts per thousand (‰) using the δ notation as follows:

$$\delta^{18}O(‰) = [(R_{sample}/ R_{standard}) - 1] \times 1000$$

whereR_{sample} and $R_{standard}$ are the molar abundance ratios ($^{18}O/^{16}O$) of the sample and Vienna Standard Mean Ocean Water, respectively (Clark and Fritz, 1997). More negative $\delta^{18}O$ values indicate a higher ratio of lighter isotopes, while more positive values indicate evaporative enrichment of heavier isotopes, relative to the standard.

Topographic Analysis

The project area ground surface was surveyed in July 2012 using a Nikon Total Station and handheld Nomad Data Logger with Survey Pro 4.1. Surveyed points, each with UTM coordinates and elevation, were imported to ArcMap 10.1 and transformed into a Triangulated Irregular Network (TIN). New TINs were created for the land surface without the dams, as well as for various scenarios for the installation of plugs into the channels. In order to calculate the volume of each dam to be cut and the volume of each plug to fill, each TIN was converted to a 1x1m cell raster. Rasters were then compared using the Cut/Fill tool to identify locations to be cut or filled, as well as their volumes in m^3. Five locations were identified for plug installation to maximize the re-distribution of water across the meadow.

After the pilot restoration was completed the dams and plugs were surveyed again to calculate the amount of material moved in the construction.

Results

Historical Photo Analysis

The Hornbeck meadow had already been altered in the earliest image available. Few dams existed on the landscape in 1938, but fence lines and corrals are visible in the image, indicating differences in land management at this early stage (Figure 2). Between 1938 and 1956, many of the dams that exist today were built. The image shows large ponds created by moving the surface of the land into a pile to create both a pool and a dam. By 1975, the dams are still in existence, but many of them no longer hold back any water. In the 20 years of the dams existence, water has eroded channels around each dam. This channelization has continued to the present day image. Channels have become longer than the 1975 image, as well as much deeper and more pronounced. The extent of wetlands in the area is difficult to determine based on image resolution and color, but it is reasonable to assume that wetland acreage declined through the years as some land became ponds, some became dams, and some was drained by the newly formed channels.

Hydrologic Monitoring

Though 2012 proved to be an anomalously dry year, water table data indicated that both channels within the project area were lowering the water table within the meadow (Figure 3), even though multiple locations were discharging water into the meadow. Monitoring wells near locations of water discharge typically had water table depths less than 0.5 m (Figure 4). Water tables near channels were much deeper than their point of origin. Water tables continually declined as they approached each channel, with a further dip into each channel, indicating that channels are acting as a drain to this meadow.

Water tables in the reference meadow were consistently less than 0.5 m from the ground surface. Though the region received very little precipitation, this data indicate a steady source of groundwater discharge to the area.

Stable Isotopes

Rain samples collected had an $\delta^{18}O$ of 0.94, consistent with the heavier isotopic signature of summer rain. Water samples collected from monitoring wells had $\delta^{18}O$ ranging from -1.36 to -0.45. Six locations of water discharge were identified by isotope values (Figure 5). More negative isotope values indicate locations near where water discharges into the meadow from a source. Water samples collected from each channel had the most evaporatively enriched samples, indicating they originated from further away.

Topographic Analysis

A total of five dams and three channels were part of the surveyed landscape (Figure 6). Three dams with a total volume of 400 m^3 were identified to be removed as part of this pilot restoration project (Figure 7).

Construction

Construction took place in October of 2012. All three dams were removed, and the fill was placed into each channel in five previously identified locations (Fig. 8).

Figures

Figure 1. Well locations within the Hornbeck Meadow at Florissant Fossil Beds National Monument. Wells were installed in transects perpendicular to channels and in other locations of possible groundwater discharge, leading to 46 total wells within the study area.

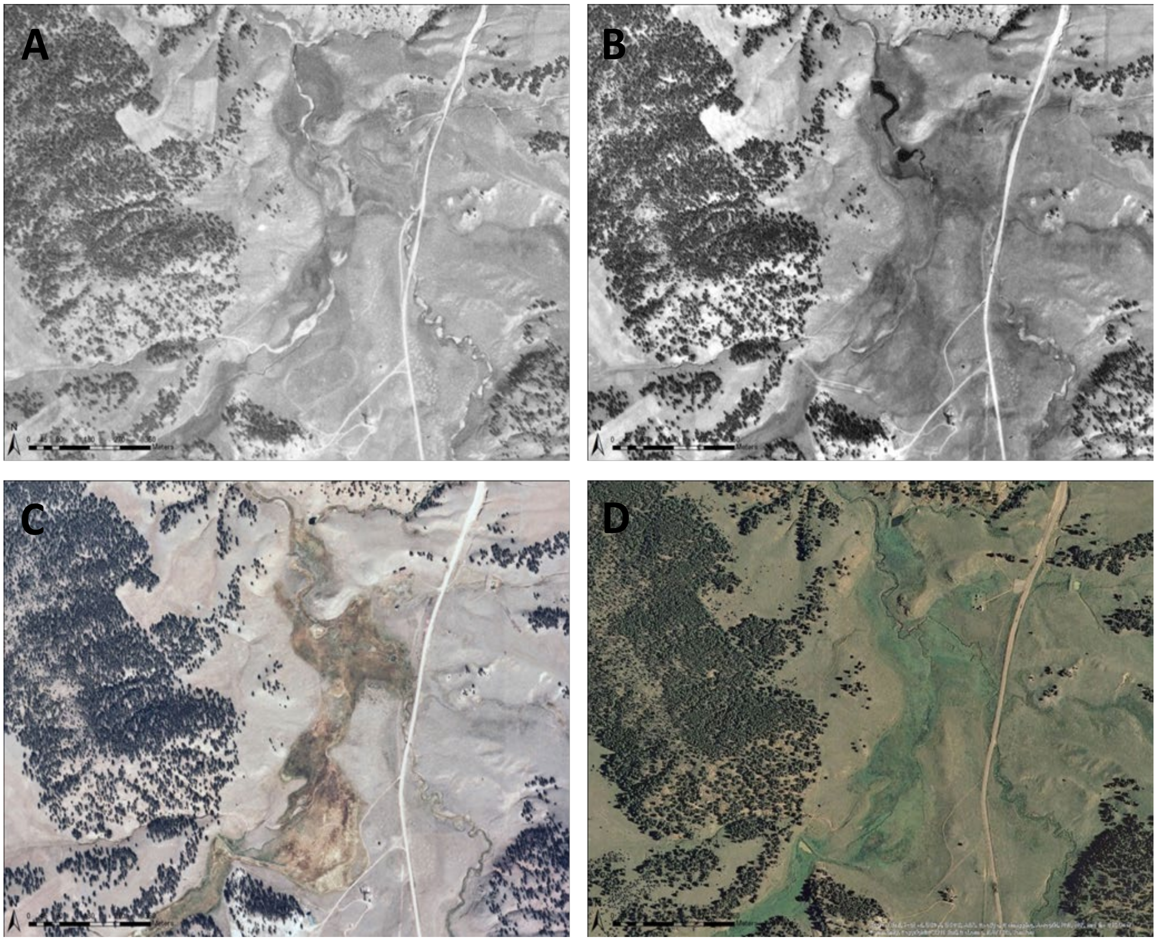
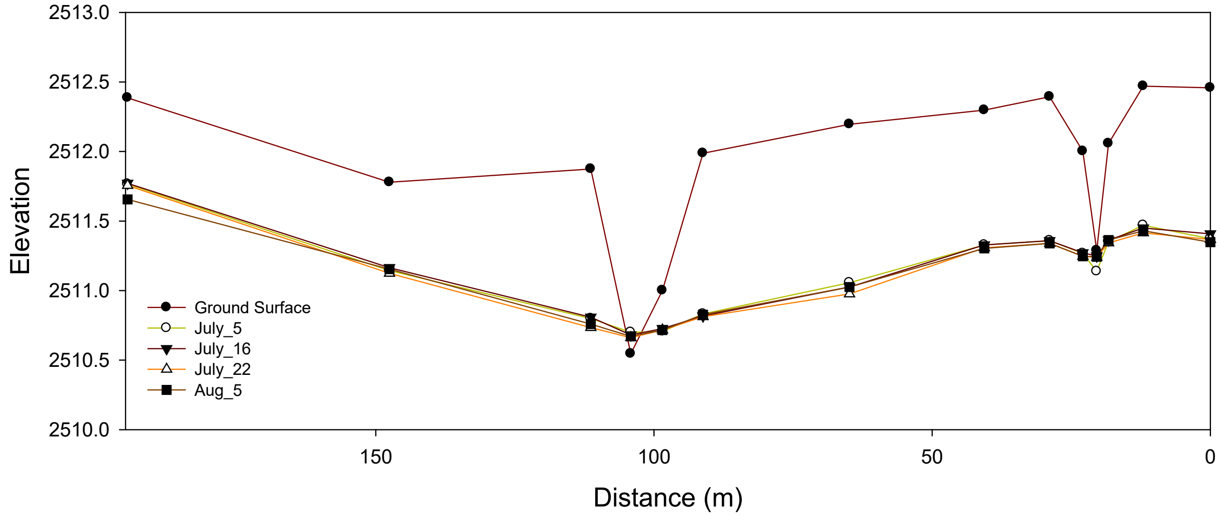


Figure 2. Aerial photos of the Hornbeck meadow from (A) 1938 (B) 1956 (C) 1975 and (D) 2010. Most changes to the landscape occurred between 1938 and 1956, when all 5 dams and associated ponds were constructed. Dams do not hold back water in 1975, and channels have formed in the 2010 photo.



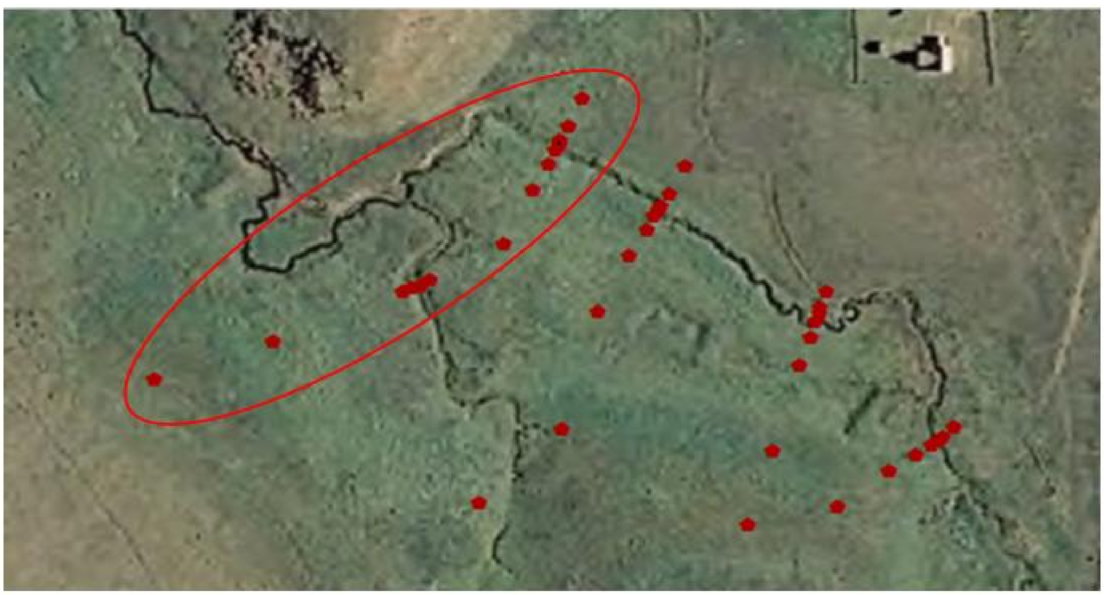
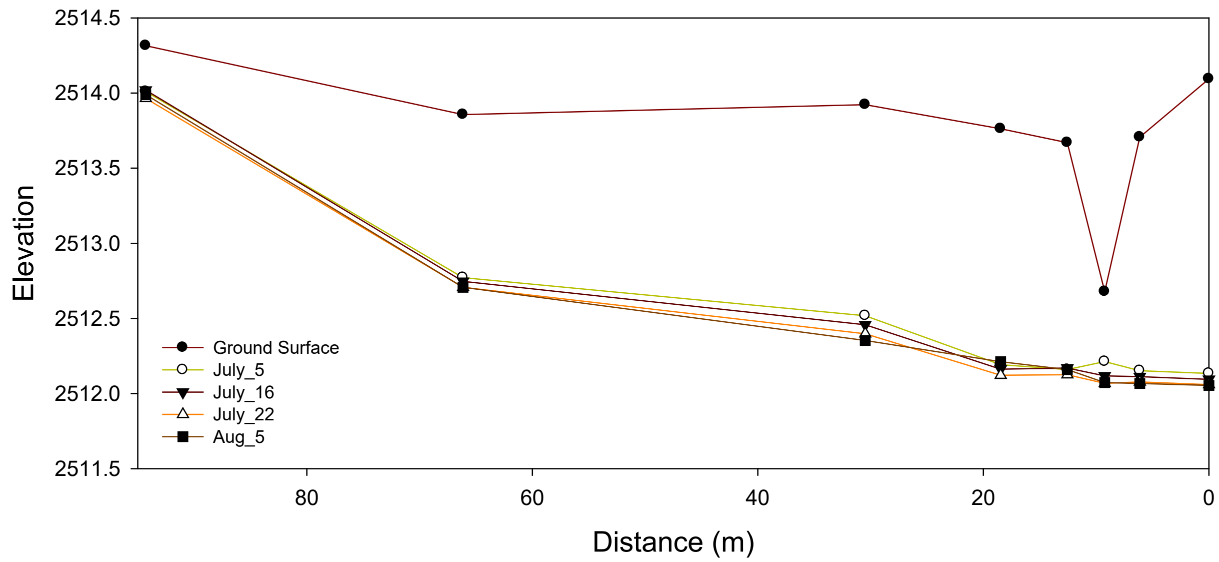


Figure 3. Top: Land surface and water table elevations within the Hornbeck meadow. Both channels can be seen with lowered water tables near each channel. Bottom: Location of wells shown in top figure.



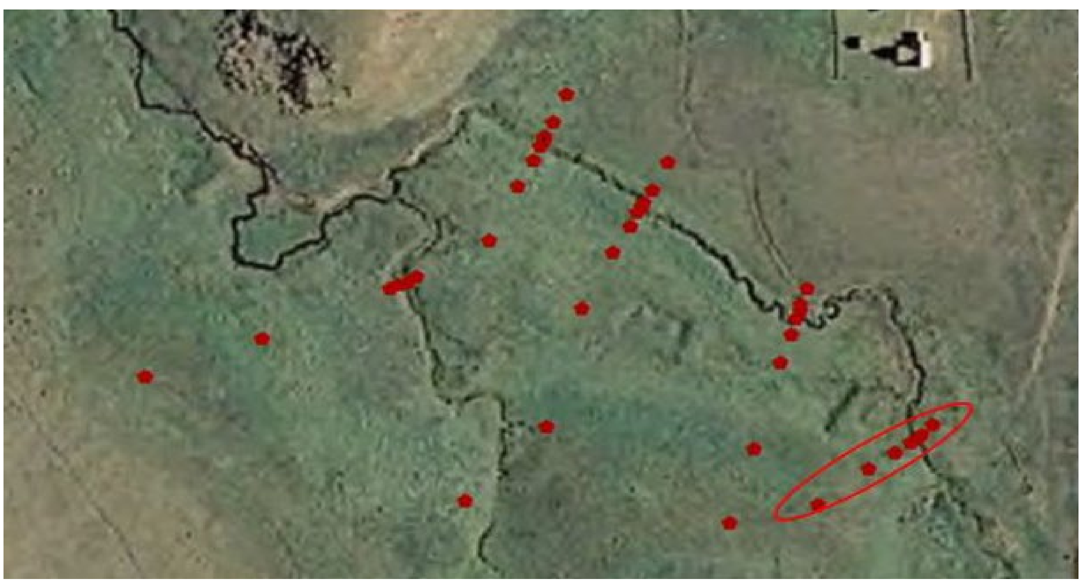


Figure 4. Top: Land surface and water table elevations within the Hornbeck meadow. Ground water discharges into the meadow (from left) and subsequently declines as it approaches the channel. Bottom: Location of wells shown in top figure.

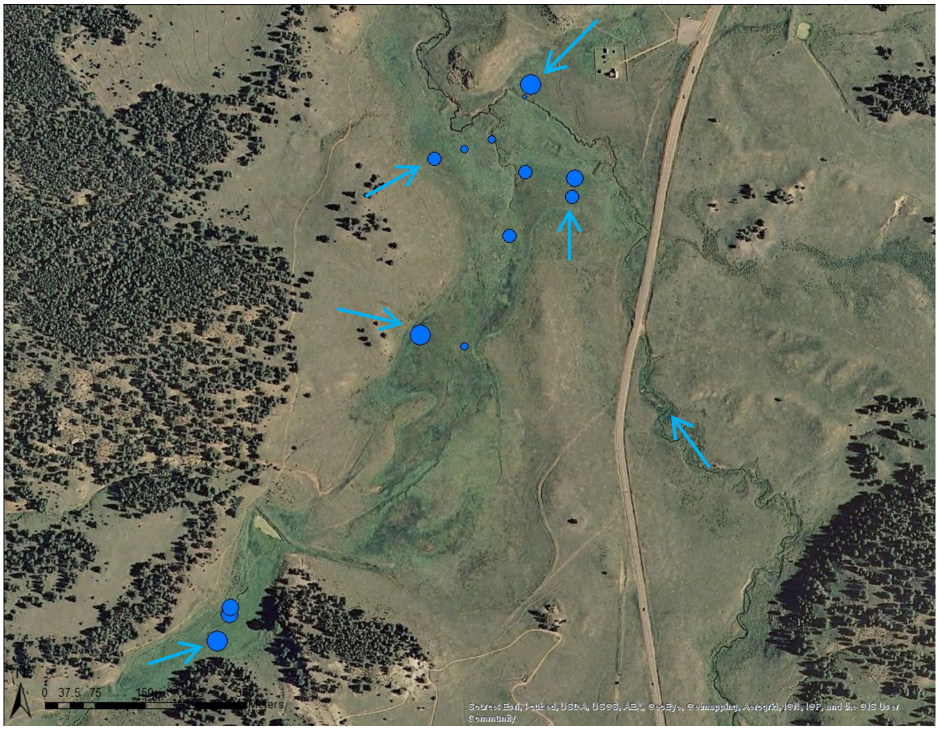


Figure 5. Isotope results with locations of apparent water discharge into the meadow. Circles indicate locations where water was collected for stable oxygen isotopic analysis. Larger circles indicate more negative values, which identify discharge points.

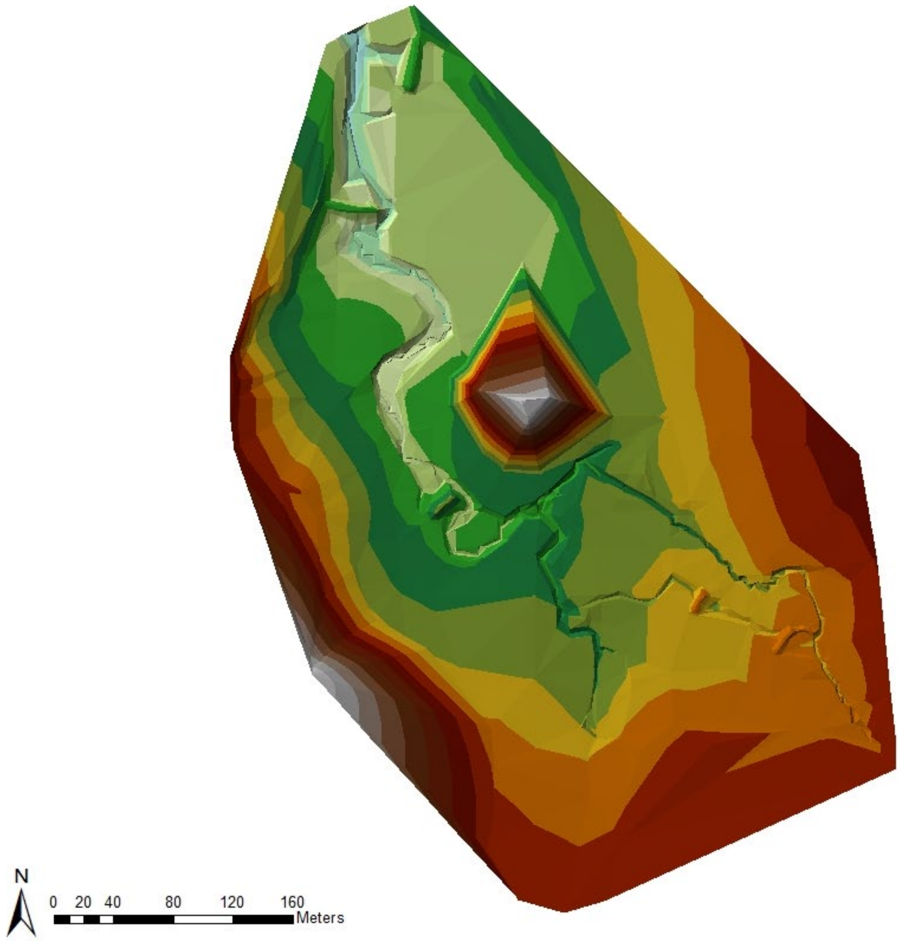


Figure 6. Triangulated Irregular Network (TIN) generated from surveyed points. Colors indicate locations of similar elevation, with each color representing 1m in elevation.

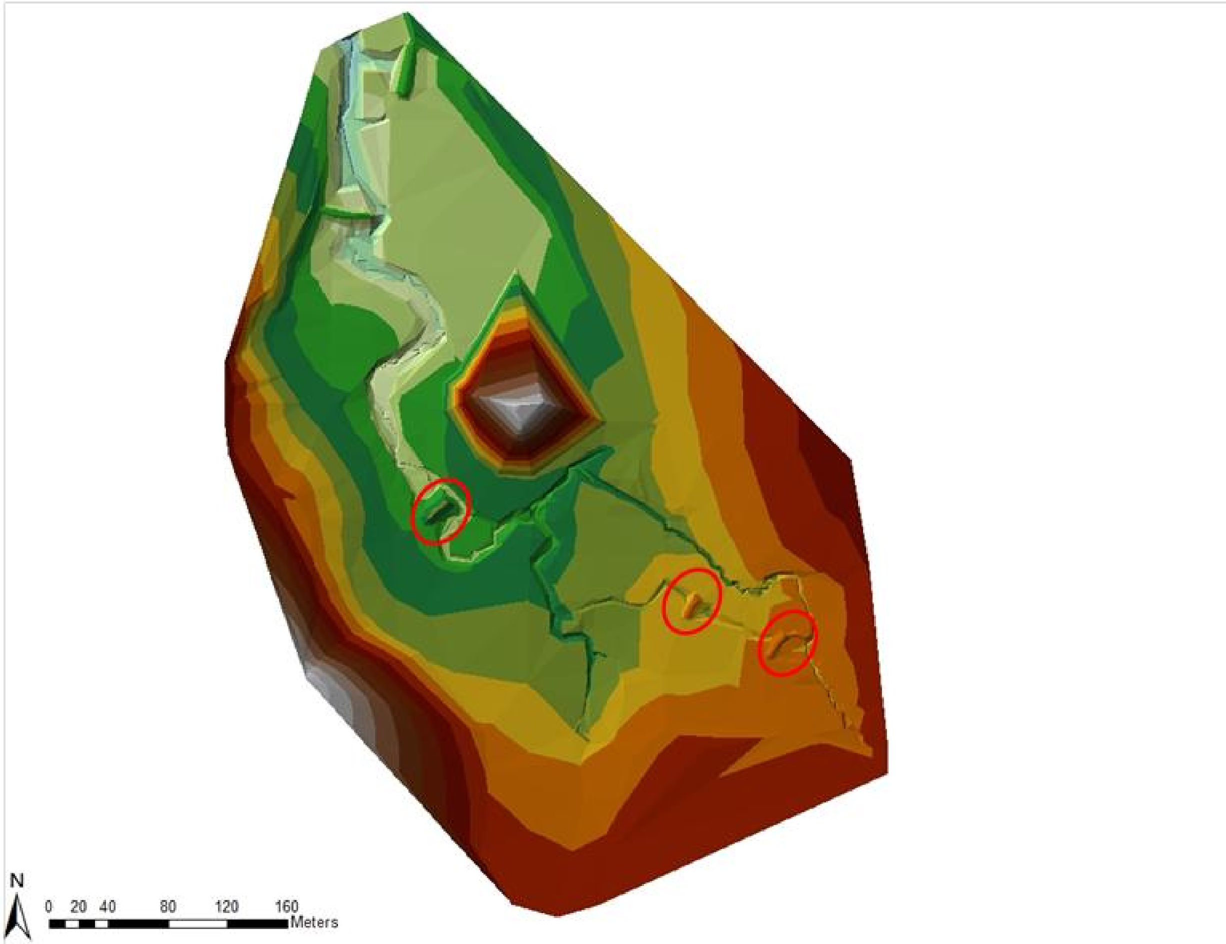


Figure 7. TIN from Figure 6 with 3 dams identified for removal circled in red.

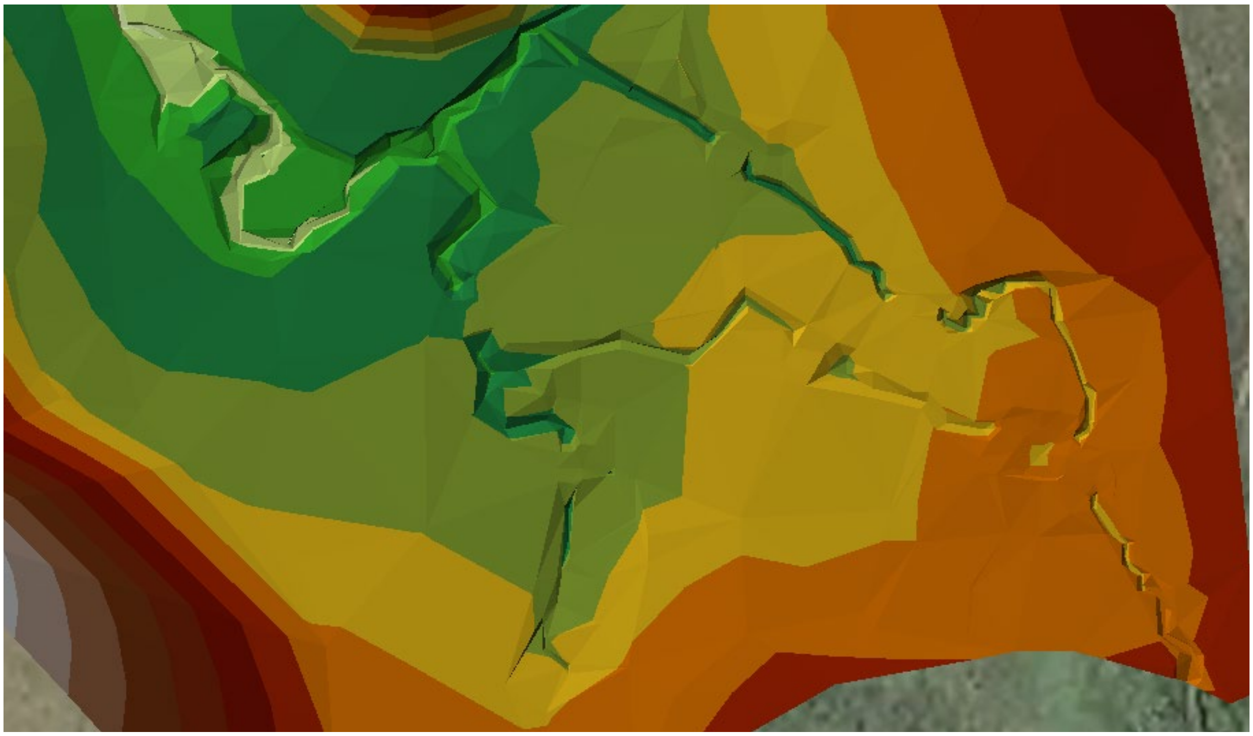


Figure 8. TIN of actual restored landscape with three dams removed and five plugs installed.

Figure 9. Hornbeck meadow channel before construction (top), during construction (middle) and after construction (bottom). This particular channel did not have any flowing water, making the efficacy of the plug installation unknown at this point.

Figure 10. Hornbeck meadow channel before construction (top) and after construction (bottom). This particular channel did not have any flowing water, making the efficacy of the plug installation unknown at this point.

Figure 11. Hornbeck meadow channel before construction (top) and after construction (bottom). Plug installation lead to the backup of water in the channel, which seemed to redistribute the flow into the adjacent meadow.