Wyoming Game and Fish Department
Fish Division, Administrative Report 2019

2018 Annual Monitoring Report for the North Platte River Restoration Project

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ABSTRACT

In 2018, the Wyoming Game and Fish Department (WGFD) continued annual monitoring efforts to evaluate the impacts of restoration projects on the North Platte River through Casper. The restoration projects are being completed in phases across seven project sites. Restoration was completed at site 1, Morad Park, in fall of 2015. Monitoring of the Morad Park site began in 2016 and continued in 2017 and 2018. Restoration was completed at sites 2 and 3, Wyoming Boulevard and Water Treatment Plant, in the fall of 2016. Monitoring began in 2017 and continued in 2018. Monitoring data were collected following protocol outlined in the monitoring plan (WGFD 2017). All planned monitoring was conducted in 2018 for Morad Park, and the results and interpretation are reported in this document. However, due to time and weather constraints, cross section profiles and bankfull line data were not collected in 2018 for the Wyoming Boulevard and Water Treatment sites. Those data will be collected in 2019 and a separate monitoring report will be written in 2019 for those project sites.

Monitoring data indicate that the reconstruction of the river channel and banks achieved the primary goals of the restoration project in the Morad Park site. In-stream structures seem to be largely intact and functioning as intended, with the exception of a rock vane that may have contributed to the formation of an eddy. A narrower and deeper river channel is maintained through the project site, and the entrenchment ratio, bank-height ratio, width-to-depth ratio, and cross-sectional area remain within the desired ranges. High flows can access the floodplain to dissipate energy, which has reduced streambank erosion rates through the reach. There is no evidence of lateral channel migration, as indicated by the matching bankfull lines of 2016 and 2018.

Fish habitat is maintained in the form of two deep pools and a toe-wood structure with an associated scour pool. Fish sampling has occurred every year since construction was completed. However, the sampling reaches and methods have varied during that time, making data difficult to evaluate. Fish sampling efforts were revised in 2018 to use a mark-recapture protocol and modified sampling and control reaches.

To folllow the monitoring plan guidance to monitor each restoration site for five years following completion of construction, the WGFD will monitor the Morad Park site will be monitored for at least two more years. Such monitoring will provide opportunities to evaluate long-term stability of the stream channel and vegetation establishment, and to detect and address maintenance needs. The five-year, post-construction monitoring schedule will be followed for each additional site as restoration is completed.

INTRODUCTION

The North Platte River is a valuable resource to the City of Casper and great efforts have been made in recent years to enhance the aesthetics and increase angling opportunities in the river through town. In addition to a large volunteer effort each year, a coalition of multiple private organizations and governmental agencies have secured funding to hire engineering and construction firms to complete restoration activities within the river corridor and improve the function of the river. Restoration sites were selected following an assessment of 13.5 miles of the North Platte River through the Town of Mills and City of Casper. Areas of mass bank wasting were documented where the river had over widened and caused divided stream flow. In the divided sections, areas of high shear stress contributed to accelerated bank erosion. Amount and quality of fish habitat was also low because long sections of the river lacked riffle pool complexes.

There are seven individual project sites through the 13.5 mile river corridor through Casper that have been identified for restoration efforts (Stantec Consulting Services 2012). To verify that restoration efforts met the intended goals of the project and to evaluate whether future maintenance efforts will be needed, a comprehensive annual monitoring plan was developed (WGFD 2017). Annual monitoring is planned for five years, beginning one year after site restoration is completed. Monitoring will document the benefits of each project and assess the condition of the stream channel and structures used to maintain the desired conditions. These efforts will also help identify any maintenance needs. This report provides the results of annual monitoring efforts completed in 2018.

Restoration was completed at the first site, Morad Park, in fall of 2015 and monitoring began in 2016 (Figure 1). The channel was excavated to remove a mid-channel island and banks were graded. Four riffle vanes were constructed to narrow the channel by directing flow to the center of the channel. A side channel was excavated behind the left bank and toe wood was installed on the right bank to protect an outside bend from erosion. Three rock arms were constructed to direct flows away from banks and create scour pools. Herbaceous and woody riparian vegetation was planted along the disturbed banks.

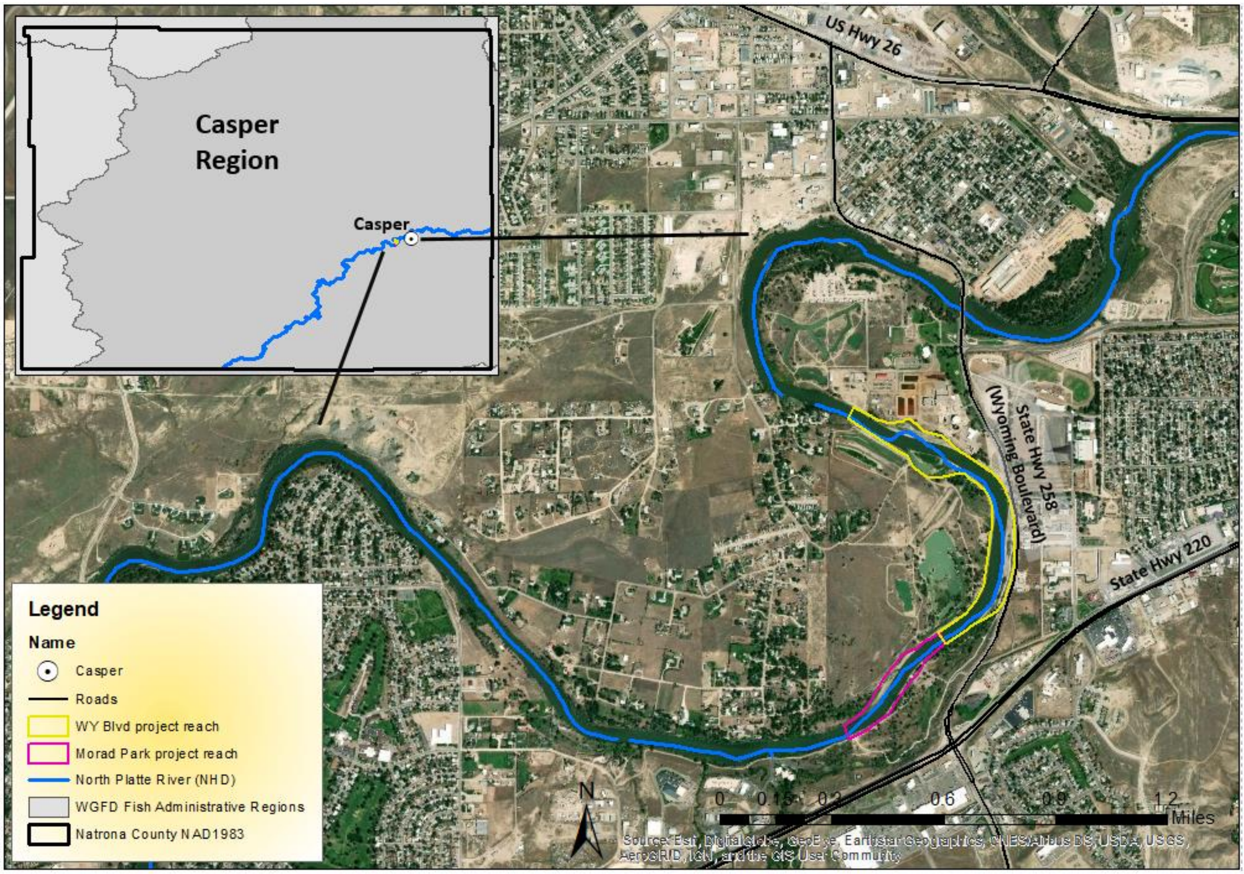

Figure 1. – Locations of the Morad Park and Wyoming Boulevard (Water Treatment Plant reach included) restored reaches.

METHODS

Monitoring was completed on Site 1, Morad Park (Figure 2), in 2016 and continued in 2017 and 2018. Data were collected by the Wyoming Game and Fish Department following protocol outlined in the Monitoring Plan (Table 1; WGFD 2017). However, due to staff changes in 2017, photo points were the only data collected in 2017. In 2018, monitoring was resumed and all data were collected according to the monitoring plan, including data collection that was skipped in 2017. Primary monitoring occurred on July 17, 2018 and October 15, 2018 to October 19, 2018. In addition, bankfull elevations were resurveyed on April 1, 2019.

Table 1. Five-year monitoring plan for the Morad Park project reach. An "X" marks planned data collection. "X (missed)" marks when data should have been collected but was not.

Category	Data Collection	As-built	2016	2017	2018	2019	2020
Visual Assessment	Photo stations (summer)	10/06/2015 - 12/09/2015	NA	8/3/2017	7/17/2018	X	X
	Photo stations (fall)		10/26/2016	11/21/2017	11/15/2018	X	X
	Rapid assessment for in-stream structures	NA	10/26/2016	X (missed)	11/15/2018	X	X
Geomorphology	Cross sections (riffle)	X (missed)	10/26/2016	X (missed)	11/15/2018	X	X
	Cross sections (pool)	X (missed)	10/26/2016	NA	11/15/2018	NA	X
	Longitudinal profile	NA	10/26/2016	NA	11/15/2018	NA	X
	BEHI & NBS	NA			11/15/2018	NA	X
	Map Bankfull Line	NA	10/26/2016	X (missed)	11/15/2018	X	X
Fisheries	Single pass electrofishing	NA	2016	10/2017	10/23/2018 - 10/25/2018	NA	X

Visual Assessment - Methods

The general condition of the channel, structures, and riparian vegetation were assessed visually each year of monitoring to identify any obvious problem areas or concerns that may not be detected using other monitoring methods. Visual assessment included both photos and a rapid assessment of the integrity of each structure installed during construction.

Photo point stations are used to document change over time. Stations are spaced closely enough that there are overlapping features in successive photographs; all portions of the project site are included in these images. Each station is marked with an iron bar and its coordinates were recorded. In the summer (July-August) and in the fall (October-December), photos are taken at each location looking upstream, downstream, and across the channel. Photos from 2017 were printed and taken into the field to help replicate the photo orientation. At the Morad Park reach, seven photo monitoring stations were established in 2016. The seven locations are roughly equivalent to the same locations monitored before, during, and immediately after construction by the engineering design firm, Stantec Consulting Services, Inc. Several of the points were moved closer to the stream edge after construction (Figure A.2.1).

The rapid assessment procedure (Table A.4.2; Miller and Craig Kochel 2013), was used to evaluate the condition of structures installed during restoration of each site. Each structure is visually assessed for its structural integrity and ranked on a score of 1-4 which are described as 'Intact', "Damaged', 'Impaired', and 'Failed'. Unintended erosion or deposition associated with each structure is ranked on a scale of 0-5; rock and wood features are ranked on the same scale but use different descriptions for each rank. Photos were also taken of each structure that was visible, although some of the visible portions of underwater structures are difficult to see in photos. The structures at the Morad Park project reach were numbered 1-8 and included (in order) a toe-wood bank stabilization structure, three rock vanes (numbered 2-4 from upstream to downstream), and four constructed riffle vane arms (numbered 5-8 from upstream to downstream).

Geomorphology - Methods

The three goals for modifying the geomorphology of the river were to 1) narrow the over-widened river, 2) improve fisheries habitat, and 3) stabilize the stream banks. In 2018, data were collected to evaluate all three of these goals for the Morad Park project reach.

A robotic total station and a rented SonarMite echosounder were used to survey ground elevations and collect bathymetry data. Surveying was done over a 6,598 ft river segment that included the Morad Park site and the two sites along Wyoming Blvd. Bathymetry bed elevation data were used to determine the thalweg location and to create a longitudinal profile. Five cross-sections (three riffle, 2 pool) in the Morad Park project reach were also surveyed and water surface, inner berm, and bankfull elevations were identified and recorded.

All cross-sections were selected in 2016, but only cross-sections 2 and 4 were monumented with rebar at that time. Cross-sections 1, 3, and 5 were monumented in 2018. Of the three riffle cross-sections (2,4 and 5), cross-section 2 has the best riffle features. Cross-section 4 was selected in 2016 based on the DEM, but field data revealed it to be much deeper than expected. Cross-section 5 is shallower and was selected in the field in 2016 and, although it is outside of the project reach, it is not an unreasonable location because the entire reach through this cross-section was restored. Bankfull elevations were identified incorrectly in October 2018 and were re-surveyed on April 1, 2019. At each cross-section, the bankfull elevation was identified in the field on both right and left banks and the best bankfull elevation (either right or left bank) was selected for calculating channel dimensions. Cross-section profiles were created in both RiverMorph and in Excel to corroborate calculations. Cross-section data from 2016 were also entered into RiverMorph in order to appropriately compare data between years. Except for flood-prone width, all channel dimensions reported for 2016 and 2018 are obtained from RiverMorph. Flood-prone width was not recorded in the field in 2018. However, because the cross-sections had changed very little since 2016, the flood-prone width points from 2016 surveying were used with other data collected in 2018.

To evaluate goal 1 (narrow the over-widened channel), we used data from the three riffle cross-sections to calculate the entrenchment ratio, bankfull height ratio, width-to-depth ratio, and cross-sectional area.

To evaluate goal 2 (improve fisheries habitat), we scored the toe-wood features using the rapid assessment procedure and calculated the maximum pool depth for the two excavated pools located near pool cross-sections 1 and 3. A Trimble Geo7X GPS unit was used to obtain spatial data (UTM coordinates with horizontal datum of NAD83 Zone 13N) for the toe-wood and rock arms.

To evaluate goal 3 (stabilize streambanks), we collected data for the Bank Erosion Hazard Index (BEHI) and near-Bank Stress (NBS) modeling tools (Rosgen 2006). These data are only collected in years three and five following project construction because vegetation establishment is an important factor in the models. A map of the bankfull line (both banks) was also collected to compare to previous monitoring.

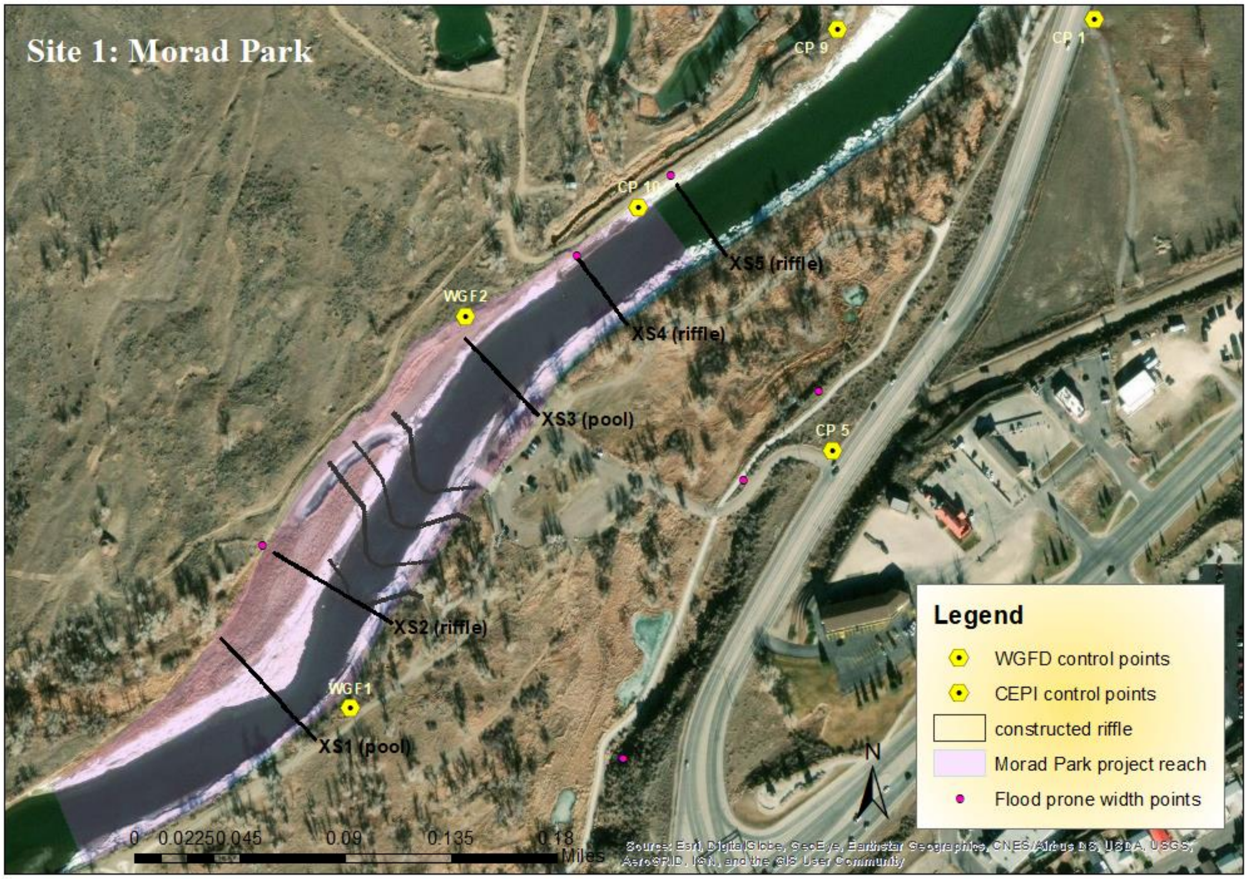

Figure 2. - Map of the Morad Park project reach including locations of survey control points, cross-sections, and flood-prone width points for riffle cross-sections.

Fisheries - Methods

Enhancing the fishery throughout the City of Casper is one of the primary goals of the Platte River Restoration project. The sampling methods, results, and interpretation are summarized in this report and more detailed information can be found in the Annual Fisheries Progress Reports on the Work Schedule (WGFD 2015; 2016; 2017b; 2018). From 2015-2018, electrofishing was used to sample the fish population to detect post-construction differences in trout abundance and size structure in the restored Morad Park reach, relative to an upstream control reach. Sampling techniques and reaches varied from 2015 to 2018 as WGFD experimented with different methods to measure population in a small segment on a large river. Sampling efforts were revised in 2018 to enable direct comparisons of trout abundance, species assemblage, and size structure between the restored reaches and a control reach (WGFD 2018). The changes included implementing a new sampling protocol and modifications to the Morad Park restored sampling reach and the control reach.

The Morad Park sampling reach was expanded in 2018 to include 5,465 ft of reconstructed river habitat immediately downstream of the WGFD office, ending just upstream of the water intake structure (Table 2). This expanded sampling reach includes all of the Morad Park restored reach and the upstream half of the WY Blvd/Water Treatment Plant reach. Beginning in 2018, results from fish sampling through the expanded reach apply to both the Morad Park and WY Blvd/Water Treatment reaches. From 2015 to 2017, the Morad Park sampling reach included only the 2,385 ft of restored river habitat downstream of the WGFD office.

A control reach (Paradise Valley control reach) was also established in 2018 that includes 5,134 ft of the North Platte River from just downstream of the Paradise Valley boat ramp to the WGFD Office (Table 2). Prior to 2018, the control reach was comprised of five stations (approximately 3000 feet each), beginning at the Robertson Road Bridge and ending at the WGFD office.

In October 2015 and 2016, fish sampling was conducted using single-pass depletion in both the control and Morad Park restored reaches (WGFD 2015, 2016). In October 2017, two methods were tested for sampling: 4-pass mark/recapture in the control reach and 5 depletion passes in the restored reach (WGFD 2017b). The depletion pass methodology was dropped in favor of mark-recapture for future sampling. In 2018, fish sampling occurred in the expanded Morad Park reach and the control reach October 23-25, following a mark-recapture protocol that is used in other FMCR standardized sites on the North Platte River (WGFD 2018). One jet boat with two netters was used to generate separate three-pass mark-recapture population estimates from each reach. Proportional size distribution (PSD) was used to compare size structure of the Rainbow Trout and Brown Trout populations.

Table 1. - Coordinates for upstream and downstream points of the restored and control reaches. All coordinates given in datum NAD83, UTM zone 13T.

Sampling reach	Years	Upstream		Downstream	
		Easting	Northing	Easting	Northing
Morad Park	2015 - 2017	387495	4741889	388026	4742321
Morad Park (extended)	2018+	387495	4741889	388114	4743069
Control (Robertson Road)	2015 - 2017	Begins at Robertson Rd bridge		Ends where power lines cross river near Audubon property boundary	
Control (Paradise Valley)	2018+	385985	4742566	387444	4741875

RESULTS

Visual Assessment - Results

Google Earth imagery from 2015 and 2017 illustrates some of the major changes in the stream following restoration (Figure 3). Photos from 2018 (Figure 2, Appendix A.2) demonstrate that the streambanks in the Morad Park project reach have remained stable since construction. The core fabric used to stabilize the stream banks during construction is still visible and intact in most places where it was used which has helped maintain a channel narrower than pre-project conditions. Woody and herbaceous vegetation has now established on most banks, although the area of bank covered by vegetation varies considerably. The right banks suffered from vandalism in 2015 when many of the recently planted willow and cottonwood stakes were removed. The right bank continues to receive substantial foot traffic due to its proximity to trails and the park (Figures A.2.4). However, photo points MP-2, MP-3, and MP-4 show that cottonwoods and willows have established well along much of the right bank (Figures A.2.4 - A.2.6). On the left bank, willow and cottonwood stakes did not survive in some areas and much of the bank is dominated by herbaceous vegetation (Figures A.2.7 - A.2.8).

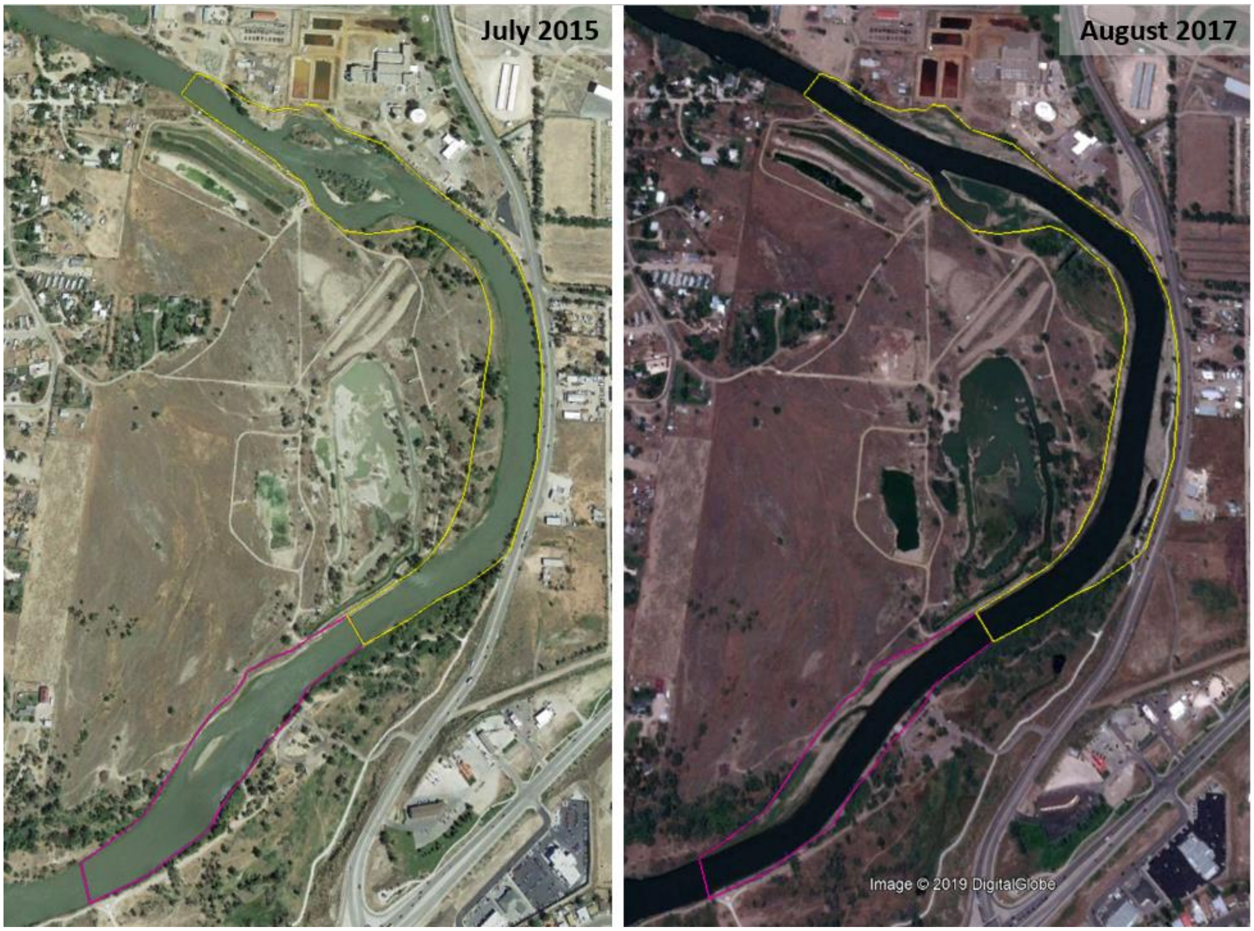

Figure 3. – Google Earth images of Morad Park (pink outline) and Wyoming Boulevard/Water Treatment Plant project reaches before construction in 2015 (left) and after construction in 2017 (right).

Overall, the visual assessment ratings indicate the instream structures are functioning as intended; ratings are included in Table A.4.1. The four constructed riffle arms remain in their appropriate locations according to design plans (Figure 4). As intended, each riffle arm is at the level of the surrounding stream bed so that rock features do not protrude into the water column. Sorted cobble-sized substrate is deposited around the riffle arms, especially near the banks, which makes the boulders appear buried. Per conversation with the Stantec design engineer, deposition along the margins of the riffle vanes is acceptable and likely enhances the function of the structure to direct flows to the center of the riffle. Excessive deposition over the center of the riffle vanes would be undesirable but was not observed. The arms of each riffle vane can be seen on the bank and scour pools are maintained on the downstream side of each riffle arm. Using the rapid assessment procedure, riffle arms 2 and 3 received an "Intact" rating for structural integrity (Table A.4.2). Riffle arms 1 and 4 received a "Damaged" rating for structural integrity because multiple boulders had moved out of place but each structure continues to function. All riffle arms seemed to have at least some deposition over them, but deposition was greater on the two downstream arms. Riffle arms 1 and 2 received an erosion/deposition rating of "1 (minor deposition)" while riffle arms 3 and 4 received a rating of "2 (deposition along 25-50% of structure)". The differences in elevation between the top of the riffle arms and the bottom of the scour pools below them are much greater in 2018 than in 2016 (Figure A.1.1). In 2016, the differences were all approximately 1 ft. In 2018, survey data showed differences of 4.57 ft, 2.43 ft, and 1.94 ft for riffle arms 1, 2, and 3, respectively (Figure A.1.1). The depths of pools between riffles arms will likely vary year to year. As a whole, the constructed riffle seems to continue to function as grade control, directs stream flow to the center of the channel to maintain narrow channel dimensions, and maintains pools for fish habitat.

The three rock vanes remain in their appropriate locations according to design plans. Sorted cobble-sized substrate was deposited downstream of the underwater portion of each rock vane, making them seem almost buried, as intended. Scour pools are well-defined on the downstream side of each rock vane. The main intent of the rock vanes is to direct flows away from the bank toe and toward the center of the channel. Rock vane 1 functions to protect the toe wood immediately downstream from scour. The intended function of rock vane 2 was to help transition out of a pool and into a riffle. According to the design engineer, a rock vane in this location may experience high aggradation and the structure may not have been essential at this location. Rock vane 3 was constructed at the upstream end of a pool and was intended to protect the left bank as the river bends to the right and to direct flows from the side channel back toward the center. All three rock vanes received a rapid assessment procedure structural integrity rating of "Intact" (Table A.4.1). Rock vanes 1 and 2 received an erosion/deposition rating of "1", because of minor deposition over the center of the structure and a well-defined pool being maintained. Rock vane 3 received an erosion/deposition rating of "2" because of more significant deposition along 25-50% of the structure that is affecting the intended function of the structure. An eddy, about 50 feet long, was observed just downstream of rock vane 3. It likely formed due to excessive deposition associated with the rock vane and may cause higher near-bank stress on the left bank. Rock vane 3 was difficult to rank for structural integrity using the rapid assessment descriptions because the structure is intact but it is likely not functioning as intended. There is no ranking that accounts for that condition.

The toe wood structure is still intact and functions to protect the outer bank and to provide cover and habitat for fish. The root wads were installed a little higher than preferred, according to the design engineer. Ideally, the root wads would be submerged during base flow, but the upper half of the root wads is exposed during base flow. Rootwads were installed with slightly wider spacing toward the downstream end of the toe-wood structure; this is not indicative of missing root wads. The toe wood received an "Intact" rating for structural integrity and a "0 (none visible)" for erosion/deposition.

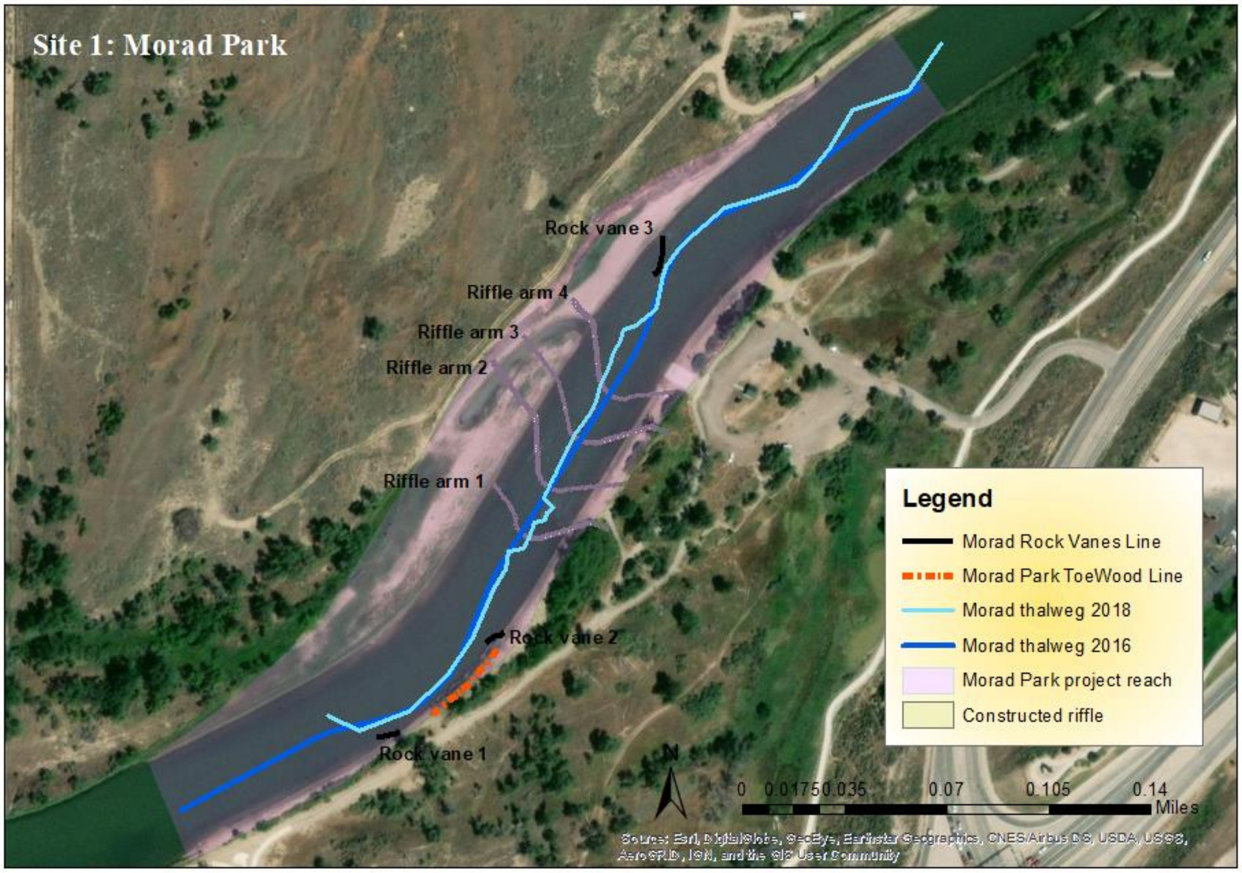

Figure 4. - Location of in-stream structures in 2018 and the thalweg lines from 2016 and 2018.

Geomorphology - Results

Geomorphology Goal 1 – Narrow Over-Widened Channel. Flood-prone width was not surveyed in 2018, but the three riffle cross-sections changed very little between 2016 and 2018, including bankfull elevation (Figures A.1.2 – A.1.4). Thus, the flood-prone width surveyed in 2016 was used for cross-sections 2, 4 and 5. Riffle cross-section 2 has the best characteristics of a riffle, followed by cross-section 5. The average entrenchment ratio of riffle cross-sections 2 and 5 in Morad Park was 4.09, very similar to the value of 4.07 in 2016 (Table 3). Entrenchment ratio ranged from 5.08 at cross-section 2 to 3.44 and 3.09 at cross-sections 4 and 5, respectively. The desired entrenchment ratio is ≥ 3.0, or, at minimum, >2.2. All cross-sections continue to have entrenchment ratios greater than 3.0 and the values differed by less than 0.12 for all three riffle cross-sections between 2016 and 2018.

Channel incision is quantified using the bankfull height ratio, with a desired value between 1.0 and 1.2. Bankfull height ratio was 1.0 at all three riffle cross sections, having not changed since 2016. The lowest bank height on at least one bank at each cross section was bankfull elevation, so low bank height and maximum bankfull depth are equal.

The width-to-depth ratio was calculated for riffle cross-sections as bankfull width divided by mean bankfull depth, with a desired value between 35 and 48. Width-to-depth ratio was reported in the 2016 report using the maximum bankfull depth instead of the mean bankfull depth. In this report, mean bankfull depth is used for all width-to-depth calculations and ratios were re-calculated accordingly for cross-section data from 2016. Width-to-depth ratios were 41.12, 35.53, and 38.67 at cross-sections 2,4, and 5, respectively (Table **2** 3). Cross-section 2 has the best riffle characteristics of the three cross-sections, and its width-to-depth ratio of 41.12 is well within the desired range. The ratio of cross-section 4 is at the low end of the desired values, but the channel profile has no significant changes since 2016 (Table 3, Figure A.1.3). This suggests that the low ratio is likely a reflection of cross-section 4 not being the best representation of a riffle. Changes in width-to-depth ratio were minimal between 2016 and 2018 for all cross-sections, except cross-section 4 where the 2018 ratio was higher by 2.4. This is likely due to the higher bankfull elevation identified in 2018. Bankfull is difficult to identify at cross-section 4.

Bankfull cross-sectional areas remained smaller than pre-project values (1,300 to 1,460 sq. ft.). Bankfull cross-sectional areas were 837, 939, and 932 sq. feet at riffle cross-sections 2, 4, and 5, respectively (Table 3). Cross-sectional area was 1097 sq.ft for both pool cross-sections 1 and 3. All of these values are within 88% of the desired value of 950 sq. ft. Cross-sectional area of riffles was expected to not vary by more than 10% between years and by not more than 15% across all cross sections. Between 2016 and 2018, no cross-section differed by more than 10% except cross-section 4, which had 13% more area in 2018 because of the higher bankfull determination that year. In 2018, differences in cross-sectional areas between cross-sections were less than 15%. The greatest difference (14%) was between riffle cross-section 2 and the pool cross-sections.

Table 2. - Summary of data collected at the Morad Park project reach in 2016 and 2018 used to evaluate Geomorphology Goal 1: Narrow the over-widened channel. Cross-section 2 (XS 2) has the best riffle characteristics of all the cross-sections, but data from all surveyed cross-sections are reported.

Monitoring parameter	Pre-project (pre-2016)	2016	2018	Criterion
Entrenchment ratio	Average=2.3	Average of 2 & 5 = 4.07 XS2 = 5.05 XS4 = 3.56 XS5 = 3.08	Average of 2 & 5 = 4.09 XS2 = 5.08 XS4 = 3.44 XS5 = 3.09	Minimum ratio >2.2; preferred ≥3.0
Channel incision	1.1 to 1.7	All XS = 1.0	All XS = 1.0	Average bank-height ratio value 1.0-1.2
Width to depth ratio	52 to >100	Average of 2 & 5 = 39.45 XS2 = 39.9 XS4 = 38.53 XS5 = 38.99	Average of 2 & 5 = 39.90 XS2 = 41.12 XS4 = 35.52 XS5 = 38.67	Between 35 and 42
Cross-sectional area	1300 to 1460 sq. ft	XS2 = 855 XS4 = 820 XS5 = 925 XS1 = 1099 XS3 = 1152	XS2 = 837 XS4 = 939 XS5 = 932 XS1 = 1097 XS3 = 1097	About 950 sq. feet. Value for riffle cross-section should not vary by more than 10% year to year or by more than 15% across all sites.

Geomorphology Goal 2 – Improve Fisheries Habitat. The one toe-wood structure in the Morad Park site was evaluated as part of the in-stream structure assessment described earlier in this report. It received a value of 1 for structural integrity (Intact) and a 0 for deposition/erosion (none visible) (Table A.4.1). Although the rootwads were installed a little higher than desired, the underside of the rootwads remain submerged at base flows and provide cover for fish.

The longitudinal profile (Figure A.1.1) shows that two deep pools are still maintained, and may have shifted slightly, as both pools were located just downstream of each of the pool cross-sections 1 and 3. The depth of the pools was calculated by substracting the elevation of the lowest point of each pool from the closest surveyed bankfull height. Pool 1 was located just downstream of cross-section 1 and had a bankfull depth of 11.64 ft (Table 4). Pool 2 was located just downstream of cross-section 3 and had a bankfull depth of 10.03 ft. The desired pool depth is at least 75% of the design depth of 12.2 ft. In 2018, pool 1 was 95% of the design depth and pool 2 was 82% of the design depth.

The longitudinal profile (Figure A.1.1) also shows 'troughs; below each of the riffle arms, which improve habitat diversity for fish. The differences in elevation between the top of the riffle arms and the bottom of the scour pools below them are much greater in 2018 than in 2016. In 2016, the differences were all approximately 1 ft. In 2018, survey data showed differences of 4.57 ft, 2.43 ft, and 1.94 ft for riffle arms 1, 2, and 3, respectively.

Table 3. – Summary of data collected at the Morad Park project reach in 2016 and 2018 used to evaluate Geomorphology Goal 2: Improve fisheries habitat.

Monitoring parameter	Pre-project (pre-2016)	2016	2018	Criterion
Toe wood	NA	Integrity: 1 Erosion/ Deposition: 0	Integrity: 1 Erosion/ Deposition: 0	Rapid assessment procedure; all structures should rank 1-2 on integrity and 0-2 on erosion/deposition.
Maximum pool depths compared to bankfull elevation	8.5 ft	Pool 1: 11.1 ft Pool 2: 10.6 ft	Pool 1: 11.64 Pool 2: 10.03	Deepest point in each pool should remain at least 75% of project design depth (12.2 ft).

Geomorphology Goal 3 – Stabilize Streambanks. Visual assessment of the stream banks revealed no areas of active erosion. Geotextile fabric continues to stabilize many of the banks. The only location of concern was downstream of rock vane 3, where an eddy had formed that may increase near-bank stress on the left bank where the bank slope is steep. Bankfull elevation was surveyed on both banks along the entire project length to compare with the bankfull line surveyed in 2016 (Figure 5). No significant changes in the bankfull locations were observed. BEHI (Figure 6) and NBS (Figure 7) data were mapped and summarized in Table 5. The goal was for BEHI and NBS to be moderate or lower on all banks within the project reach. BEHI was moderate on 36.3% of the bank lengths and low on 63.7%. No banks received a BEHI rating greater than moderate in 2018. NBS was low on 61.8% of the bank length, which is much greater than the 15.8% pre-project value. NBS was high on 12.4% of the banks, which is not desirable but is a reduction from 21% of banks rated high before the project.

Table 4. - Percent of bank length with each BEHI and NBS rating in 2018 and prior to construction.

	BEHI		NBS	
Rating	Pre-project	2018	Pre-project	2018
Very Low	36.3%	0.0%	23.6%	11.0%
Low	26.9%	63.7%	15.8%	61.8%
Moderate	15.8%	36.3%	39.6%	14.8%
High	21.0%	0.0%	21.0%	12.4%
Very High	0.0%	0.0%	0.0%	0.0%

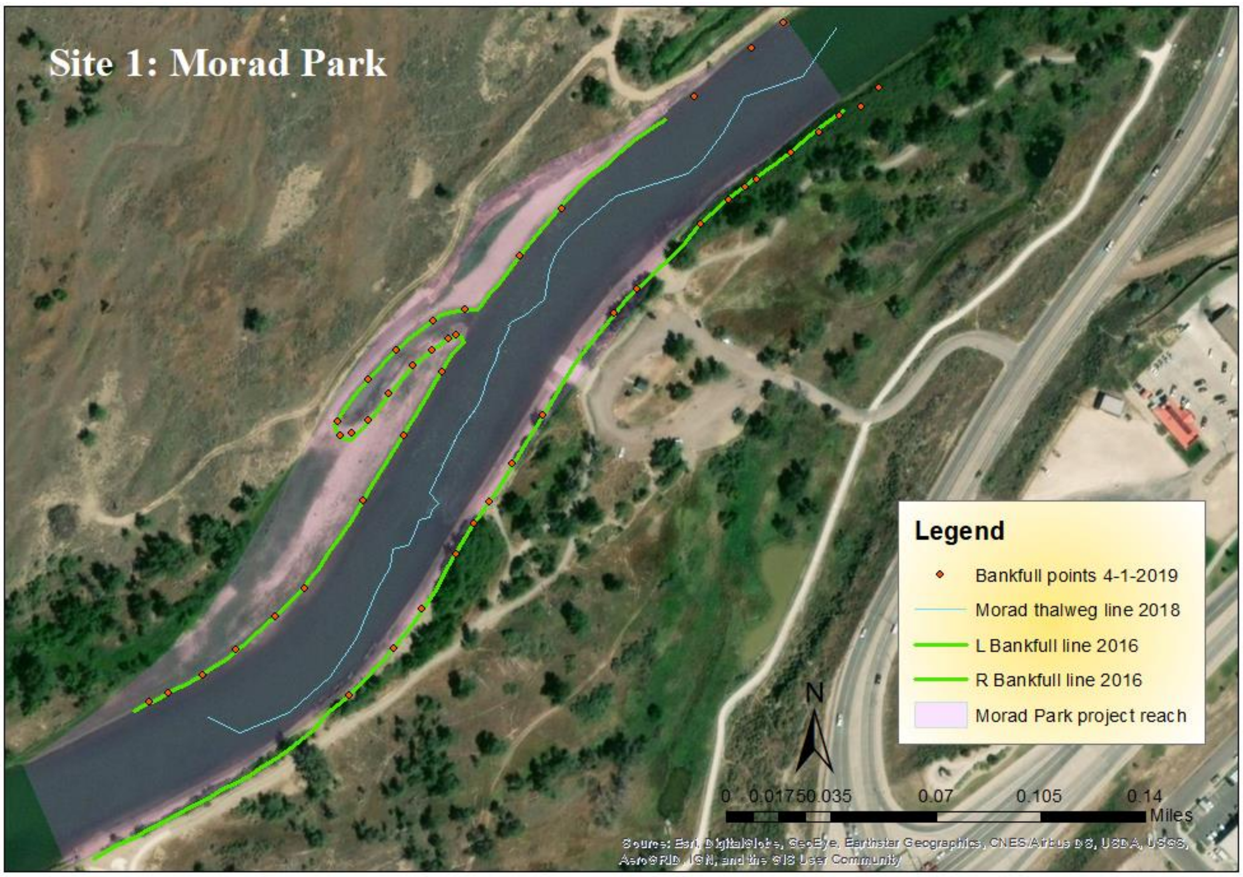

Figure 5. – Map of bankfull elevations along both banks of the Morad Park restored reach in 2016 and 2018.

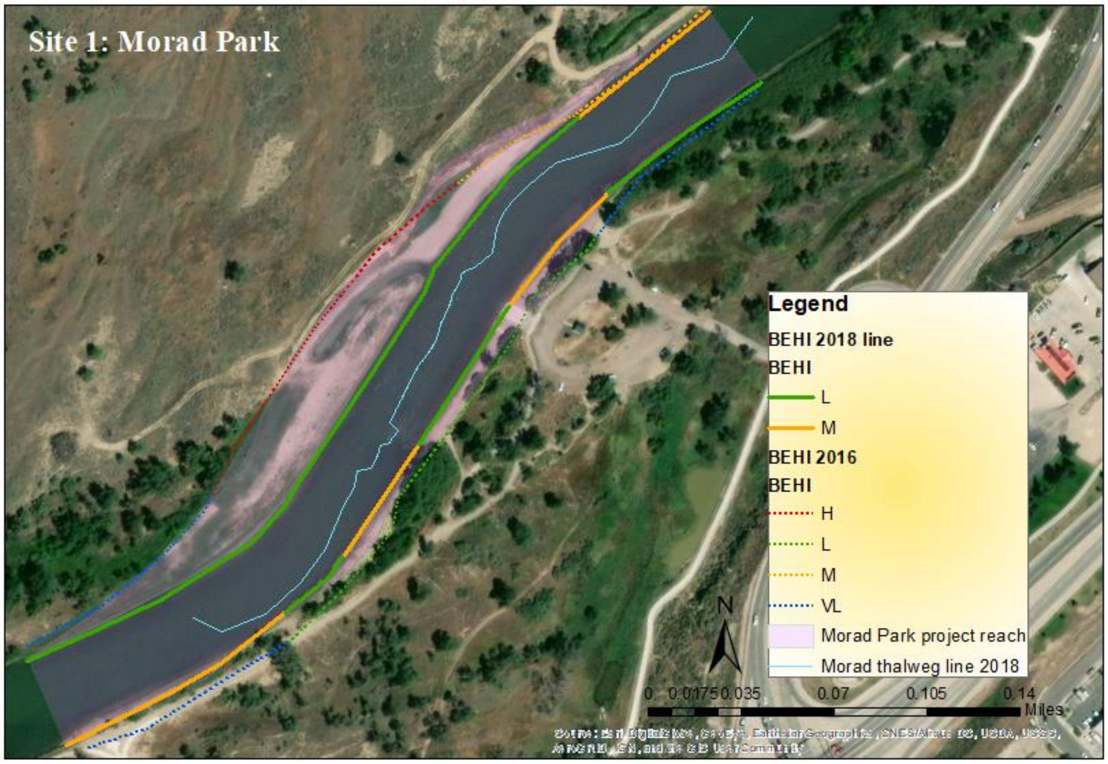

Figure 6. - Bank Erosion Hazard Index (BEHI) ratings for the banks in the Morad Park restored reach before restoration (dotted lines) and three years post-restoration in 2018 (solid lines).

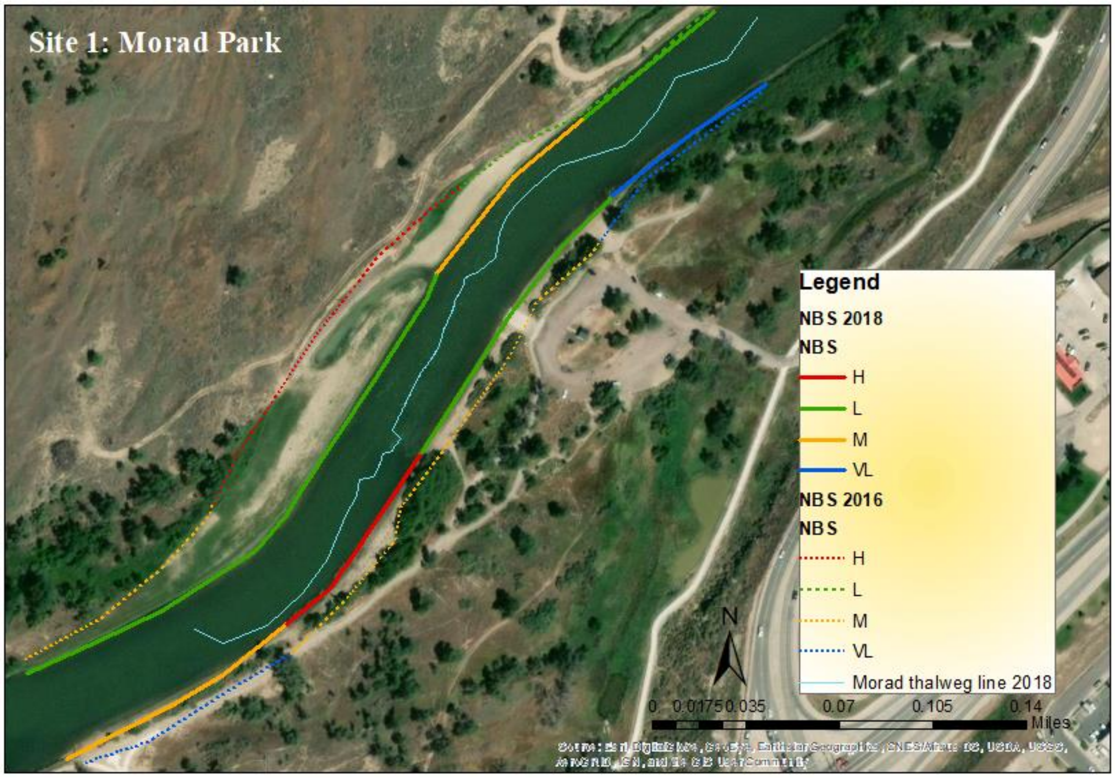

Figure 7. Near-bank Stress (NBS) ratings for the banks in the Morad Park project reach before restoration (dotted lines) and three years post-restoration in 2018 (solid lines).

Fisheries - Results

Fish sampling results are summarized in this report and additional details can be found in the Annual Fisheries Progress Reports on the Work Schedule (WGFD 2015; 2016; 2017b; 2018). In 2017, catch per unit of effort (CPUE), was significantly higher in the Morad Park reach, relative to the upstream Robertson Road control reach (Tables 6-7). Single pass CPUE from 2016 and 2017 consistently show more fish in the Morad Park reach compared to the upstream control reach (Figure 8). CPUE is a measure of relative abundance, but does not provide a population estimate. Population estimates generated in 2017 for the control reach using 4-pass mark/recapture and Morad Park using 5-pass depletion show a substantially higher number of fish per mile in the control reach (Figure 8). The evident discord between measures of relative abundance (in the form of standardized CPUE) and actual population estimates (generated from disparate methodologies) is the reason that fish sampling methods were revised in 2018 to use a mark-recapture protocol. This better allows for direct comparisons of CPUE, species assemblage, and size structure between the restored reach and the control reach.

Table 5. - Number (N) and pound (Lbs) per mile, with standard error (SE), for each species-specific size group from a four-pass mark/recapture population estimate for fish captured in 3.7 miles of the North Platte River in the control reach, 3-6 October 2017.

Species	Size Group	Type	N/mi ± SE	CV	Lbs/mi ± SE	CV

BNT	≥ 8.0	All BNT	137 ± 35	25.5	198 ± 20	10.1
RBT	8.0 – 11.4	Age 1	22 ± 13	59.1	12 ± 6	50.0
RBT	11.5 – 14.4	Age 2	234 ± 51	21.8	213 ± 30	14.1
RBT	14.5 – 15.9	-	282 ± 40	14.2	371 ± 50	13.5
RBT	≥ 16.0	-	117 ± 21	17.9	209 ± 29	13.9
RBT	≥ 8.0	All RBT	656 ± 70	10.7	805 ± 65	8.1
TRT	≥ 8.0	All TRT	792 ± 78	9.8	1003 ± 68	6.8

Table 6. - Number (N) and pounds (Lbs) per mile for each species-specific size group from a five-pass depletion population estimate for fish captured in 0.45 miles of the restored section of the North Platte River in Morad Park, 13 October 2017.

Species	Size Group	Type	N/mi ± SE	CV	Lbs/mi ± SE	CV
BNT	≥ 8.0	All BNT	31 ± 2	6.5	41.1 ± 6.5	15.8
RBT	8.0 – 12.4	Age 1	55 ± 5	8.5	38.6 ± 1.0	2.7
RBT	12.5 – 13.9	Age 2	44 ± 3	6.2	42.6 ± 1.3	3.0
RBT	14.0 – 15.9	-	124 ± 7	5.5	160.8 ± 2.6	1.6
RBT	≥ 16.0	-	31 ± 5	16.3	59.2 ± 2.4	4.1
RBT	≥ 8.0	Sum RBT	254 ± 10	4.1	301.2 ± 3.9	1.3
TRT	≥ 8.0	Sum TRT	285 ± 11	3.7	342.3 ± 7.6	2.2

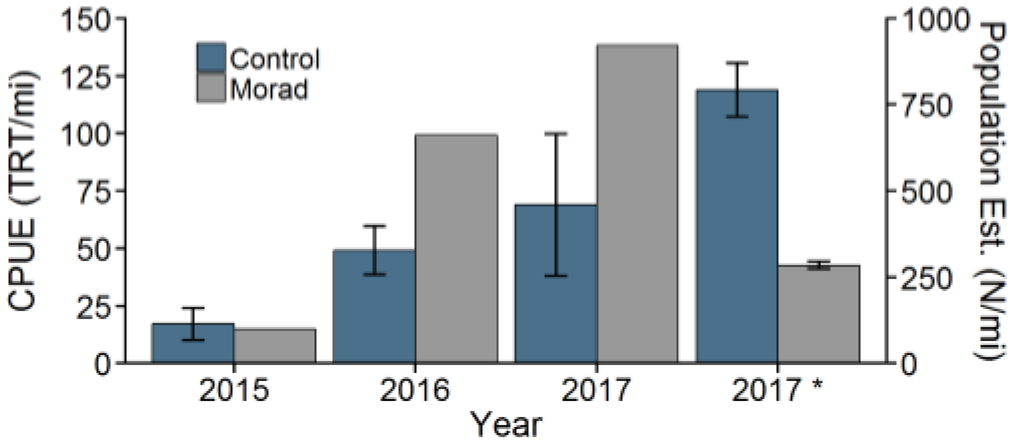

Figure 8. - Mean first-pass CPUE (±1 SD) from upstream control stations (N=5 in 2015; N=7 in 2017) between Robertson Road Bridge and the WGFD office compared to first-pass CPUE through the Morad Park reach before restoration (2015) and after construction (2016 and 2017). The 2017 bars with an asterisks(*) symbol correspond to the population estimates generated for the control reach (4-pass mark/recapture) and the Morad Park reach (5-pass depletion).

In 2018, a total of three mark-recapture passes yielded 177 trout from the Morad Park reach and 200 trout from the control reach that were at least 6.5-inches in length (Table 8). There was no evidence of significant difference in abundance or biomass between the Morad Park reach and the Paradise Valley control reach (Table 10). Significantly more age-2 RBT and significantly fewer age-3 RBT were caught in the Morad Park reach relative to the control reach but there were no significant differences in the overall size structure (PSD) of the RBT population between the two reaches (Table 9). Observed differences in BNT size structure between the two sampling reaches was likely an artifact of low sample size.

Table 7. - Species, number, mean length with ranges, mean weight, and mean relative weight (Wr) of fish captured by BF in the Morad Park restoration reach and Paradise Valley control reach of the North Platte River, 23-25 October 2018.

Species	Number	Mean Length (n, SD)	Range	Mean Weight (n, SD)	Mean Wr
Morad Park Restoration Reach					
BNT	9	15.0 (9, 1.8)	12.4 - 17.7	1.3 (9, 0.5)	98
RBT	168	14.3 (168, 2.4)	6.9 - 19.6	1.2 (168, 0.6)	97
Paradise Valley Control Reach					
BNT	14	14.0 (14, 3.5)	10.1 - 22.3	1.4 (14, 1.0)	98
BRC	1	11.0	11.7 - 11.7	0.6	99
RBT	185	14.0 (185, 2.3)	10.1 -18.9	1.3 (185, 0.6)	98

Table 8. - Proportional Size Distribution (PSD) for BNT and RBT captured by BF in the Morad Park restoration reach and Paradise Valley control reach of the North Platte River, 23-25 October 2018.

Species	N ≥ S	PSD	PSD-P	PSD-M	PSD-T
		Morad Park Restoration Reach			
BNT	9	100	100	44	
RBT	167	28			
		Paradise Valley Control Reach			
BNT	14	100	79	29	14
RBT	185	34			

Table 9. - Number sampled, mean length (in), number per mile (± SD) and pounds per mile (± SD) for each species-specific size group from a three-pass mark-recapture population estimate for fish captured in 1.04 miles of restored habitat in Morad Park reach and 1.13 miles of unrestored habitat in Paradise Valley reach of the North Platte River, 23-25 October 2018.

Species	Size Group	Number	Mean Length	Number/mi ± SE	Mean Weight	Pounds/mi ± SE
			Morad Park Restoration Reach			
BNT	≥10.00	9	15.0	21 ± 14	1.32	28 ± 13
RBT	≥8.0;≤11.9	25	11.3	197 ± 174	0.58	113 ± 85
RBT	≥12.0;≤14.4	63	12.9	243 ± 85	0.83	201 ± 48
RBT	≥14.5;≤17.4	60	15.8	103 ± 18	1.53	158 ± 17
RBT	≥17.50	19	18.4	44 ± 19	2.41	107 ± 30
RBT	≥8.00			587 ± 195		579 ± 104
TRT	≥8.00			609 ± 196		607 ± 104
			Paradise Valley Control Reach			
BNT	≥10.00	14	14.7	31 ± 15	1.40	43 ± 17
RBT	≥8.0;≤11.9	25	11.2	175 ± 154	0.56	99 ± 69
RBT	≥12.0;≤14.4	63	12.9	128 ± 28	0.85	109 ± 17
RBT	≥14.5;≤17.4	51	15.6	163 ± 35	1.48	264 ± 36
RBT	≥17.50	46	17.4	45 ± 19	2.00	97 ± 30
RBT	≥8.00			511 ± 161		570 ± 85
TRT	≥8.00			542 ± 161		613 ± 87

DISCUSSION

Since completion of construction in 2015, the North Platte River through the Morad Park restored site experienced two years with high flow events. Construction was completed in fall of 2015 and, in June 2016, runoff flows exceeded 7,100 cfs through the project site (Figure A.5.1). Flows in 2016 remained above bankfull flow (4,300 cfs; WGFD 2017) and inundated the floodplain for over one month. In June 2017, flows exceeded 4,600 cfs and remained above bankfull for approximately two weeks. After these high flow events that had the potential to change geomorphic conditions of the site, there is no evidence of channel migration, banks appear stable, and in-stream structures largely continue to function.

Overall, the in-stream structures seem to be intact and functioning as intended. The structural integrity goal for in-stream structures is a ranking of “Intact” or “Damaged”. The four riffle arms are in place, with the exception of a few boulders that have shifted, and maintain grade as intended. Turbulence was observed over each arm and the longitudinal profile reveals deeper ‘troughs” between each arm. Although deposition was observed over the riffle arms, it is not concentrated in the center, so it is not negatively affecting the function of the constructed riffle. The toe-wood feature also seems intact and is functioning to protect the bank and provide cover for fish. Two of the three rock vanes are functioning as intended by diverting flows toward the center of the channel. Rock vane 3 should continue to be monitored to evaluate the effects of the eddy on the left bank. Riffle arms 1 and 4 were the only structures to change structural integrity ratings, from “Intact” to “Damaged”, due to movement of boulders. All other structures are “Intact” and none require maintenance at this time.

The erosion/deposition ratings for in-stream structures refer to *unintended* erosion or deposition and desired ratings are 0 (none visible) or 1 (minor deposition/erosion). Erosion or deposition is likely to continue when structures have a rating of 2 and structures with ratings of 3, 4, or 5 should be considered for maintenance (see Table A.4.2 for descriptions of these ratings). The erosion/deposition ratings for all riffle arms and rock vanes increased by at least 1 since they were rated in 2016. However, none of the structures is rated higher than 2, so no maintenance is required at this time. Notably, all of the monitoring in 2018 was conducted by individuals who had not been present at the time of construction or during 2016 monitoring. This rating system is somewhat subjective and the higher ratings in 2018 may be at least partially influenced by different individuals doing the evaluations in 2016 and 2018. Future monitoring efforts will allow opportunity to evaluate whether these structures continue to function as intended over time.

All three of the goals associated with geomorphology are being met at this time. The first goal was to narrow the over-widened river channel and success is evaluated using entrenchment ratio, bankfull height ratio, width to depth ratio, and bankfull cross-sectional area. Prior to construction, the channel was wide with a narrow floodplain, represented with an average entrenchment ratio of 2.3 through the project reach. The preferred entrenchment ratio for the riffle cross-sections is ≥3.0. All three riffle cross-sections met this criteria in 2018, with values of 5.08, 3.44, and 3.09. Because flood-prone and bankfull width have changed little since 2016, the entrenchment ratios are essentially identical. The higher entrenchment ratio is due to a narrower channel and wider floodplain, which enable high flows to dissipate energy over a wider area and reduce shear stress on banks. Channel incision has also improved, as indicated by bankfull height ratios of 1. At all cross-sections, the low bank is the same elevation as the bankfull elevation, which enables high flows to access the floodplain.

The width to depth ratio and cross-sectional area values are also within the desired ranges associated with the goal of narrowing the river channel. The riffle cross-section with the best riffle features had a width to depth ratio of 41.1. The other two riffle cross-sections are less representative of riffle features, but still had width to depth ratios of 35.5 and 38.7. These lowered width to depth ratios remain similar to those in 2016 and reflect the channel's capacity to more effectively move sediment and avoid accumulation of sediments in the channel.

Bankfull cross-sectional area is also an important component of sediment transport capacity of the channel. Bankfull cross-sectional areas for the three riffle cross-sections were between 88% and 99% of the desired 950 sq. ft area. The only cross-section to change by more than 10% since 2016 was cross-section 4, which had 13% more area than in 2016. However, this difference seems due to a difference in identification of bankfull elevation between the two years, rather than an actual physical change in the channel. Also, differences in cross-sectional areas between all five cross-sections were less than 15%, as desired.

The second goal of channel morphology modification was to improve fisheries habitat. The toe-wood structure was intact, with at least some of the root wads submerged at base flow to provide fish habitat. Rock arm 1, located upstream of the toe-wood structured is also functioning to help maintain the scour pool along the toe-wood. The two excavated pools are expected to remain within 75% of the design depth of 12.2 ft. below bankfull elevation. Some deposition in the pools is expected, especially after the high flows of 2016 and 2017. The two excavated pools are meeting the desired criteria with depths of 82% and 95% of the design depth.

The third goal of the channel morphology modification was to stabilize streambanks. Bank erosion was not visually observed in the project reach. Bank stability was evaluated in more detail using the Bank Erosion Hazard Index (BEHI) and Near-Bank Stress (NBS) tools and compared to pre-project BEHI and NBS values. In 2018, all banks received a BEHI rating of low or moderate, and none were rated as high. Prior to construction, 21% of the bank lengths received a high BEHI rating and 36% received a very low BEHI rating. No banks received a very low rating in 2018, although a majority (64%) of the bank length was rated low, which is much better than the 15.8% pre-project value. The lack of very low BEHI ratings in 2018 was likely due to low rooting density and low surface protection. Vegetation has established well along many banks, but is limited along some. The difference in the very low ratings between years may also be partially due to different people assigning the ratings. Overall, the majority of stream banks in the project reach have a low BEHI rating and none were rated high, which indicates an improvement in bank stabilization.

The NBS ratings also improved compared to pre-project ratings. In 2018, 73% of the banks received an NBS rating of low or very low, compared to only 40% before construction. Additionally, the percentage of bank length with a high NBS rating decreased from 21% to 12.4% and the percentage with a moderate NBS rating decreased from 39.6% to 14.8%. The only section of bank that received a high NBS rating in 2018 was along the outer bend at the upstream end of the project reach where the thalweg is located near the bank. However, stress on the bank is mitigated by the toe-wood structure and the two rock vanes upstream and downstream of it. The only location of concern was downstream of rock vane three, where an eddy has formed and is increasing near-bank stress on the left bank. No bank erosion was evident in 2018, but this area should be monitored in the future. Bankfull elevation was surveyed along both banks of the project reach and compared to a bankfull line from 2016. No significant changes in the location of bankfull were observed, indicating that lateral channel migration is not occurring.

Vegetation restoration is an important factor in the long-term stability of the restored channel and streambanks. The monitoring plan does not include any data collection to monitor vegetation establishment, except for photo points. Cottonwoods and willows have established along much of the right bank although there are several areas that have little vegetation because of disturbance associated with the boat ramp, trails, and the dog park. The left bank receives little human disturbance and most of the observed vegetation was herbaceous. Willow and cottonwood stakes did not survive in some areas along the reconstructed bank. Although streamflow is directed more toward the right banks through this site, long-term bank stability of the left bank may be at risk in some places as the core fabric deteriorates and if woody vegetation establishment does not increase.

Fish sampling efforts in 2016 and 2017 showed a higher relative abundance of trout (CPUE) in the Morad Park reach, compared to the upstream control reach. In 2018, a mark-recapture protocol was adopted for fish sampling to better allow for direct comparison of population estimates, species assemblage, and size structure between the restored Morad Park reach and the Paradise Valley control reach. In 2018, abundance and biomass of trout did not differ between the Morad Park reach and the control reach. More age-2 RBT and fewer age-3 RBT were caught in the Morad Park reach relative to the control reach. The number of age-3 RBT is reduced throughout the North Platte River largely due to the advancement of a weak 2015 age-class. However, the increased catch of age-2 and decreased catch of age-3 fish in the Morad Park reach relative to the control reach is at least partially explained by differences in habitat types and capture efficiency. More specifically, the vast majority of restructured habitat in Morad Park consists of broad, shallow, and swift habitat that may recruit an increased number of juvenile fish and where sampling evasion by smaller fish results in a decreased number of recaptures. Conversely, the majority of the control reach consists of deep pool and channelized run habitat with an increased number of larger fish that had a lower probability of capture. In light of these differences, it seems plausible that sampling efficiency was hampered by the lack of a second electrofishing boat as no pilots were available at a time when the technicians were still under contract. Standardized mark-recapture methods with two jet-boats will be used for all future sampling to better allow for direct comparisons of population density, species assemblage, and size structure between the restored Morad Park reach and the Paradise Valley control reach.

Recommendations

Three years after project completion, monitoring data indicates that, overall, the restoration is meeting all goals. The project site should continue to be monitored for two additional years, following the monitoring timeline (Table) and some aspects of the project should be monitored closely. The left bank, downstream of rock vane 3 should be monitored for potential bank erosion due to the eddy that was observed in 2018. Areas with little vegetation on the right bank should be monitored for erosion and woody vegetation growth and establishment should be evaluated on the left bank. Photos of in-stream structures should be taken each year if they are visible to help in evaluating any changes in the structures.

The Casper fisheries biologist plans to sample the Morad Park and control reaches each fall using the mark-recapture methodology for at least three additional years (through 2021) to build a dataset that can be used to identify trends in fish populations. Variation in trout abundance from year to year may be due to a range of factors that influence population dynamics. Several years of data are necessary to appropriately attribute changes in population dynamics to any specific factor.

Finally, the rating system for structural integrity of in-stream structures could be improved to more clearly differentiate between physical integrity of the structure and whether it functions as intended. Rock vane 3 had no visible damage, but an eddy has formed downstream of it, increasing near-bank stress. Thus, it is not functioning as intended to direct flows away from the bank. A rating system that separates structural integrity, function, and erosion/deposition may be more useful in evaluating what is happening with in-stream structures.

ACKNOWLEDGEMENTS

Data collection was completed by Del Lobb (WGFD Instream Flow Biologist), Joanna Harter (Aquatic Habitat Project Biologist), and Alex Wooding (Instream Flow Technician). Jeff Glaid (Casper Fisheries Biologist) provided results and interpretation of fish sampling. Del Lobb reviewed a draft manuscript and provided comments to improve the report's clarity. T.C. Dinkins of Stantec Engineering was provided with a draft of this report.

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APPENDIX A.1. LONGITUDINAL PROFILE AND CROSS-SECTIONS

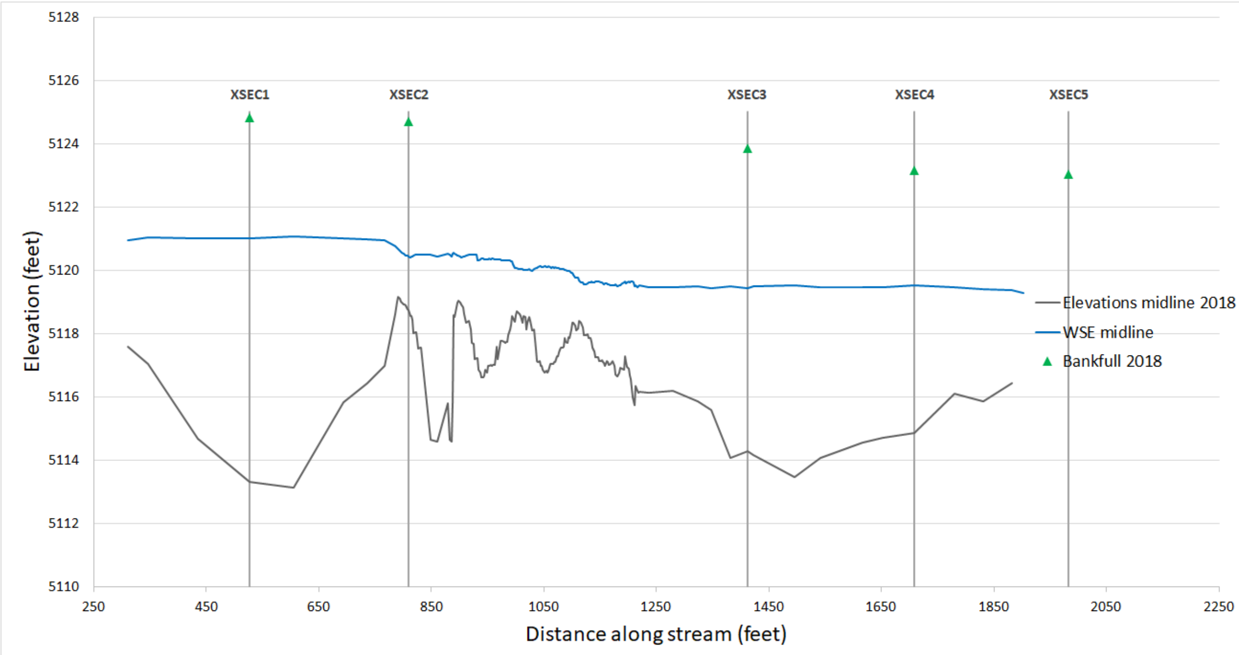

Figure A.1.1. – The longitudinal profile of the Morad Park project reach in October 2018.

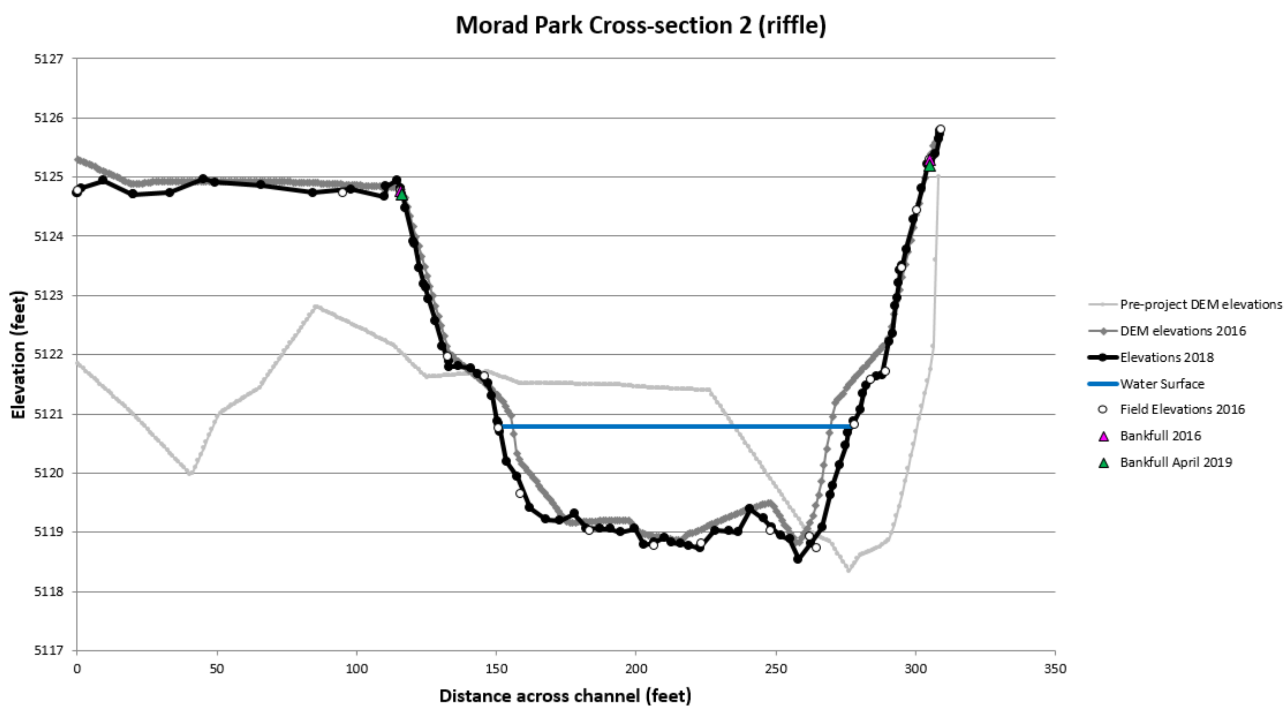

Figure A.1.2. – Profiles of river bed and bank elevations at cross-section 2 in 2018, 2016, and before construction.

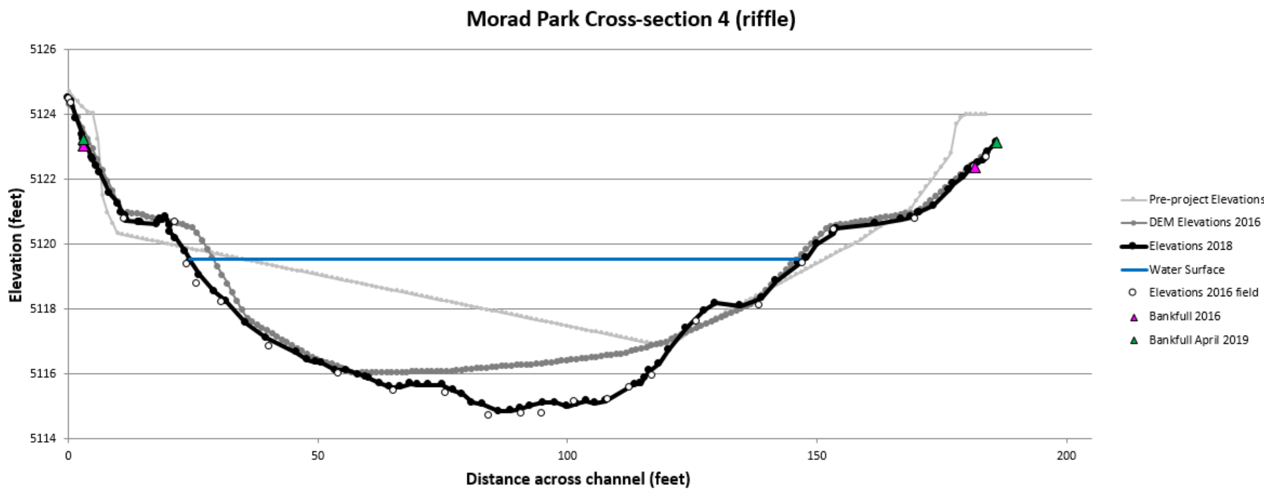

Figure A.1.3. – Profiles of river bed and bank elevations at cross-section 4 in 2018, 2016, and before construction.

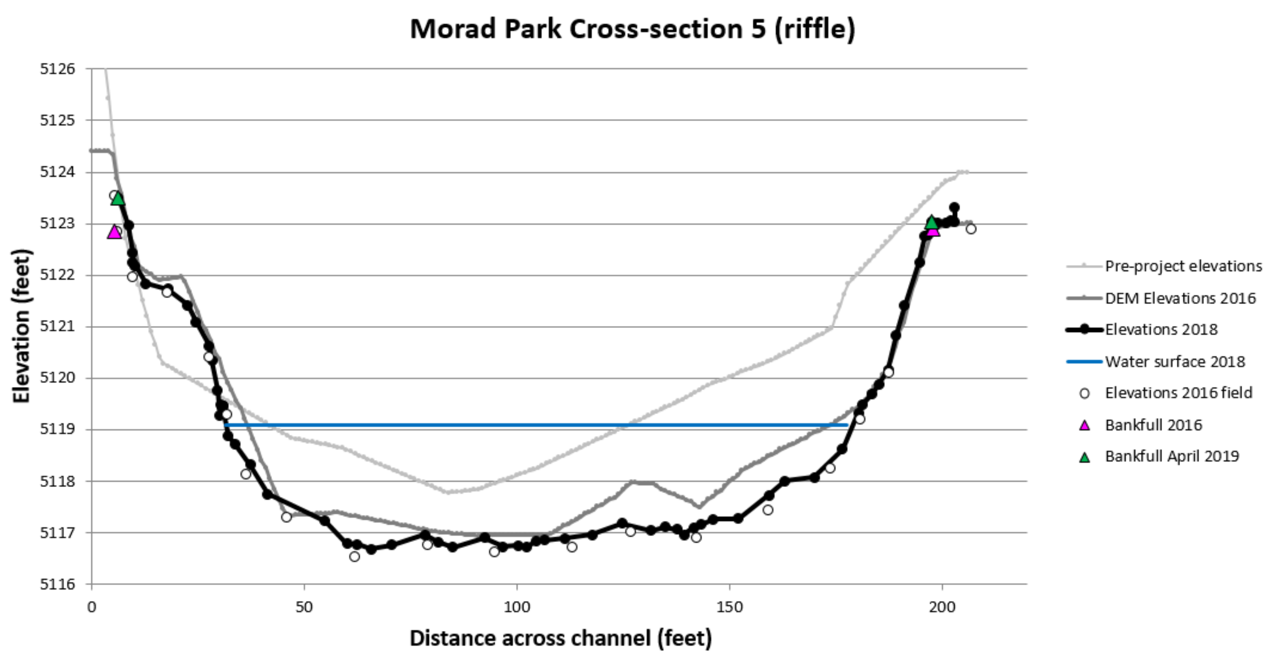

Figure A.1.4. – Profiles of river bed and bank elevations at cross-section 5 in 2018, 2016, and before construction.

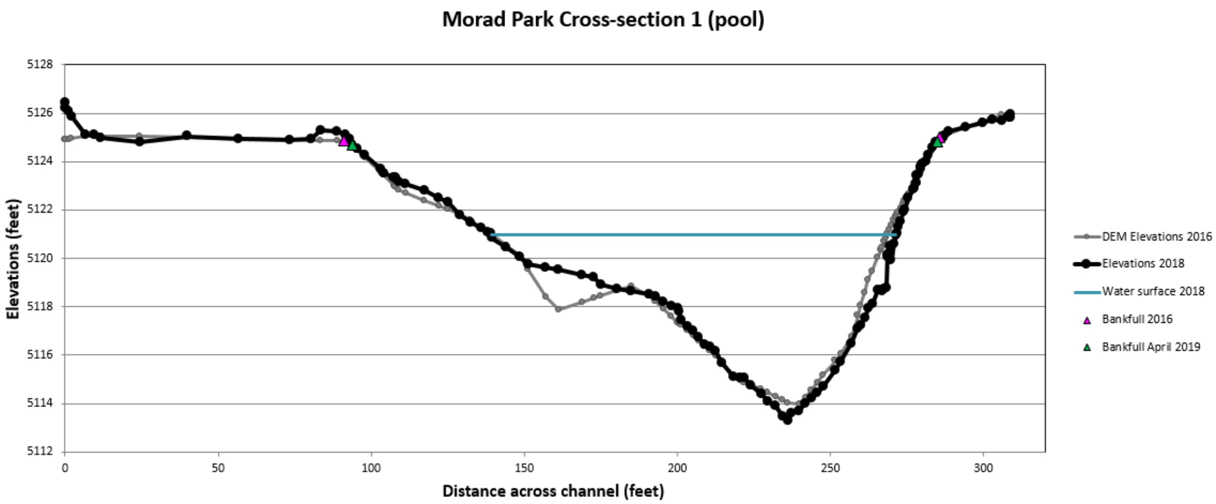

Figure A.1.5. – Profiles of river bed and bank elevations at cross-section 1 in 2018 and 2016.

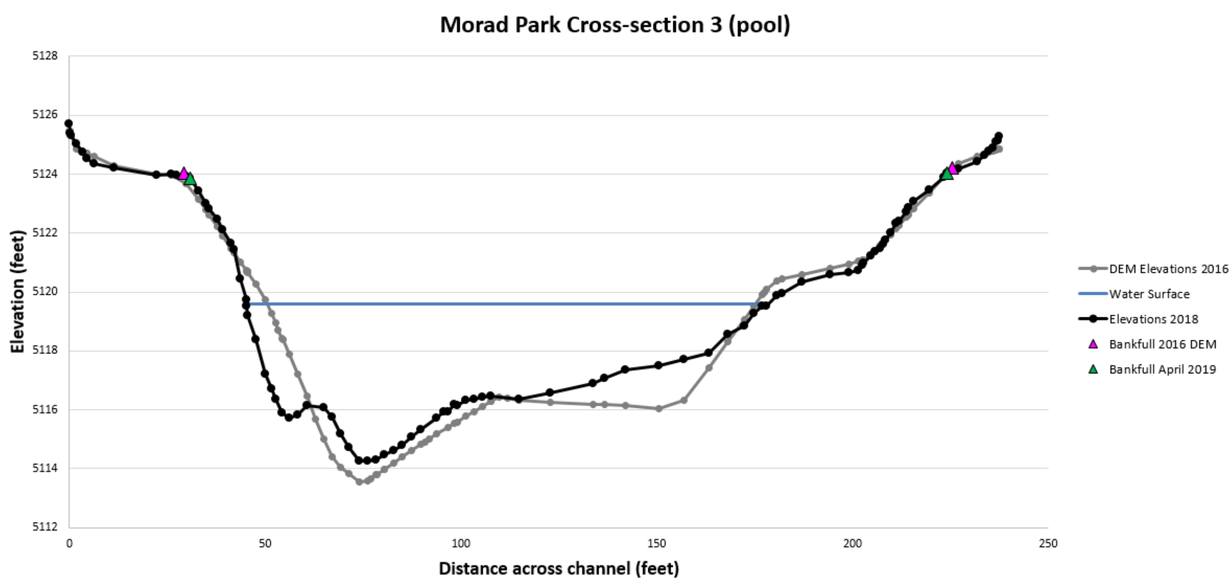

Figure A.1.6. – Profiles of river bed and bank elevations at cross-section 3 in 2018 and 2016.

APPENDIX A.2. MONITORING PHOTOS

All photos from photo point stations (Figures A.2.2 – A.2.8) were taken on July 17, 2018 (top row of photos) and again on October 15, 2018 (bottom row of photos).

Figure A.2.1. Location of seven photo monitoring points at the Morad Park project site.

Figure A.2.2. Views from photo point MP-1 looking upstream (left), across (middle), and downstream (right). Looking upstream, deposition near the right bank continues to maintain the cobble/gravel bar. Vandalism affected vegetation plantings along these banks, but some willows and cottonwoods survived. This area receives a lot of foot traffic. Establishment of vegetation over much of the area may be difficult.

Figure A.2.3. Views from photo point MP-2 looking upstream (left), across (middle), and downstream (right). There is significant vegetation growth both upstream and downstream, compared to the 2015 and 2016 photos. In the downstream photo, willow establishment and growth is evident above the toe wood structure.

Figure A.2.4. Views from photo point MP-3 looking upstream (left), across (middle), and downstream (right). Photos indicate that there has been some increase in vegetation growth since 2016 along the right bank. Vandalism in 2015 resulted in all live stakes being removed but many willow and cottonwood shoots are currently growing near the inner berm. Cottonwoods have also sprouted from natural sources nearer to the mature willow line. The turbulence in these images are caused by the constructed riffle arms; each created a distinct riffle feature that still appear to be holding the grade of the stream bed as intended.

Figure A.2.5. Views from photo point MP-4 looking upstream (left), across (middle), and downstream (right). Vandalism in 2016 also resulted in loss of most stakes along this bank. Most of the vegetation establishment has been herbaceous, although many young willows have established downstream.

Figure A.2.6. Views from photo point MP-5 looking downstream (left), across (middle), and upstream (right). Almost all of the vegetation growth along this left bank is herbaceous. Even though vandalism didn't affect the planted stakes in 2016 here, many of the stakes did not survive.

Figure A.2.7. Views from photo point MP-6 looking downstream (left), across (middle), and upstream (right). Many cottonwoods and willows are established and doing well both upstream and downstream. However, the top of these banks are still mostly bare. The upstream image shows the constructed riffle vanes, which continue to function to control the grade and direct flow to the center of the channel.

Figure A.2.8. Views from photo point MP-7 looking downstream (left), across (middle), and upstream (right). In the channel at this station an island was removed from the channel and a backwater wetland was created (not visible in photos). Herbaceous vegetation has established on this site and there is no evidence of any of the planted stakes surviving. Although much of the banks have vegetation cover, bank stability may be at risk if woody vegetation does not establish.

APPENDIX A.3. PHOTOS OF INSTREAM STRUCTURES

Figure A.3.1. Site 1 - Morad Park, standing on the left bank, looking downstream at the constructed riffle (left) on 10/15/2018. Arm 1 of the constructed riffle is in the foreground, with multiple boulders visible out of water on the right bank. Turbulence from arms 2 and 3 can be seen downstream in background. On the left is one of the only visible boulders in the fourth (most downstream) arm of the constructed riffle.

Figure A.3.2. Site 1 - Morad Park, standing on right bank, looking across the channel at Rock vane 1 (left). The header boulders are visible above base flow in the foreground (left). Boulders underwater at the same level of the surrounding substrate further into the channel (right).

Figure A.3.3. Site 1 - Morad Park, standing on right bank, looking downstream at toe wood.

APPENDIX A.4. - RAPID ASSESSMENT DATA FOR IN-STREAM STRUCTURES

Table A.4.1 - Ratings for in-stream structures following the rapid assessment protocol. Red, bold numbers indicate a structure whose rating changed between 2016 and 2018.

Structure Description	Number	Structural Integrity Rating (1-4)		Erosion / Deposition rating (0-5)	
		2016	2018	2016	2018
Toe wood	1	1	1	0	0
Rock vane (1)	2	1	1	0	**1**
Rock vane (2)	3	1	1	0	**1**
Rock vane (3)	4	1	1	0	**2**
Constructed riffle arm (1)	5	1	**2**	0	**1**
Constructed riffle arm (2)	6	1	1	0	**1**
Constructed riffle arm (3)	7	1	1	0	**2**
Constructed riffle arm (4)	8	1	**2**	0	**2**

Table A.4.2 – Rapid assessment ratings used for in-stream structures (Miller and Kochel 2013).

Ranking	Description
(A) Rankings used to classify in-stream rock or log structures for structural integrity	
Intact (1)	No visible damage; fully operational in terms of integrity
Damaged (2)	Structure functions as intended, but at least 10 % of structure visibly damaged; usually involved movement of one or more boulders
Impaired (3)	Structural components in general location of original structure, but feature no longer functions as intended; 25–75 % of structure remaining
Failed (4)	Significant parts (>75 %) have been removed from site; severely fragmented; incapable of achieving intended objective

Rating	Description	
	Erosion	Deposition
(B) Ranking system used to categorize structures for unintended erosion or deposition		
0	None visible	None visible
1	Minor localized erosion along margins of feature; structure maintains continuity with bank and bed; undermining of footings	Minor deposition over center of structure; pool remains well-defined
2	Localized erosion visible, which is likely to continue. Eroded area likely to influence flow	Deposition along 25–50 % of structure in channel; pool poorly developed and/or partially filled
3	Structure remains in contact with bank, but erosion has occurred along entire zone of contact with bank. Unintended erosion of channel bed must exceed 50 cm and be clearly related to the structure	Deposition occurs long 50–75 % of structure's length in channel; pool very weakly defined or filled
4	Structure partially detached from bank; complete detachment eminent; feature no longer functions as intended	Sediments bury 75–90 % of structure in channel; no pool present
5	Structure completely detached from bank; no longer performs function intended	Sediments bury 90–100 % of structure in channel; no pool present

Structure	Description
(C) Ranking system used to evaluate the performance of rootwads	
0	No visible erosion
1	Rootwads intact, but minor localized erosion visible around <25 % of root mass
2	Erosion visible around 25–90 % of root mass; stump remains buried, or as presumed to be at time of construction
3	Erosion around entire rootwad; stump locally exposed
4	Erosion around entire rootwad, exposing stump; rootwad no longer located along bank, but extends into channel and effects local flow field
5	Erosion has exposed most of buried stump; rootwad located in channel and affects flow field

APPENDIX A.5. MEAN DAILY FLOW HYDROGRAPH

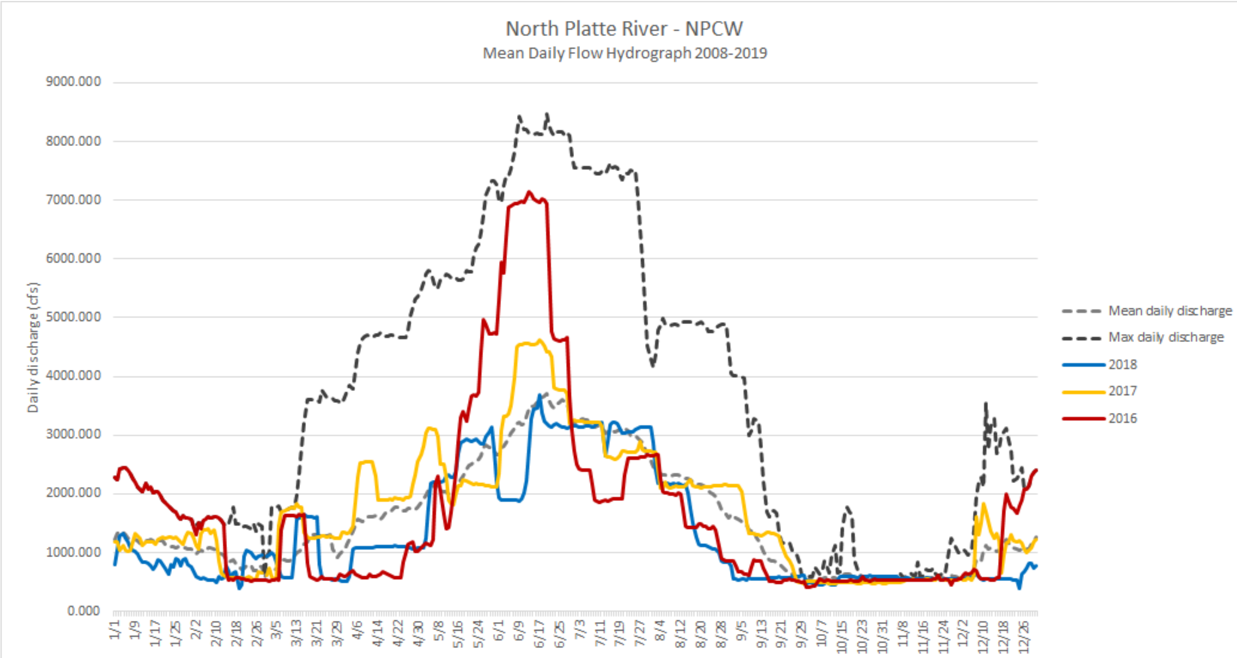

Figure A.5.1 - Mean daily flow in the North Platte River at BOR station NPCW, located approximately 4.5 miles downstream of the Morad Park restored reach.