Multnomah Channel Marsh Natural Area Floodplain Restoration Project

Multnomah Channel, NW Oregon

Basis of Design Report
70% Design

Existing water control structure at the Multnomah Channel Marsh Natural Area 9-3-2020, R. Cooper-Caroselli

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1.0 PROJECT BACKGROUND

The purpose of the Multnomah Channel Marsh Natural Area (MCMNA) Floodplain Restoration Project is to enhance floodplain and tidal wetland habitat and improve fish passage and accessibility at the MCMNA in Multnomah County, Oregon. The MCMNA is a 278-acre floodplain wetland located along the west side of Multnomah Channel between RM 15 and 17 (Figure 1). Multnomah Channel is the largest distributary channel in the lower Columbia River (21 miles long) connecting the lower Willamette River to the Columbia River (at RM 86) and running along the west side of Sauvie Island.

The MCMNA site (center point lat/long: 45.6794, -122.8712) is owned and managed by Metro Regional Government (Metro) and includes tidal wetlands, perennial and ephemeral streams, and riparian and forested habitats. The property contains approximately 3,000 feet of stream frontage along Crabapple Creek which flows through the site to join with the wetlands and swales, which are in turn drained by the two large tidal sloughs. To the South the site is separated by two privately-owned and one Metro-owned parcel from the 400-acre BPA-owned Burlington Bottoms wetlands (Zonick, 2018). Key features at the site include a levee along Multnomah Channel, North and South water control structures (WCSs), North and South wetlands, and Crabapple Creek entering the site from the west. The WCSs were installed by Metro in 2001 to allow for hydrologic manipulation of the site. There is a Portland General Electric (PGE) utility easement running along the eastern edge of the site parallel to the Multnomah Channel (Zonick, 2018).

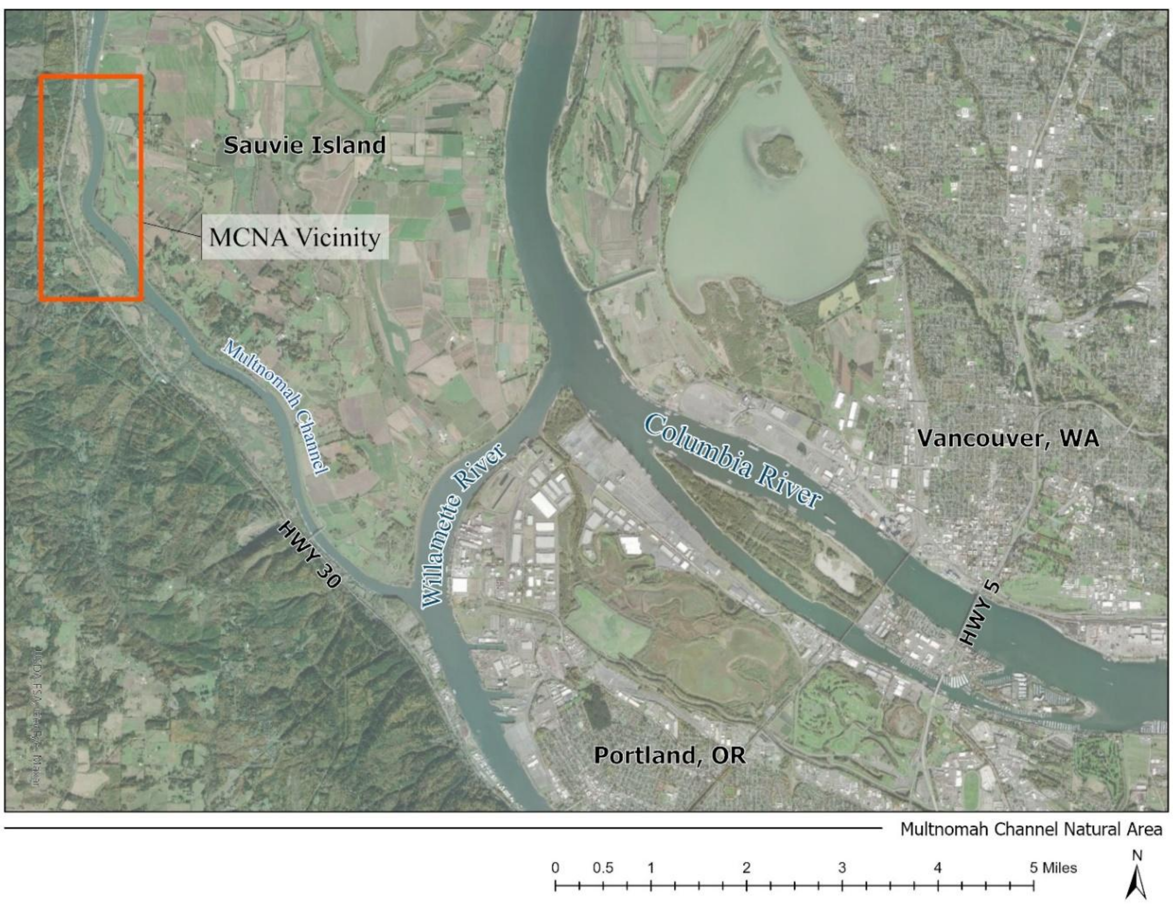

Figure 1. Multnomah Channel Marsh Natural Area Location.

PROJECT GOALS AND OBJECTIVES

The MCMNA Floodplain Restoration Project is developed in the context of overarching site management goals and objectives. Project site treatments are selected to enhance site function in line with the site management goals and objectives. This report is intended to document project design. Specific goals and objectives for management of the MMCMNA include:

1. **Floodplain Connectivity:** Restore site process and function provided by the existing Columbia R, Willamette R, and Multnomah Channel (MC) flow regime.
    a. Improve hydrologic connectivity between MC and site, allowing flood-pulse processes and the transport of material (sediment, wood, macroinvertebrates, and detritus) in and out of site.
    b. Improve fish access- Provide multiple access points for juvenile salmon ingress and egress to/from off-channel habitats during key outmigration/rearing timing (Nov- June for Columbia R and Willamette R populations).
    c. Improve water quality (temp, DO, pH) to reflect connectivity to Multnomah Channel.

2. **Landscape Connectivity:** Increase Crabapple Cr. connection to floodplain and upstream Tualatin Mountain habitats.
    a. Improve hydrologic connectivity and transport of material through appropriately sized Crabapple Cr. crossing.
    b. Improve aquatic and wildlife permeability between floodplain and Crabapple Cr, with specific focus on salmonids, lamprey, and amphibians.

3. **Habitat Quality and Diversity:** Enhance habitat suitability for fish and wildlife and ensure a mosaic of habitats are naturally sustained.
    a. Native fish species including salmonids and lamprey: Expand off-channel habitat quality, quantity, and diversity and improve access.
    b. Native amphibian species including red-legged frog: Ensure portions of wetland habitat remain suitable for breeding and egg laying stages.
    c. Beavers: Encourage beavers to expand on the site by ensuring forage and dam building material is available.
    d. Turtles, birds, ungulates, and other wildlife: Maintain diverse habitat features to suit a wide range of uses.

4. **Native Plant Communities:** Restore function and structure offered by diverse native plant communities.
    a. Promote hydrology and topography conditions that allow diverse native plant communities to be self-maintaining, such as provision of flooded spring conditions to suppress reed canarygrass.
    b. Expand diverse native plant communities to match reference Columbia River floodplain plant community elevation ranges (Borde et al. 2020) and revegetate in highest priority habitat areas, such as wetland and stream channel buffers.

5. **Maintain Access for Infrastructure**
    a. Maintain road and easement under powerline, as needed by Metro and PGE, while making modifications feasible and necessary to meet the goals of the restoration project.

6. **Engage Community:** Identify opportunities to engage Indigenous and other historically marginalized communities at the site.
    a. Identify culturally relevant plant material harvest or access values that the site may offer.
    b. Engage green workforce education and training opportunities at the site.

1.1 NAME AND TITLES OF SPONSOR, FIRMS, AND INDIVIDUALS RESPONSIBLE FOR DESIGN.

Project Sponsor – Lower Columbia Estuary Partnership (EP).
Design Engineer – Wolf Water Resources (W2r).
Landowner/Manager – Metro

1.2 LIST OF PROJECT ELEMENTS THAT HAVE BEEN DESIGNED BY A LICENSED PROFESSIONAL ENGINEER.

The proposed project elements have been designed by a licensed engineer and are summarized below:

- North water control structure removal;
- South water control structure removal;
- Levee breach lowering;
- Marshplain lowering (MPL);
- Strategic fill placement;
- Wood Habitat Structures (WHS); and
- Beaver Dam Analogue (BDA) structures.

The outcomes expected from the restoration actions include:

- Improved connectivity of the floodplain and adjacent wetland complexes;
- Improved access and suitability of off-channel networks and shallow-water habitat for juvenile salmonids;
- Expanded edge habitat, which will benefit multiple species by increasing primary production and prey availability within the food web;
- Increased frequency of ponding along slough profile through encouraging future beaver activity with BDAs & WHSs;
- Maintained surface water ponding to support pond turtle and amphibian habitat; and
- Increased water quality in the wetland complex due to improved hydrologic connections.

1.3 RISK TO INFRASTRUCTURE, POTENTIAL CONSEQUENCES, AND COMPENSATING ANALYSIS TO REDUCE UNCERTAINTY.

- No damage to infrastructure beyond the WCSs identified for removal by the project is anticipated as result of the proposed restoration actions.

- Infrastructure within the Project area includes power lines and towers and a railroad running along the landward (west) boundary of the property. Flood risk and risk of erosion at or around these structures is not expected to be increased by the project.
- The project will remove two existing crossings and WCSs.
- The project will excavate additional material from two levee breaches that were constructed by METRO in 2014 to improve connection at high flows. This is intended to provide additional access points for fish use and is not expected to alter flood elevations or risks as the site regularly floods extensively under existing conditions.
- The project is designed to result in no rise of 100-year Base Flood Elevation (BFE) at, upstream of, or downstream of the project.

1.4 EXPLANATION AND BACKGROUND ON FISHERIES USE (BY LIFE STAGE - PERIOD) AND LIMITING FACTORS ADDRESSED BY PROJECT.

A study of fish assemblages and habitat use within the MCMNA was performed by the National Marine Fisheries Service and Oregon Department of Fish and Wildlife (NMFS/ODFW) over the course of three years from 2014 to 2016. Three salmonid species were present in small numbers: Chinook salmon, Coho salmon, and coastal cutthroat trout (McNatt, et al., 2017). The study included the following key findings:

- Patterson and Crabapple creeks were inhabited almost entirely by native fish and amphibians, while wetland ponds were inhabited by a greater proportion of non-native taxa, including a high proportion of pollution-tolerant species.
- A variety of potential salmonid predators also occupied the ponds, including an apparent resident spawning population of largemouth bass (*Micropterus salmoides*).
- In the Multnomah Channel and the mainstem Columbia River, four salmonid species were captured in addition to other native and non-native fish species.
- Fish tagged and released from upriver locations were detected within the MCMNA North and South outlet channels. These fish seemed to move toward the flooded wetland at the site; however, they were not detected past the WCS.
- Salmonids released at the site had a hard time passing through the South WCS (only 26% were successful) but were able to pass the North WCS.
- The growth rate of juvenile salmonids was better in areas with natural emergent vegetation than in areas dominated by RCG.
- The study occurred during an El Niño period characterized by drought and uncharacteristically low water levels on the Multnomah Channel and wider river system. Although more typical hydrographs predicted an almost annual event that would overtop the engineered high-water spillways built to improve connections between the Multnomah Channel and the MCMNA wetlands, only a single event (2016) occurred during the NOAA/ODFW study period. , During that period, however, several juvenile coho salmon were captured moving into the wetlands via the South high-water spillway, indicating the spillways could serve as an additional connection between the Multnomah Channel and the MCMNA wetlands for juvenile salmon.

Salmonid access within the MCMNA is summarized in Table 1.

Table 1. MCMNA Salmonid Access

Management Scenario	Typical Timing	Ingress	Egress
WCSs open	July - December	Passable – through WCSs	Passable – through WCSs
WCSs closed	January - June	Limited Passage – WCS passage not documented	Partial Passage – at the North WCS 50% fish passed; at the South WCS 9% passed
Levee notch connection	High flow event > 16 feet NAVD88	Passable – but at risk of stranding if water goes down	Passable

Overall, the NMFS/ODFW study showed there is reduced hydrologic connectivity between MCMNA and the Multnomah Channel when the two WCSs at MCMNA are fully closed. This loss of connectivity results in limited access by juvenile salmonids, provides suitable habitat for non-native species, and degrades water quality by affecting water temperatures and dissolved oxygen levels (McNatt et al, 2017).

Since the completion of the NOAA/ODFW study, Metro adjusted management at the wetlands to seek improvements in permeability and habitat (water) quality for salmonids while maintaining a balanced biotic management approach that also benefits native amphibians and native vegetation.

In 2017, Metro developed a planning matrix assessing five management alternatives: Natural System (no WCSs), Open System (WCSs remain but are not closed), Partially-Closed System (one WCS is closed, the other open), Lower Seasonal Flooding System (WCSs remain and are closed but boards are removed to store water at lower levels), Closed System (WCS remain and are managed as before, fully closed to maximize storage). The different scenarios were scored from 0 (worst) to 5 (best) for each of eight criteria (water quality, salmonids, native amphibians, native birds, nutria [suppression], bottomland hardwood forest, RCG [control], native emergent wetlands). The scores were averaged to arrive at a scored assessment for the alternative(s) that provided the best results for the broader biotic community. The assessment suggested the alternative providing the best outcome for the broader biotic community at MCMNA was the Lower Seasonal Flooding System, which scored 3.125/5, followed by the Natural System (2.875/5) and the Partially Closed System (2.75/5).

In the spring of 2019, following the native amphibian breeding season, Metro reduced the level of engineered storage at MCMNA from approximately 12’ to 10’. The move to lower seasonal flood storage was accompanied by a revegetation project targeting the acres where seasonal floodwater was once stored to help mitigate the release of RCG in those areas and provide better alternative native wetland habitat. When managed seasonal flooding began again in 2021, managed flooding was further reduced to 9.5’. The lower level of stored flooding is accompanied by reduced obstructions between the Multnomah Channel and MCMNA wetlands via the reduced height of obstructing stoplogs in the WCS.

A broader summary of multi-species use including turtles and amphibians is included in the Feasibility Assessment Report in Appendix A.

1.5 LIST OF PRIMARY PROJECT FEATURES INCLUDING CONSTRUCTED OR NATURAL ELEMENTS.

The project aims to enhance habitat quality and connectivity/accessibility in the following ways.

- Improve fish access – Remove two WCSs that restrict fish passage and lower existing levee breaches to improve access during high water.
- Improve wetland habitat – MPL grading will improve inundation of surfaces to improve fish access at low-water. MPL will also mechanically remove RCG, suppress it hydrologically, and enable revegetation with diverse native emergent wetland species.
- Improve wetland connectivity within the site – MPL grading is designed to improve connection between low lying wetlands across the site. This will improve fish access to interior wetlands at lower water levels and reduce the risk of fish stranding in isolated wetland depressions.
- Install habitat forming natural structures – Large wood will be installed in the North and South sloughs to increase channel roughness and complexity. BDA structures will be installed in conveyance channels to improve and sustain ponding of wetland habitat.

1.6 DESCRIPTION OF PERFORMANCE / SUSTAINABILITY CRITERIA FOR PROJECT ELEMENTS AND ASSESSMENT OF RISK OF FAILURE TO PERFORM.

The design and construction of the project will incorporate the following to reduce or eliminate potential risk and consequences:

- Excavation within wetlands will be restricted to areas dominated by RCG. Mechanical removal of the overlying invasive vegetation will allow for better establishment of diverse plantings of emergent wetland vegetation. Target elevations are selected to hydrologically suppress the regrowth of RCG and support the target species. Elevation targets detailed in section 4.2.1 below. Pretreatment of work areas with herbicide may be done at the discretion of the landowner in compliance with all relevant permits.
- No fill will be added placed in wetlands with high proportions of native species or that will result in the conversion of wetland to non-wetland.
- The project monitoring and adaptive management plan will be developed in collaboration with Metro and EP.

1.7 DESCRIPTION OF DISTURBANCE INCLUDING TIMING AND AREAL EXTENT AND POTENTIAL IMPACTS ASSOCIATED WITH IMPLEMENTATION OF EACH ELEMENT.

Construction of project elements below Ordinary High Water (OHW) will be carried out during the summer in-water work window for Multnomah Channel, July 1st through October 31st (ODFW, Oregon Guidelines for Timing of In-Water Work to Protect Fish and Wildlife Resources, 2008). Timing of excavation at the site will coincide with site hydrology, which can be variable depending on the timing of the spring freshets. Freshet timing is dependent on water year, spring storms, and snowpack throughout the Columbia River Basin. As excavation is planned in areas that are generally above summer low flow levels, once the spring freshet has passed, soils in the grading areas are anticipated to dry out and become firm at the surface. This surface drying is unlikely to prevent soil pumping during construction in low lying high traffic areas, particularly as excavation proceeds. Grading areas are designed (by use of long/narrow aspect ratio) to limit a need to drive across excavated areas repeatedly. Low ground pressure machines will need to be used for construction.

2.0 RESOURCE INVENTORY AND EVALUATION

2.1 LAND MANAGEMENT HISTORY AND STRUCTURAL CONTROLS

Historically, flooding from the Columbia River would periodically inundate, erode, and deposit material on its floodplain allowing for the development of a complex ecosystem of wetland, meadow, and riparian habitats in the Lower Columbia River estuary. Much of the historical floodplain habitat has been lost to development or isolated from the river by levees for agriculture, with up to 80% of bottomland forests lost in the Willamette River Basin. Additionally, due to alterations to the natural hydrologic regime from the flow management via hydropower and flood control dams, only remnant bottomland habitat like that found at the MCMNA property remain. These remnant habitat sites are maintained in a degraded state (in terms of native migratory fish accessibility) due to the absence of the historical disturbance regime and lack of tidal connectivity.

Prior to its acquisition by Metro in the late 1990s, the MCMNA site had been used as a pasture for dairy cattle grazing. The site had been heavily graded by the previous landowner in an attempt to reduce ponding on site and promote drainage (Figure 2).

Most of the site was dominated by RCG, thistle, non-native blackberries, and other invasive weedy plants.

Modest tracts of Oregon ash and black cottonwood forest remained along the site's edges. Since the late 1990s, Metro and its partners have planted hundreds of thousands of native trees and shrubs to expand bottomland forest and shrub habitat at the site (Zonick, 2018), including an effort in 2019 to revegetate many of the ecotone areas lying between the established forests and the seasonally flooded emergent wetland units.

In 2001, the first large phase of hydrologic enhancement was implemented. Two WCSs (one on the North side and one on the South side of the site) were installed with the intent to restore a seasonal flood regime to nearly 150 acres. The goal of installing these water control structures was to convert extensive fields of RCG monocultures back to native emergent wetlands (Zonick, 2018) and to improve habitat for native wetland species including salmon, pond-breeding amphibians, birds, and mammals. The WCSs were initially closed from October through early June; however, the managed flood period has been refined over the past decade to limit non-essential flooding in the fall to help control nutria. This refinement was extended through the end of June after graduate research at the site established that R. aurora were not completely metamorphosing by early June and would benefit from more prolonged flooding through the end of the month. Since about 2011, the WCSs have been typically closed from early January through early July to retain water on the MCMNA site.

In addition to revegetation efforts, Metro undertook a couple floodplain reconnection projects at the site. In 2008, a Crabapple Creek was restored back into its pre-settlement alignment. The purpose of the project was to increase flows to the Northern wetland area (and out through the North WCS), promote more reliable seasonal ponding in the North wetland basin, and increase the potential for fish use at the site. In 2014, Metro removed three culverts along Crabapple Creek under the main access road (replacing the culverts with a bridge) and cut two 100-foot-long high-water spillways into the eastern riparian berm (one on the North and one on the South side of the site). These spillways provide hydrologic connections between the Multnomah Channel and the two wetland basins at MCMNA at 12.5 feet above mean sea level (16 ft NAVD88). The purpose of both projects was to enhance connectivity between the North and South wetlands and allow for greater connectivity seasonally with Multnomah Channel (Zonick, 2018).

Figure 2. A 1995 aerial photo showing the Northern 2/3 of MCMNA (left). Extensive grading of the site is evident. The site was being scoped for development by the landowner and large areas of the floodplain were graded to dewater the site and redirect water to the western edges of the floodplain. Metro acquired the site a couple years later after the 1996 Flood submerged the entire property.

The image at right shows the heaviest cover of RCG at the site in 2000 (shown in diagonal green hatched shading), as mapped by Adolfson and Associates as part of an ecological inventory of the site.

2.2 SITE GEOMORPHOLOGY

Today the Multnomah Channel floodplain, together with Sauvie Island and Bachelor Island, makes up the widest floodplain reach of the upper estuary. The floodplain is composed of wetlands and many seasonal ponds within ridge and swale deposits and scoured bedrock areas, as well as terraces and rocky outcroppings. Many of the wetland complexes are separated from the mainstem Columbia River channel by the slightly higher floodplain ridge and swale deposits generated by lateral channel migration. The floodplain is circumscribed by distributary channels, most notably Multnomah Channel, and tie channels such as Crane Slough and Gilbert River. Many circuitous sloughs and tidal channels connect swale wetlands embedded in the ridge and swale topography.

Each of the Catena classifications (Figure 3) reflects the dominant geomorphic character in the corresponding coverage area, which in turn correspond with the landforms present at the site (Figure 4). The two large lake beds and flanking tributary fans associated with Crabapple Creek and the unnamed stream to the South of the site are dominant geomorphic features at MCMNA.

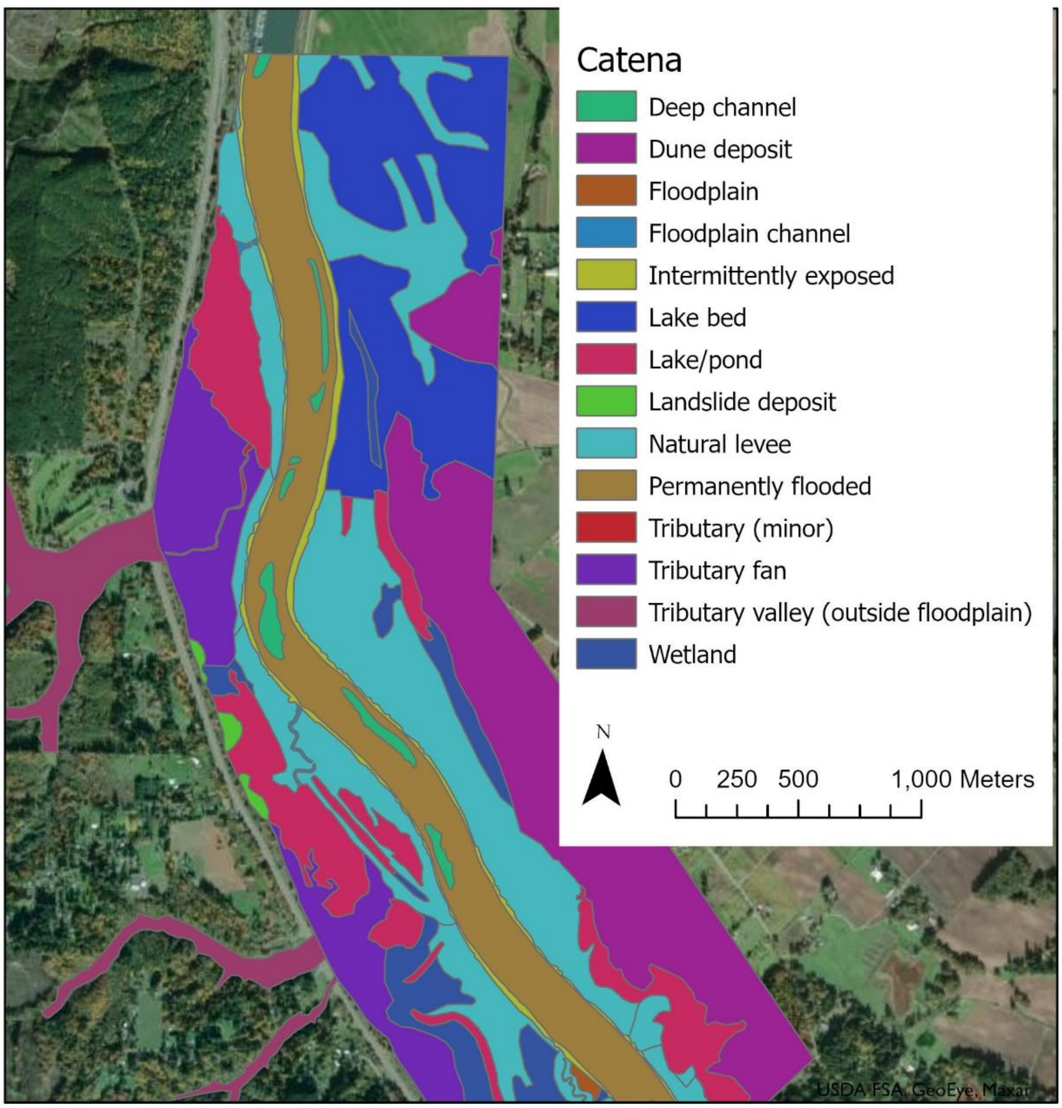

Figure 3. Reach F site scale geomorphic catena (Simenstad et. al., 2011).

2.2.1 VALLEY WALL

A basaltic valley wall forms the western boundary of the MCMNA site. At the North end of the site the Multnomah channel is pushed against this bluff bounding the western floodplain.

2.2.2 TRIBUTARY FANS

Tributary creeks, including Crabapple Creek and Patterson Creek, flow down off the valley wall, fed by runoff from the Tualatin Mountains, and then onto the floodplain. At the break in slope, where slope and stream power diminish, these creeks drop their coarse sediment load, forming an alluvial fan. The materials deposited in these locations are more porous and hydraulically transmissive than the fine sediments deposited by mainstem flows.

2.2.3 NATURAL LEVEES, RIDGES, AND SWALES

Floodplain deposition processes along the Multnomah Channel gradually form natural levees, which build up adjacent to the main channels on the floodplain.

Natural levees form during floods as water flows onto the floodplain and previously entrained sediments are deposited in abundance closest to the channel on the inside edge of the floodplain. Over the course of many successive floods, these deposits of sediments on the inside edge of the floodplain build up higher and higher, thus forming natural levees. These natural levees act to keep Multnomah Channel waters from flowing directly onto the floodplain during smaller flood events, but the natural levees would have historically been overtopped or naturally breached during large flood events before post-European settlement modifications to the river systems. When the natural levees are breached, floodwaters deposit sediment inside of the natural levees, thus creating crevasse splays across the bar and scroll complex.

Most of the bank along Multnomah Channel at the project site presently ranges in elevation between 15 to 25 feet NAVD88. These levees overtop in places where the natural levee is lower with some frequency (Section 3.3, Table 4) but depth of flows over the top of the levees for all but the very largest modern floods are likely insufficient to initiate large-scale erosion and reworking of the floodplain.

Natural channel migration forms successive natural levees, roughly paralleling the contour of the point bar and progressively building out from it over time, which together form the bar and scroll complex. In meandering systems, levee position on the meander may strongly control levee growth. The outside bank of a meander bend experiences a very different flow field of overtopping channel waters than does the inside bank.

Figure 4. MCMNA fluvial geomorphic features.

Floodplain ridge and swale topography is formed by deposition of coarse alluvium along the inside of a meander as the channel migrates down valley and towards the outer bank and represents a younger floodplain surface. The ridges are formed as scroll bars parallel to the curved channel and separated from the inner bank by a swale (Nanson, 1980). The low-lying swales are preferential pathways for cutoffs rather than the elevated ridges (Zinger et al., 2011). Several studies have suggested that each scrollbar is formed during one flood event (Nanson, 1980; Nanson and Hickin, 1983). The formation of ridge and swale topography of point bars is a consequence of channel widening induced by outer bank erosion (bank-pull) mechanism rather than a bar expansion following deposition (bar-push) mechanism (Van de Lageweg et al 2014).

Figure 4 also shows the rhythmic bar and swale topography associated with MCMNA's position on the bend of the Multnomah Channel, though some of the features at the Southeast corner appear unnaturally linear and may have been altered by humans. Active bar and swale features may be less common now that the flows in the Columbia River are regulated.

Flood waters would have been historically detained on site by the natural levees and the bar and scroll topography, increasing the period of inundation within the swale elements of the terrain even after the Multnomah Channel levels dropped. It is also likely that groundwater, controlled by water levels in the Multnomah Channel, plays a role in flooding the backswamp. Flood elevations in the Willamette, Multnomah, and Columbia are now managed and are lower than historic levels so that the present frequency of flooding is lower as the natural levees are higher relative to water levels. The associated delivery of water, fine sediment, and nutrients to the backswamp is also reduced as a result.

2.2.4 BACKSWAMP WETLANDS, PONDS, AND LAKES

Backswamps form between the natural levees and the terrace. Natural levee formation and deposition of fine sediment hinders floodplain drainage. The MCMNA parcel (Figure 4) is a backswamp bounded to the east by a natural levee running along Multnomah Channel and to the west by the valley wall. These areas often have the lowest topography, resulting in ponding of freshets. In addition, tributary streams flowed onto the floodplain behind the natural levees and flowed parallel to the main river until they found a topographic break in the natural levees, which enabled them to join the main river. Tributary creeks provide more constant inflow to the lakes and so they may be more persistent than floodplain lakes found on Sauvie Island. At MCMNA these floodplain lakes may have formed in the relict course of a side channel created as point bars formed on the inside of the bend in the Multnomah Channel, which would explain their elongated shape.

Backswamps are parts of the floodplain where aggradation has lagged (Cannon 2015). In backswamp-dominated reaches, vertical accretion is concentrated on natural levees along channels and in crevasse splays. Growth of natural levees likely promotes sediment bypassing, particularly during times of high streamflow.

Tie channels are perennial waterways that connect floodplain lakes to the Multnomah Channel. Narrow and sinuous, tie channels commonly are flanked on both sides by natural levees which can be seen in the Lidar topography in Figure 4. Tie channels are created by a sediment-laden jet entering the still water of a lake (Rowland and Dietrich). The jet sorts the sediment load. The coarsest particles form levees whose continued growth propagates the channel lakeward as a prograding delta. The finest sediments, the largest fraction of the load, settle in deeper portions of the lake and blanket the coarse sediments adding cohesion and strength to the channel banks. This strength results in narrow width to depth ratios and a channel cross-sectional geometry controlled by a combination of massive failures and sediment drapes. Tie channels are characteristically narrow, naturally leveed, and stable. As the levees develop, they separate areas of backswamp from floodplain lakes, leaving higher perched wetland depressions.

2.3 WETLAND RESOURCES

The site is dominated by wetland habitats, primarily freshwater emergent wetland, and freshwater forested/shrub wetland. These wetland classes are identified by the National Wetlands Inventory (NWI). The NWI wetland classes and extents are shown below in Figure 5. No further wetland determination or delineation has been performed.

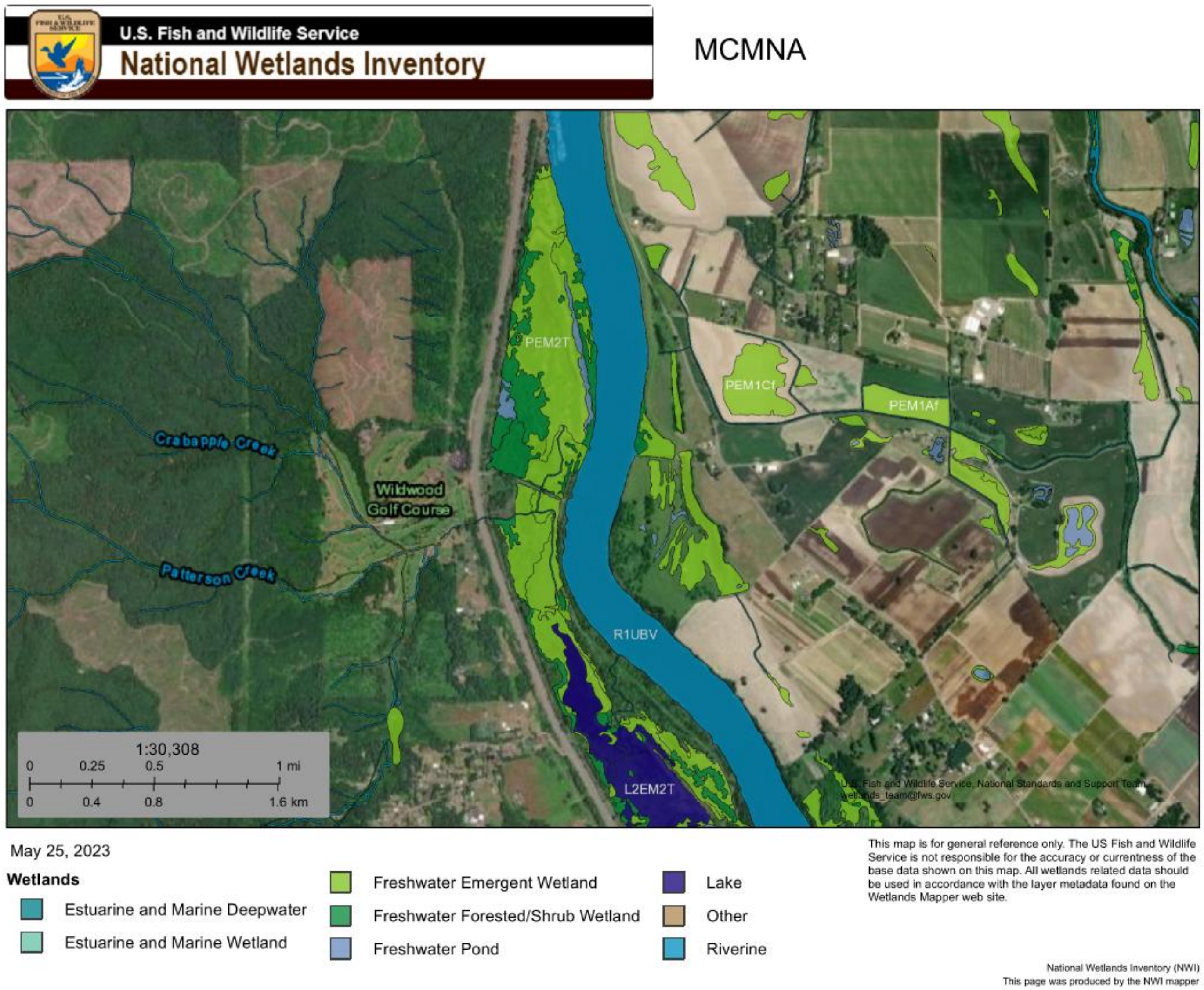

Figure 5. National Wetlands Inventory map of the MCMNA Property.

In July 2018 EP staff performed an analysis of plant community distribution using multispectral drone imagery, a digital elevation model, and field vegetation survey data. This study confirmed that wetland vegetation communities are dominant throughout the site. The results of this mapping effort showed that the Northern portion of the site remains largely dominated by heavy RCG (covering 50% of the North unit) despite years of sporadic seasonal flood management. Riparian forest/scrub-shrub habitat (covering 39% of the North unit) are the dominant secondary habitats in the North basin.

The higher portions of the site's Southern basin were also still dominated by persistent heavy RCG (covering 44% of the South unit) with secondary areas of riparian forest/scrub-shrub habitat (covering 31% of the South unit); however, high marsh and emergent wetland area had a higher percent cover than in the Northern portion of the site. It was also noted that the patches dominated by RCG were typically located at elevations higher than where emergent and high marsh vegetation were dominant. Images produced from this analysis are displayed below.

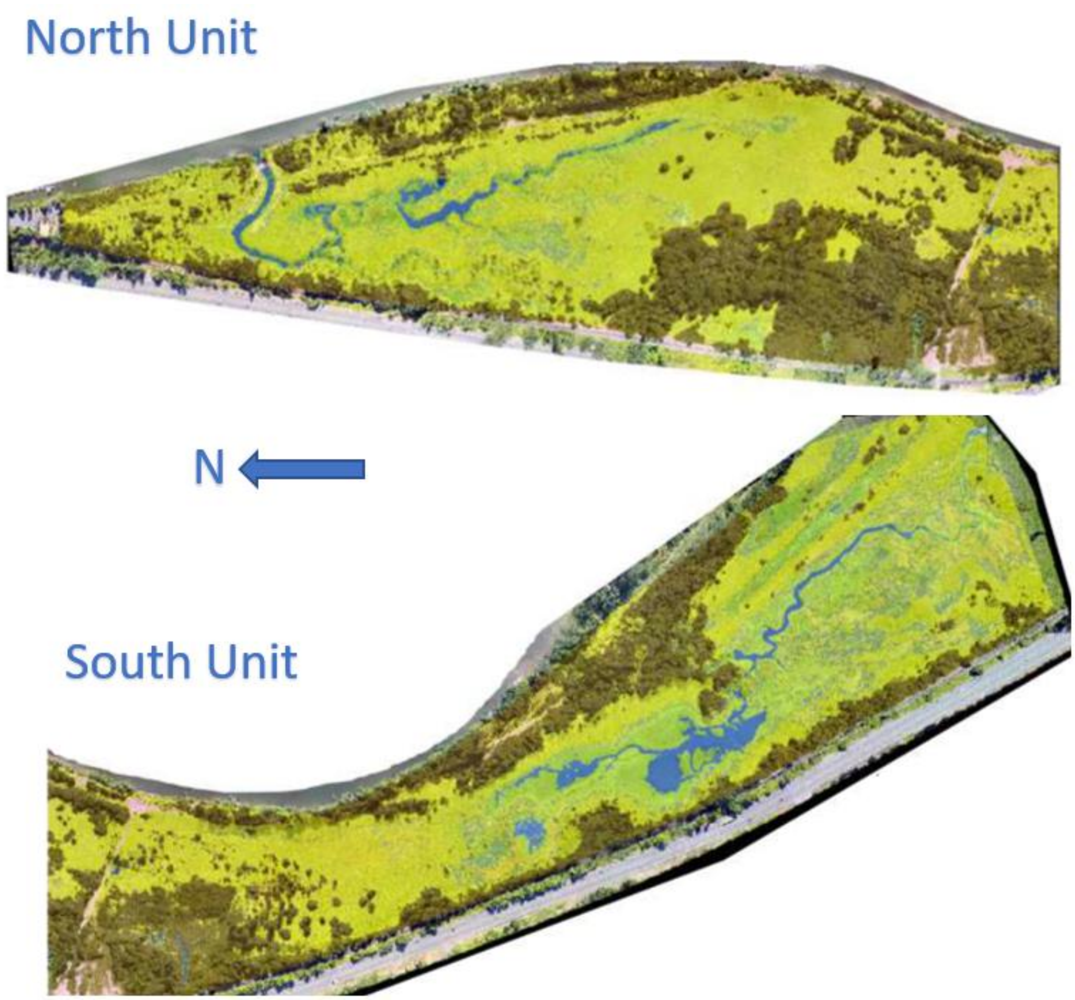

Figure 6. Drone-Based Vegetation Analysis (EP, Personal Correspondence , 2018).

Existing plant community elevation ranges (color-coded and corresponding to Figure 6 (above)) were also derived from EP's vegetation analysis and are included in the table below. The elevations EP identified at the site are further compared to elevations identified by a recent study of wetland vegetation associated within the lower Columbia River and estuary floodplain (Borde et al., 2020). The elevation data presented in this study shows consistently lower mean elevations than those observed at MCMNA as well as elevation ranges for each of the relevant herbaceous plant strata: emergent, high marsh mix, and RCG. This is likely explained by a combination of perched fluvial inputs to the site from Crabapple Creek, beaver activity, and the hydrological manipulation with the WCS. Notably, the elevations for the North wetland are much closer to the Borde et al elevation. It seems likely that the hydrologic difference between the North wetland and an unmanaged site is not significant. EP performed another veg classification UAV flight in 2020 which will be available soon and will inform the veracity of this hypothesis.

Table 2. MCMNA and Lower Columbia River Estuary (LCRE) Plant Community Elevation Ranges.

Plant Community Elevation Ranges (meters NAVD88)	North Unit[1]		South Unit[1]		LCRE Zone 4[2]	
	Mean	Min/ Max	Mean	Min/ Max	Mean	Min/ Max
Open Water	2.7	N/A	3.3	N/A	N/A	N/A
Emergent *(Wapato, aquatic mix)*	3.1	1.9/3.4	3.4	2.6/3.9	2.9	2.2/3.7
High Marsh Mix *(Sedges, rushes, RCG)*	3.7	2.7/3.8	4.1	3.6/4.8	3.2	2.5/4.1
Reed Canary Grass (RCG)	4.3	2.4/6.7	4.9	3.4/7.0	3.9	2.6/5.2
Riparian Forest/Scrub-Shrub	5.5	4.1/12.3	6.5	3.8/14.5	N/A	N/A

1. Based on July 2018 UAV and topographical data collected by EP
2. Based on data from Adolfson and Associates, 2000 and Borde et al., 2020

3.0 TECHNICAL DATA

3.0.1 ALTERNATIVE DEVELOPMENT AND PREFERRED ALTERNATIVE SELECTION AND INITIAL REVIEW

The alternatives analysis coincided with an in-depth feasibility study and is described in detail in the Feasibility Assessment Report included in Appendix A. The feasibility assessment did not compare discrete alternatives, but instead assessed a wide range of potential restoration and enhancement actions that are available to improve the MCMNA site and weighed the relative costs and benefits of each to select the preferred set of actions best suited to achieve the project objectives.

The following opportunities and constraints were identified by the Feasibility Assessment:

Opportunities:

- Enhancement of aquatic permeability between the site's wetlands and the Multnomah Channel.
- Enhancement of wildlife permeability between the MCMNA and the Tualatin Mountains through the current railroad, HWY 30 barrier.

- Improvement of off-channel habitat and wetland water quality through restoration of floodplain connectivity.
- Remove need for maintenance and management of WCS.
- Expansion or enhancement of emergent marsh and amphibian/turtle habitat.
- Expansion or enhancement of bottom forest habitat.

Constraints/Risks:

- Need to protect maintenance access for powerlines.
- Large costs associated with working under railroad and along a state highway.
- Basin-wide system of dams has fundamentally altered the lower Columbia River System's hydrology and limits hydraulic energy available for natural creation of habitat at the site.
- Need to anticipate the effects of climate change on the site.
- Removal of WCS reduces ability to control water levels to assist in revegetation and post-planting release actions.
- Removal of WCS reduces ability to control water levels to assist in weed abatement actions.
- Increased habitat acreage for invasive species that opportunistically use permanently flooded areas and are currently controlled through the existing management regime (bullfrogs, nutria, yellow-flag iris, purple loosestrife).
- Most (but not all) areas of the site have recently been planted.

The considered actions and the associated risks, challenges, and benefits are summarized in a Restoration Treatment Matrix shown in Table 3.

Table 3. MCMNA Restoration and Enhancement Opportunity Matrix.

Selected	Treatment	Intent	Risks / Challenges	Connection to Metro SCP	Connection to ODFW Conservation Strategy
	Revegetation	Assist reestablishment of native veg in disturbed areas	Inability to revegetate some areas if they have become semi-permanently flooded by beaver dams/BDAs. Competition from Invasives. Site grading designed to mitigate this risk, but additional veg management likely needed during establishment period.	Expand bottomland hardwood and riparian forest and shrub wetland areas currently dominated by pasture grass and emergent wetland.	Invasive species such as RCG are a limiting factor within estuaries and invasive plants can alter ecological community dynamics, such as competition, predation, or even parasitic relationships with native species.
	Beaver Dam Analogues	Retain water, speed up beaver response, alter flows.	Access challenges may require adaptive management if beaver do not maintain them. Risk of creating semi-permanent flooded areas that are challenging to replant, or support infestations of invasive species (e.g., bullfrogs, iris, loosestrife) that might be difficult or impossible to suppress.	Allow continued water impoundment alongside change in WCS management for water quality improvement.	Support and encourage beaver dam-building activity. Where appropriate, allow beavers to continue maintaining habitat complexity.
	Swale Excavation	Improve fish access, surface water connectivity, beaver dam establishment, amphibian habitat support.	Access challenges, disturbance.	Expand shrub wetlands and riparian forests. Enhance water quality.	Loss of riparian habitat, floodplain function, and habitat complexity is a limiting factor in riparian habitats. Where feasible, work to restore historical hydrological conditions.
	Lower Levee Breach Notches	Improve and increase frequency of hydraulic connection between Mult. Ch. and site, improve water quality, fish access.	Increased risk of flooding/dewatering the site, risk of fish stranding. Increases likelihood that juvenile fish will enter wetlands and be impacted by high temps/low DO, invasive/exotic pressure.	Promote greater water quality conditions and create even greater mixing and fish migration opportunities.	Loss of riparian habitat, floodplain function, and habitat complexity is a limiting factor in riparian habitats. Where feasible, work to restore historical hydrological conditions.
	Marshplain Lowering	RCG management, adaptation of emergent marsh to altered hydrology.	Costly. Access challenges, disturbance, need to be coordinated with current planting efforts.	Improve percentage of native cover in wetlands under natural hydrologic conditions.	Maintaining wetland and surrounding upland habitat near communities can provide safe passage corridors for fish and wildlife.
	Strategic Fill Placement	Enhance/expand turtle nesting habitat, upland grassland, small mammal, and reptile refugia, suppress RCG.	Access challenges, disturbance, RCG recolonization.	Expand bottomland hardwood and riparian forest and shrub wetland areas currently dominated by pasture grass and emergent wetland. Provide nesting habitat opportunities for birds including great blue heron and bald eagles.	Identify, maintain, and restore important stopover sites for migratory birds and bats. Enhance wildlife habitat and connectivity with consideration of climate change impacts.
	Wood Habitat Structures in Sloughs and Wetlands	Add cover for fish/turtles, induce local scour, enhance turtle basking habitat.	Access challenges, disturbance, may increase perches for piscivorous birds. May float away or end up in undesirable areas.	N/A	When planning aquatic passage projects, consider the needs of other aquatic species and terrestrial wildlife in addition to fish.
	WCS Removal (North or South)	Allow Fish Access/Egress.	May allow site to drain more rapidly, will not allow for future hydrologic manipulation by humans.	Aquatic connectivity for native fish is a key desired condition at the natural area.	Continue work with the OWEB, ODOT, ODF, USFS, BLM, Counties, local municipalities, irrigation districts, and other partners to inventory, prioritize, and provide fish passage at artificial obstructions. Enhance current work done by the ODFW Fish Passage Task Force to expand implementation of fish passage priorities.
Undecided	**Crabapple Creek Culvert Replacements**	Fish passage, wildlife passage.	Very Costly; must be done in collaboration with RR and ODOT.	Develop designs for crossing through HWY 30/RR; Improve landscape connectivity.	Provide connectivity of habitat for the broad array of wildlife species throughout Oregon.

3.1 INCORPORATION OF HIPIV SPECIFIC ACTIVITY CONSERVATION MEASURES FOR ALL INCLUDED PROJECT ELEMENTS.

The MCMNA Floodplain Restoration Project was designed using HIP specific conservation measures. Design, construction drawings, and specifications will follow and include all HIP Conservation Measures specific to these activities, as well as the general conservation and construction measures. Primary project actions are described in the context of the HIP Activity Specific Conservation Measures as follows:

- **Category 1a – Water Control Structure Removal (low risk)**
    - Two WCSs (North and South) will be removed to improve year-round access to the site for juvenile salmonids and prevent stranding as water levels recede.
    - The slough gradient is nearly flat at the locations of each WCS. There is a bed profile drop of approximately zero feet across the south water control structure and approximately one half to one foot across the north water control structure.
    - Due to the low energy/gradient environment there is no supply of course sediment to the sloughs in the vicinity of the water control structures and tidal flushing has been sufficient to prevent significant sedimentation of fine material in the slough. The quantity of impounded sediment upstream of each WCS is insignificant.
    - There is no spawning habitat downstream of either water control structure.
    - Holes/voids left by structure removal will be filled in with native material from marshplain lowering (category 2a) to match the existing channel morphology.
- **Category 1h – Installation of Fords (low risk)**
    - At grade compacted round rock fills will be constructed in the high levee breaches (Category 2a) to retain a drivable surface in the summer and fall for maintenance access along the power lines.
    - These breaches are only seasonally inundated by backwater from the Multnomah Channel during the freshet. They do not have the water surface gradient or course bed material to support spawning.
    - There is no livestock grazing in the MCMNA and no need for exclusion fencing.
    - The ford is located entirely within the footprint of the levee breach grading which will be revegetated.
- **Category 2a – Improve Secondary Channel and Floodplain Connectivity (medium risk)**
    - Floodplain connectivity will be enhanced by lowering two existing breaches (breached in 2014) in the levee that separates the site from the Multnomah Channel.
    - Interior hydrologic connectivity will be improved by excavation of a swale to connect a relict slough along the northwest side of the site to a historic distributary of Crabapple Creek.
    - 4.2 acres of marshplain lowering will create new self-sustaining emergent wetland habitat and increase available habitat for juvenile salmonids and amphibians at low flows.
    - Finish grade elevations of fill placement are designed to avoid wetland conversion. Fill placed below the observed wetland horizon elevation (20ft NAVD88) will have a maximum finished grade elevation of 17.5 ft NAVD88. No fill will be placed in wetlands with a high proportion of native species.
- **Category 2d – Install habitat forming instream structures - Large Wood & Small Wood (low risk)**

  - In both the North and South sloughs logs will be installed in wood habitat structure (WHS) to improve instream complexity and roughen the slough channels
  - BDA structures will be installed in the primary Crabapple Creek distributary channels and the North and South sloughs to enhance wetland hydrology and increase ponding.
- **Category 2e – Riparian and Wetland Vegetation Planting**
  - Areas graded for marshplain lowering and fill placement will be revegetated with appropriate native riparian and wetland species, replacing the dominant RCG.
- **Categories 3a and 3b – Invasive Vegetation Management and Revegetation**
  - If herbicides are used for invasive vegetation control, only those listed in the HIP manual and appropriate for the targeted species will be used. Application will comply with label application rates and will be transported, mixed, and applied by a licensed applicator, who will prepare and follow the safety/spill response plan.

3.2 SUMMARY OF SITE INFORMATION AND MEASUREMENTS (SURVEY, HYDROLOGY, VEGETATION, ETC.) USED TO SUPPORT ASSESSMENT AND DESIGN.

Since Metro's acquisition of the MCMNA property the site has been the focus of extensive pre-project monitoring and assessment, including the following studies:

- Topographic and Bathymetric Survey:
  - LiDAR 2014
  - LiDAR 2019
  - Supplemental RTK survey to verify LiDAR by EP and W2r
- Water level monitoring:
  - Water level data were collected at three locations by EP from 2019 – 2020 to compare annual water surface elevations behind each of the existing water control structures to those in the mainstem Multnomah Channel.
- Water quality monitoring:
  - Temperature and dissolved oxygen data were collected at three locations by EP from 2019 – 2020 to compare conditions for juvenile salmonid survivability within the North and South sloughs on the MCMNA site to the conditions within the mainstem Multnomah Channel.
- Vegetation assessments:
  - An initial post-acquisition vegetation assessment was commissioned by Metro in 2000 (Adolfson and Associates, 2000).
  - From 2002-2012 Metro collected data annually from eleven permanent transects to track vegetation using point intercept sampling and photo-point monitoring following the installation of the North and South WCS.
  - In July 2018 EP developed an updated plant community map using high-resolution multispectral drone imagery combined with a digital elevation model and field vegetation surveys.
- Wildlife Surveys:

- A study of fish assemblages and habitat use within MCMNA was performed by NMFS/ODFW over the course of three years from 2014 to 2016. Three salmonid species were present in small numbers: Chinook salmon, Coho salmon, and coastal cutthroat trout (McNatt, et al., 2017). The results of this study have been described above in Section 1.4.
- Since 2000 (prior to the WCS installation) the MCMNA property Metro has performed systematic amphibian egg mass surveys, demonstrating that the wetlands support amphibian species including the Northern red legged frog and Northwestern salamanders. Prior to the WCS installation native amphibian breeding was limited to two small areas, these areas expanded after the WCS installation.
- Western Pond Turtles have been documented on several occasions but are generally uncommon.
- In 2019 Metro completed a rapid beaver population assessment of beaver activity in the area around the central access road with a focus on options for management. The study identified one active beaver colony in this area and concluded that the area has the potential to support mor than one colony, but the carrying capacity is currently limited by the availability of forage within the simplified vegetation community.

These studies are summarized in more detail in the Feasibility Assessment Report included in Appendix A.

3.3 SUMMARY OF HYDROLOGIC ANALYSES CONDUCTED, INCLUDING DATA SOURCES AND PERIOD OF RECORD INCLUDING A LIST OF DESIGN DISCHARGE (Q) AND RETURN INTERVAL (RI) FOR EACH DESIGN ELEMENT.

In the Columbia River, and similarly in the Willamette River, freshwater inflows are the result of the combined effects of geologic processes, climatic regimes, individual storm events, and a series of significant water impoundments and managed releases. The dominant high flow mechanism in the Columbia River is the spring freshet, whereas in the Willamette high flows are governed more by winter and spring rainstorms on the western slopes of the Cascades.

The Multnomah Channel distributes from the Willamette River roughly three miles upstream of the Willamette-Columbia confluence, further complicating the hydrology of the site. This reach has modest tidal behavior, but during high river discharge the signal is muted or nonexistent. Higher winter flows can occur in either river from November into March. Due to its size relative to the Willamette River, the Columbia River tends to dominate surface water conditions in the Multnomah Channel both during the spring freshet and via tidal influence at lower water. Relevant benchmark water surface elevations for the Multnomah Channel are included in Table 4. Water levels in Table 4 were derived as follows.

- Tidal datums from St Helens, OR and Vancouver, WA were converted to NAVD 88 and interpolated by Columbia River mile to the project site (USGS, 2017).
- OHW was interpolated by river mile from the ERTG lower Columbia water level analysis (ERTG, 2013) for the 2-year flood along Multnomah Channel.
- The 1% exceedance elevation is the published FEMA base flood elevation at the project site (FEMA, 2017).

Table 4. Project specific water surface elevations.

Design Water Levels	Multnomah Channel at MCMNA (meters NAVD 88)	Multnomah Channel at MCMNA (ft NAVD 88)	Multnomah Channel at MCMNA (ft AMSL)
MTL (Mean Tide Level)	2.4	7.9	4.4
MHHW (Mean Higher High Water)	3.0	9.8	6.3
OHW = Q2 = 50% Exceedance Flood	5.9	18.2	15.9
Q100 = 1% Exceedance Flood	9.1	29.7	26.2

The MCMNA site is also influenced by drainage from the Tualatin Mountains to the west. Historic maps demonstrate that Crabapple Creek and other headwater streams once flowed in a Northeasterly direction through the North and South portions of the site before joining the Multnomah Channel. Subsequent alterations to the site by private landowners between 1860 and 1996 redirected the flow of these creeks through the South portion of the site, substantially altering the site's hydrology (Zonick, 2018). As previously mentioned, Metro has worked to restore Crabapple Creek to a more natural condition.

The magnitude, frequency, and duration of fluvial inputs to the site from the Tualatin Mountains can be estimated by regression of a suite of descriptive drainage parameters using StreamStats (USGS, 2020) as shown in Table 5.

Table 5. Crabapple Creek Hydrology (USGS, 2020).

Annual Chance Exceedance (ACE) Event	Return Period (years)	Flow in Crabapple Creek USGS StreamStats (CFS)
95% Continuous Exceedance Flow	-	0.08
50% Continuous Exceedance Flow	-	4
Spring Median (March-June)	-	7
5% Continuous Exceedance Flow	-	45
Half the 50% ACE event	-	96
50% ACE Event	2	192
20% ACE Event	5	289
10% ACE Event	10	354

Annual Chance Exceedance (ACE) Event	Return Period (years)	Flow in Crabapple Creek USGS StreamStats (CFS)
4% ACE Event	25	436
2% ACE Event	50	497
1% ACE Event	100	558
0.2% ACE Event	500	699

While the flows in Crabapple Creek are many orders of magnitude smaller than the flows in the Multnomah Channel, they are still important for function in the site. These fluvial inputs allow the development and maintenance of wetlands above the tidal range and can provide cool, oxygenated water to the site at certain times of year. Currently, habitat continuity across the railroad and Highway 30 in Crabapple creek is limited by culvert crossings:

- 5’ x 8’ x 245’ box culvert under Highway 30
- Overgrown, undersized double barrel culvert under the railroad

Immediately downstream of the crossings the stream is intermittently blocked by beaver activity as well.

To understand the influence of discrete local storm pulses on site hydrology, an unsteady hydrograph was developed for use in the hydraulic modeling exercise. There is no gage on Crabapple Creek, so a sample hydrograph was taken from a nearby gage in a similar watershed, Gales Creek (USGS Gage 14203750). That hydrograph was scaled to peak at half the 2-year flow predicted in crabapple creek (Table 5) and compressed in time so the volume of discharge approximately matched the expected runoff volume in Crabapple Creek using the 2-year 24-hour rainfall intensity and an NRCS Curve Number of 72.

HISTORICAL CONDITIONS

Positioned downstream of the confluence of the Willamette and Columbia Rivers, this reach has been particularly vulnerable to flooding from combined Columbia River Basin freshets and Willamette valley storms prior to completion of the substantial flood control capacity in the Willamette River basin during the mid- to late-20th century. Flooding from the atmospheric rivers (Colle and Mass, 2000) can influence this reach, including five floods of three meters above Willamette River flood stage since 1876, with the most recent in 1996. Prior to completion of flood-control dams in the 1960s, the annual spring freshet of the Columbia and Willamette Rivers would have inundated the MCMNA to a greater extent and more frequently. The levee breaches constructed by Metro in 2014 have improved the frequency of inundation in theory, but it appears the increase is not sufficient to provide frequent connections between the site and the Multnomah Channel.

CURRENT CONDITIONS

Between January and July (when the boards are typically installed in the WCS), the average South wetland water surface elevation (WSE) usually holds just below the levee breach elevation of 12.5 feet above mean sea level (16 ft / 4.9 m NAVD88), while the average North wetland WSE fluctuates more with the Multnomah Channel even when the WCS is closed (Figure 7). Both sides fill rapidly following winter storms as shown by the steep rise in late February of 2019 (Figure 7) which is associated with a rainfall event, not a rise in the Multnomah Channel, so it appears that closure of the North structure is insufficient for impoundment of water in the site. Also contributing to reduced flows into the North, are the effects of a large beaver dam just upslope of the central bridge, which has been diverting much of flow from Crabapple Creek away from the North basin and into the South basin, counteracting the effects of the 2008 hydrologic modification.

While the WCSs are left open site water levels fall off rapidly but are maintained above the sill elevations of the structures. This persistent modest flooding appears likely to be a function of existing beaver dams in the site.

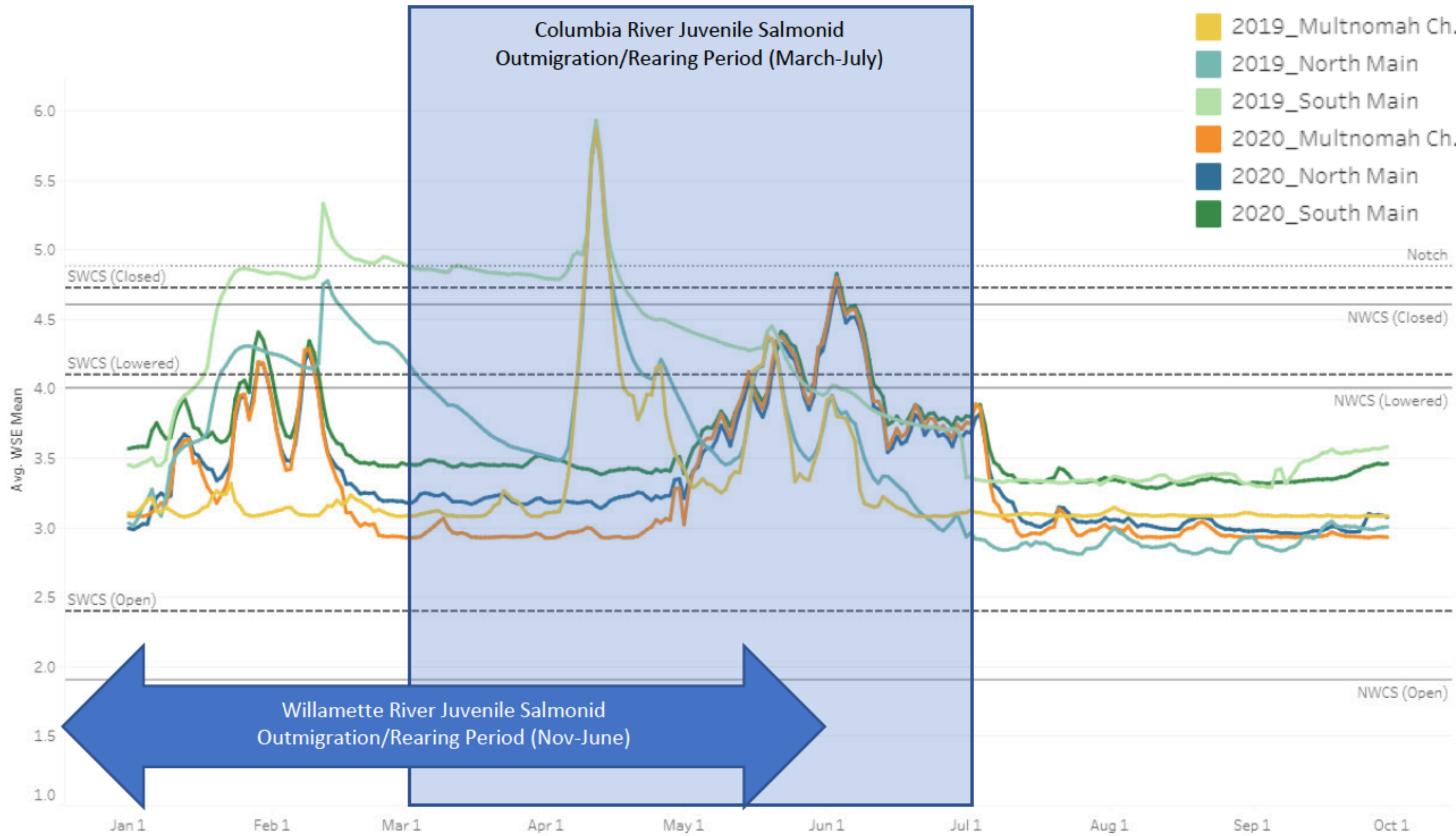

Figure 7. MCMNA Water levels 2019-2020.

In 2022 and 2023 the WCS gates were left open with the flashboards removed to examine more natural site hydrology. Additionally, a tree fell on the south WCS in the late summer/fall of 2022 and damaged it, rendering it inoperable. This highlights the question of how to prioritize/undertake maintenance of the structures if they were not removed in the context that they impair fish passage. The water level data from this period has not been formally analyzed but the site has visibly responded. Water levels are lower and the beavers on site are playing catchup to maintain the depth of their aquatic routes through the site by moving mud around and continuing to build and maintain dams. It is anticipated that beavers will increase dam building activity in the absence of the WCSs such that their preferred habitat at the site is maintained.

3.5 SUMMARY OF HYDRAULIC MODELING OR ANALYSES CONDUCTED AND OUTCOMES – IMPLICATIONS RELATIVE TO PROPOSED DESIGN.

3.5.1 MODEL DEVELOPMENT

A 2D HEC-RAS (version 6.3.1) model has been developed to evaluate the existing conditions and proposed design and to conduct a floodplain analysis. This modeling software uses a 2D mesh laid over a high-resolution terrain dataset to provide quality representation of the ground surface while remaining computationally robust and efficient. A 2D model was selected to better simulate the complex hydraulic interactions that occur between the MCMNA floodplain, the Multnomah Channel, and the influence of tributary inputs from Crabapple Creek. This allows for better evaluation of the impacts of project actions such as WCS removal and the installation of Beaver Dam Analogues (BDAs) on retention of tributary flood pulses and wetted area and depths during a typical low-water tidal fluctuation. The primary objective of the hydraulic analysis is to evaluate existing flow patterns, hydraulic parameters, and inundation extents to characterize current riverine conditions within the project reach. Establishing baseline hydraulic conditions enables quantitative comparison with the proposed condition modeling, representing restoration actions to be completed in future project phases. This comparison is critical to ensure that the design elements meet project goals without increasing risk to adjacent and downstream structures and properties.

Metro commissioned a LIDAR survey in the fall of 2019. This survey provided a high-resolution topographic surface for the existing and proposed model terrains. The LIDAR surface has been compared with supplemental topographic survey and found to be generally adequate for comparative hydraulic modeling. A supplemental survey was conducted by W2r in June 2023. Minor terrain modifications were made using HEC-RAS Mapper tools to lower the terrain downstream of the entrance road bridge to reflect surveyed elevations and to incorporate a large beaver dam upstream of the same bridge that was constructed after the LiDAR collection. Water Control Structures (WCSs) were included in the north and south sloughs using elevations from as-constructed plans provided by METRO, the current modeling assumes that these structures remain fully open representing present day operation of the WCSs.

It's important to note that the hydrology of the site is particularly complex and that many of the site actions target low flow conditions which are very sensitive to slight differences in the modeled terrain and the 2D mesh layout. Dense vegetation and pockets of water prevent accurate collection of LiDAR. LiDAR elevations were up to 1.5 feet higher than the surveyed. Additionally, the site is heavily modified in multiple areas, such as the Crabapple Creek alluvial fan by active beaver colonies. These sensitivities and uncertainties mean that the modeled results may vary from observed conditions and represent only one possible scenario. As such, these model results are intended to provide a basis of comparison between existing and proposed conditions to evaluate the potential uplift of restoration actions and should not be interpreted to be a guarantee of resulting habitat conditions.

Based on desired project outcomes, permitting needs, and to characterize typical site hydrology, several modeling scenarios were selected to evaluate the impacts of the proposed project actions and to select appropriate hydrualic design parameters. These model scenarios, and their related analyses are listed below in Table 8.

MODEL GEOMETRY

The model geometry consists of a 2D mesh overlain on a composite LiDAR surface created from the 2019 METRO LiDAR, 2014 METRO LiDAR, and Multnomah Channel Bathymetric Survey from 2010 (EP, 2010). The model extends from the Sauvie Island Bridge (RM 19.9) downstream to the Skyline Moorage & Marina (RM 14.4). The project site itself extends from RM 14.4 to RM16.5 (See Figure 8). This extended model domain is important to properly model the 1% ACE flood event due to the complex floodplain interactions occurring throughout this reach. The model geometry and roughness coverages are displayed in Figure 8 below. A range of cell sizes was used to limit complexity in areas beyond the project site and improve detail around key design elements and areas of concern. Within the project site a higher resolution mesh is created with a refinement region and break-lines to delineate high ground barriers and improve resolution along defined channels.

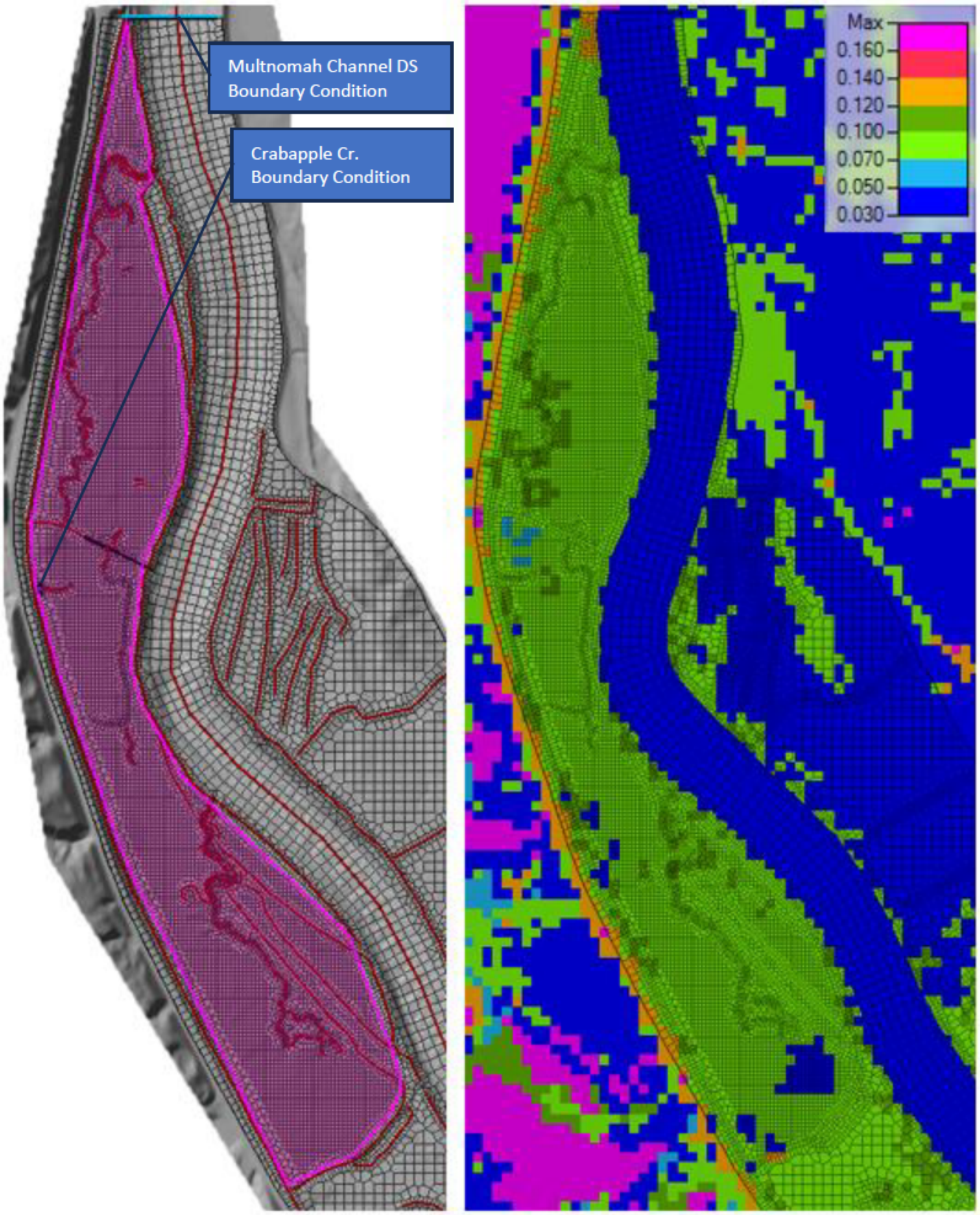

Figure 8. Cropped view of 2D mesh with break-lines and the MCMNA refinement region shown alongside the final Manning's n value raster. The Multnomah Channel upstream boundary condition is located at the Sauvie Island Bridge (not shown).

Manning's n values used in the model are spatially varied and assigned by landcover type in accordance with standard hydraulic reference manuals (Chow, 1959). Typically, Manning's n values decrease as the depth of flow increases; however, this model makes the simplifying assumption that the values are constant through all flow events. This assumption likely overestimates the Manning's n values during extreme flood events, providing a conservative estimate of flood extents. The assigned values are shown in Table 6.

Table 6. Manning's n Values Assigned to NLCD Raster and Design Elements.

NLCD Land use Classification / Design Element	Manning's n
Mixed Forest	0.16
Evergreen Forest	0.16
Shrub-Scrub	0.1
Deciduous Forest	0.16
Developed, Open Space	0.04
Developed, Low Intensity	0.08
Developed, Medium Intensity	0.12
Emergent Herbaceous Wetlands	0.07
Open Water	0.04
Cultivated Crops	0.04
Pasture-Hay	0.04
Grassland-Herbaceous	0.05
Woody Wetlands	0.1
Developed, High Intensity	0.16
Barren Land Rock-Sand-Clay	0.04
Slough (North & South) - Existing	0.05
Slough (North & South) – Proposed Continuous Log Complex	0.07
*Slough (North & South) – Proposed Continuous Log Complex w/ high n-value	0.16

**Value used for sensitivity analysis only*

The explicit simulation of culvert and bridge structures is limited to those on the project site. The hydraulic structures included in the model geometry as 2D Area Connections are:

- The Entrance Road Box Culvert/Bridge;
- North Slough Water Control Structure; and
- South Slough Water Control Structure.

Throughout the rest of the 2D area small breaches were added through roadway embankments and berms to allow flows to access areas shown as Zone AE in the FEMA National Flood Hazard Layer (NFHL).

The modifications to the model geometry made to simulate proposed design elements are summarized below in Table 7.

Table 7. Proposed Design Elements Incorporated in Model

Proposed Design Element	Modeling Method
Water Control Structure (WCS) Removal	Water controls structures are represented in the existing conditions terrain and incorporated as culverts. The RAS Mapper terrain modification tool was used to remove the berms and the culverts were deleted from the geometry to simulate the proposed design.
Marshplain Lowering, Wetland Habitat Enhancement, and Upland Habitat Enhancement	These areas identify grading activities. The proposed conditions surfaces were exported from the AutoCAD designs and incorporated into the terrain.
Beaver Dam Analogues (BDAs)	BDA structures were incorporated in the terrain using RAS Mapper terrain modification tools and set to elevations matching those shown in the Design Plans.
Continuous Log Complex	The continuous log structures are represented by increased Manning's n values within the north and south sloughs. As a sensitivity analysis to assess these structures' ability to improve storage retention two levels of roughness were applied and modeled.

MODEL BOUNDARY CONDITIONS

Boundary conditions for the hydrologic scenarios selected for modeling are summarized below in Table 8.

Table 8. Modeled Hydrologic Scenarios

Model Scenario	Boundary Conditions	Primary Analysis
Spring Tidal w/ Crabapple Creek Storm Pulse	**Multnomah Channel:** 24-hour spring tidal period with measured water level data from June 16th, 2019 in the Multnomah Channel adjacent to the nearby upstream Palensky Wildlife Area. WSE range of 8.59 to 11.54 feet NAVD88. **Crabapple Creek:** Unsteady half-Q2 hydrograph representing a spring rain event with flows ranging from 7 to 96 cfs.	• Identify flow distribution patterns from tributary input (Crabapple Cr.) • Determine effectiveness of roughening the sloughs with large wood to slow site draining following high-flow tributary inputs and high tides. • Determine the effects of WCS removal and BDA installation on overall wetted areas and storage. • Analyze slough hydraulics for large wood structures.

Model Scenario	Boundary Conditions	Primary Analysis
Spring Median w/ Crabapple Creek Storm Pulse	**<u>Multnomah Channel:</u>** Steady state elevations representing a median spring river level. Upstream elevation of 12.9 feet and downstream elevation of 12.4 feet simulating observed water surface gradients to drive flow. **<u>Crabapple Creek:</u>** Unsteady half-Q2 hydrograph representing a spring rain event with flows ranging from 7 to 96 cfs.	• Identify flow distribution patterns from tributary input (Crabapple Cr.). • Assess the effects of the lowered levee breaches near their threshold activation level. • Analyze slough hydraulics for large wood structures.
OHW (Q2)	**<u>Multnomah Channel:</u>** Steady state elevations representing a median spring river level. Upstream and downstream elevations for boundary conditions determined from ERTG 2013 to drive flow with known water surface gradient. **<u>Crabapple Creek:</u>** No contributing flow. Site hydrology is dominated by Multnomah Channel.	• Assess the impact of the lowered levee breaches during an ordinary-high-water event. • Analyze slough hydraulics for large wood structures.
Q100	**<u>Multnomah Channel:</u>** Steady state elevation representing FEMA Base Flood. Upstream steady state discharge of 112,000 CFS and downstream elevation of 29.6 ft NAVD88. **<u>Crabapple Creek:</u>** No contributing flow. Site hydrology is dominated by Multnomah Channel.	• Modeled to satisfy "No-Rise" condition for floodplain development permit. • Analyze slough hydraulics for large wood structures.

3.5.2 MODEL RESULTS

The key takeaways from the model results as they pertain to each design element are summarized in the following sub-sections. Figures showing inundated area under existing and proposed conditions are included in Appendix D.

WCS REMOVAL

The removal of the water control structures was not shown to significantly impact drainage patterns from either slough, compared with present day operation (structures left fully open). The results of the unsteady spring tidal simulation, which also contains a moderate flood pulse from Crabapple Creek, showed how timing and magnitude of flow in the North Slough was affected, with the tidal influx at peak tide increasing by an average of 5.1 cfs (10%) during peak tide.

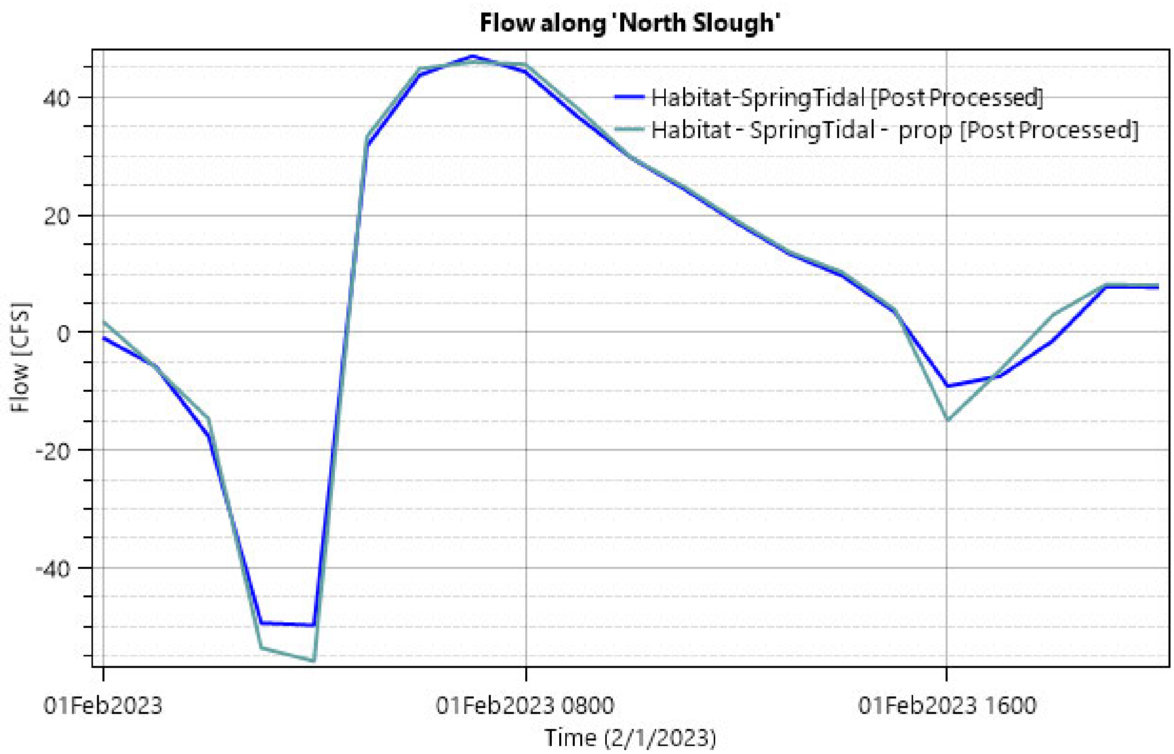

Figure 9. Existing versus proposed flow rates at the mouth of the North Slough. The negative values represent influx and positive represent efflux from the site.

Conditions in South Slough showed a greater change in flow rates. The proposed conditions show slight decreases during periods of both influx and efflux. This reduction is likely attributable to the BDAs in the terrain reducing the cross-sectional area of the slough by raising the bed. While the BDAs beneficially retain interior site water levels, they may reduce tidal mixing between the wetlands, slough, and Multnomah channel during periods of low water when the site hydrology is driven by tidal fluctuation. The assumption that the BDAs are impermeable should be considered in interpretation of these results as it exaggerates both the retention of water and the reduction of tidal mixing. There will, however, likely be variability in permeability of BDAs over the site profile.

- Higher in the site (~ elevations 10 and up) the BDAs will support more active vegetation growth of the willows included in construction as well as RCG. This active vegetation growth is likely to make the higher BDAs less permeable over time which will tend to support retention of water in the broader wetland areas as is observed in the model.
- Lower in the site, (~elevations 9 and below) robust woody veg/willows and RCG will be hydrologically suppressed, and higher hydraulic energy is available to clean out, flank, and scour the BDAs which will tend to retain the permeability of those structures. The processes informing the

long-term permeability of BDAS lower in the landscape indicate that they are less likely to prevent mixing and have the detrimental effect on water quality suggested by the model results.

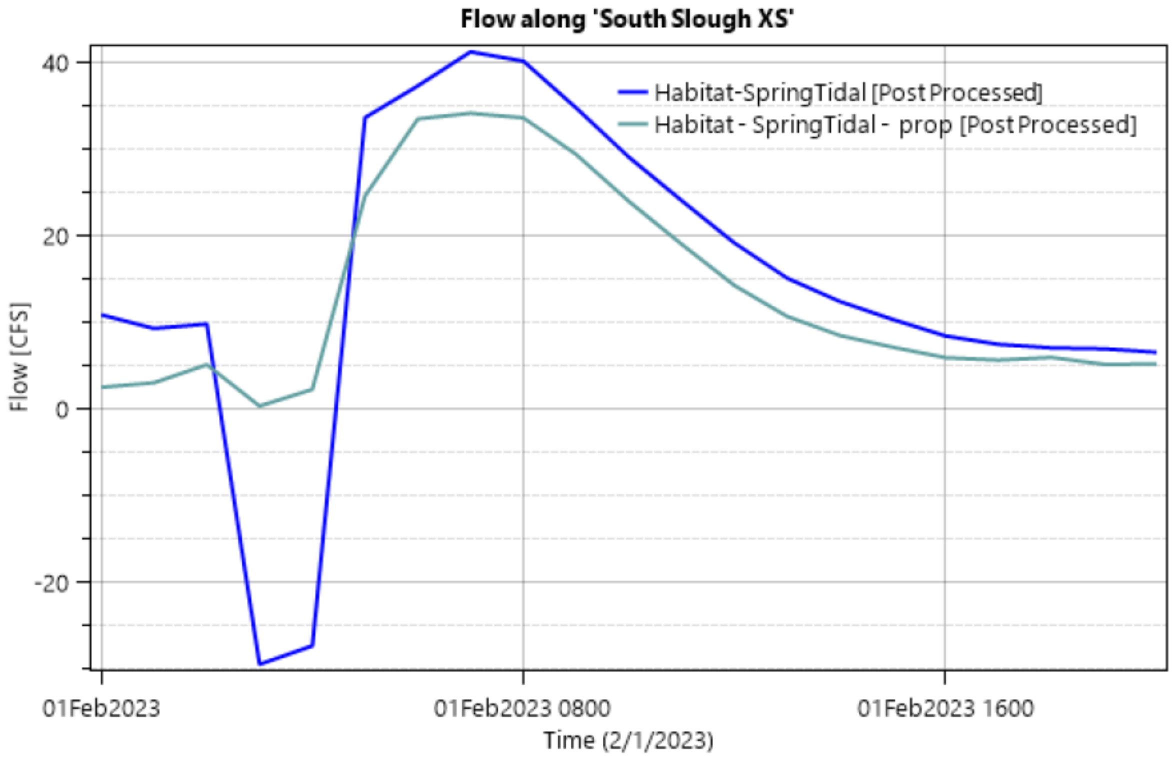

Figure 10. Existing versus proposed flow rates at the mouth of the South Slough. The negative values represent influx and positive represent efflux from the site.

MARSHPLAIN GRADING

The Marshplain Grading in combination with BDA installations shows an expansion in wetted area up to the 2-year flood. The most meaningful increases are seen at low water levels, particularly with typical spring tributary inputs. Under this condition there was a 9 acre increase in wetted area. This increase is simply the increase in wetted area and includes very shallow wetted areas newly retained upslope of some of the fills, the actual increase in quality salmonid habitat at this flow is likely represented better by the MPL area for the project (4.2 acres). At these low flows the BDAs have a significant effect on storage volumes and wetted area. A summary of the simulated changes to wetted area under proposed conditions is shown below in Table 9.

Table 9. Modeled expansion of wetted area under proposed conditions.

	Spring Tidal (low-tide)	Spring Tidal (high-tide)	Spring Median	50% ACE (2-year)	1% ACE (100-year)
Existing Wetted Area (Acres)	26.7	40.5	76.5	234.0	288.2
Proposed Wetted Area (Acres)	35.7	49.4	76.6	234.1	287.5

	Spring Tidal (low-tide)	Spring Tidal (high-tide)	Spring Median	50% ACE (2-year)	1% ACE (100-year)
Change (Acres)	+9.0	+8.9	+0.1	+0.1	-0.7

With a low backwater (~8.6 feet NAVD88) the depths in the marshplain lowering areas range between approximately 1.5 feet and 2 feet.

A slight reduction in wetted area during the modeled 1% ACE event is caused by the Upland Habitat Enhancement Area located adjacent to the entrance road. This reduction is located on the floodplain fringe far from the floodway boundary and does not result in any reduction of cross-sectional conveyance or a rise in the BFE. A cross-section displaying the existing versus proposed terrains and water surface elevations is shown below in Figure 11.

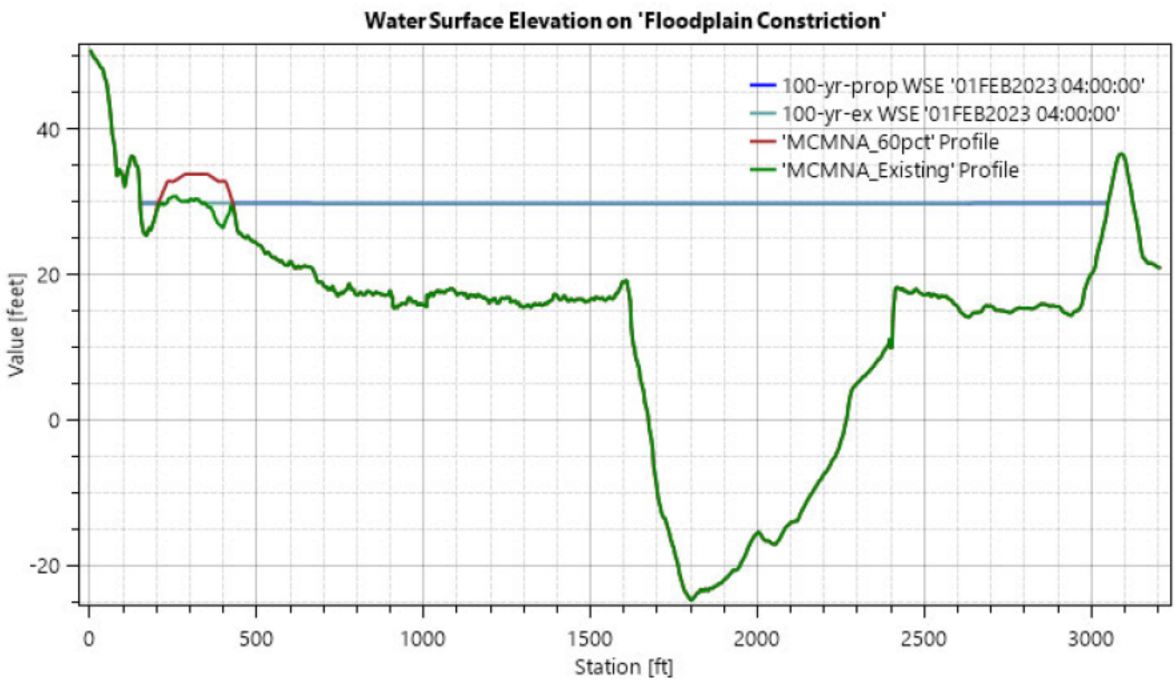

Figure 11. Cross-section of 1% ACE water surface elevations and terrain at the location of the Upland Habitat Enhancement fill placement.

BDAS

In combination with marshplain grading, the modeling suggests that well-constructed BDAs are an important action that would significantly benefit site hydrology. The benefit of these structures is highly dependent on their initial construction and permeability, as well as their continued maintenance and/or whether beaver move into the reaches, taking over maintenance of some of these structures and constructing their own dams. The potential benefits to storage from these structures is shown below in Figure 12.

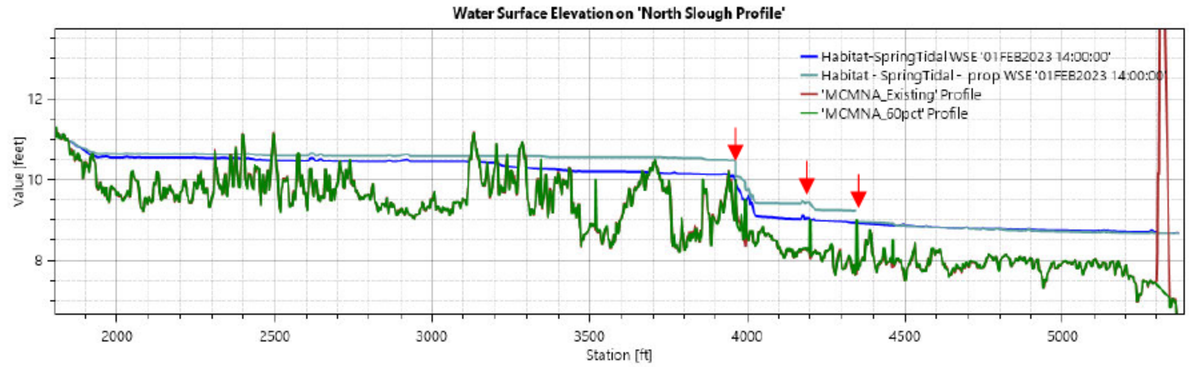

Figure 12. Modeled profile of the North Slough with BDAs at low-tide. The existing conditions WSE is shown in dark blue and the proposed condition in light blue. Red arrows identify BDA locations.

The modeled condition assumes that the BDAs are impermeable and as such shows the maximum potential benefit they may provide, but also a condition which may develop naturally if beaver colonization continues to expand throughout the site. Due to the temporary nature of BDAs, it is important that these structures be implemented alongside extensive riparian planting and invasive species management efforts to create conditions that are attractive for beaver colonization.

LEVEE BREACH LOWERING

The levee breaches were assessed based on flow delivered to the site under the median spring condition and the 50% ACE event. These lowered breaches are activated as water surface elevations reach approximately 12.0 feet NAVD88, which is slightly less than the median spring water level in the Multnomah channel. These changes in flow rates are summarized in Table 10 and Table 11.

Table 10. North levee breach influx rates.

Site Condition	Spring Median	50% ACE (2-year)
Existing	0.0 cfs	331.4 cfs
Proposed	3.9 cfs	694.4 cfs
Change	**+3.9 cfs**	**+363 cfs (+109%)**

Table 11. South levee breach influx rates.

Site Condition	Spring Median	50% ACE (2-year)
Existing	0.0	131.2 cfs
Proposed	0.1 cfs	153.2 cfs
Change	**+0.1 cfs**	**+ 22 cfs (+14%)**

The results showed the north levee breach to be the more impactful of the two. Under existing conditions there is little tributary input to the wetland complex north of the entrance road. Simulation of the median spring condition (no tide) shows that the existing spring base flow through North Slough is 2.6 cfs, the proposed condition with the additional connection to the Multnomah Channel more than doubles this to 6.3 cfs during the Spring Median scenario. This suggests that during much of the spring season this connection will significantly improve inflows and mixing in the north wetland complex, potentially improving water quality.

The activation of the south levee breach was not found to be significant during the same Spring Median scenario. This levee breach will provide benefits more tightly tied with the Columbia River freshet.

Neither levee breach is expected to increase risk of erosion or significantly alter flow patterns in the north or south wetland complexes. Despite the large increase in flow influx during the 50% ACE event, peak velocities in North Slough increase only from 0.45 to 0.51 feet per second. Additionally, there does not appear to be any risk of the north breach changing the outlet location of Crabapple Creek.

WOOD HABITAT STRUCTURES

To assess the potential for continuous log complexes to improve storage during low water tidal periods and of pulses from tributary inputs a sensitivity analysis was performed with two levels of roughness used to represent the log complexes to simulate a “typical-roughness” (value of 0.07) and “high-roughness” (value of 0.16) conditions. By comparing these roughness conditions, we can estimate whether it’s reasonable to expect the log complexes to have any meaningful effects on site hydrology.

The change in roughness was not found to have any effect on the periodicity of flow through either slough or on the water surface elevation. This is due to the already very low velocities and the location of complexes below series of BDAs. This modeling approach does not explicitly simulate the loss of conveyance and increase in low flow sinuosity in the slough that would result from the wood placement and cannot fully capture the resulting hydraulic effects.

While the modeling does not indicate that these complexes provide benefits to broader site hydrology, they do provide important aquatic habitat in the form of structure and cover for rearing juvenile fish in a location where they can benefit from the cooler and more oxygenated waters of the mainstem Multnomah Channel while remaining in close proximity to the productive wetland habitats within the MCMNA for foraging during high tides.

VELOCITY ANALYSIS

Existing and proposed conditions peak velocities from the modeling exercise are summarized below in Table 12.

Table 12. Simulated velocity summary

Location	Hydrologic Condition	EC Peak Velocity (ft/s)	PC Peak Velocity (ft/s)	Notes
North Slough	Q100	1.8	2.2	Inside WCS, Approx Sta. 108+00
	Q2	0.6	0.6	Inside WCS, Approx Sta. 108+00
	Spring Median	0.5	0.3	Inside WCS, Approx Sta. 108+00
	Spring Tidal	2.6	2.6	Inside WCS, Approx Sta. 108+00
North Breach	Q100	1.0	1.0	Near riverside inlet
	Q2	1.3	1.2	Near riverside inlet

	Spring Median	0.0	0.15	
	Spring Tidal	0.0	0.3	
South Slough	Q100	1.7	2.2	Outside of WCS, Sta. 1+00
	Q2	0.7	0.1	Inside of WCS, Sta. 11+00
	Spring Median	0.7	0.7	Inside of WCS, Sta.12+00
	Spring Tidal	2.3	2.4	Inside of WCS, Approx Sta. 12+00
South Breach	Q100	1.3	1.7	Near riverside inlet
	Q2	0.6	0.9	Near riverside inlet
	Spring Median	0.0	0.4	Near riverside inlet
	Spring Tidal	0.0	0.2	Mid-breach

Velocities in the site are generally quite low. For conservatism in the wood structure design, the largest observed representative velocity (2.6 ft/s) was used for the force balances.

3.5.3 FLOOD RISK ASSESSMENT

As identified by the Multnomah County Flood Insurance Rate Maps (FIRMs), the project area lies within Special Flood Hazard Area (SFHA) Zone AE, which describes areas that are subject to inundation by the 1% annual chance flood and have a determined BFE. Base flood Elevations on the site range from approximately 29.6 to 30 feet (NAVD88). With the exception of the south levee breach, the project actions do not extend into the Multnomah Channel Floodway.

The project's location within a Zone AE flood hazard area requires hydraulic modeling of the existing and proposed conditions to determine that the project will cause no rise in water surface elevations during the 1% annual chance exceedance flood event. A formal No-Rise is required due to the proposed south levee breaches location within the regulatory floodway. This modeling is summarized in the "No-Rise" Technical Memorandum (Appendix H).

3.6 STABILITY ANALYSES AND COMPUTATIONS FOR PROJECT ELEMENTS, AND COMPREHENSIVE PROJECT PLAN.

3.6.1 WOOD HABITAT STRUCTURES

The wood structures are designed using a force balance factor of safety (FOS) analysis, calculations for which are presented in appendix F. Log jam stability calculations verify the wood habitat structures designed for this project will remain stable to an appropriate safety factor when exposed to buoyant, shearing, and rotating hydraulic forces. These calculations verify that the embedment lengths/depths and associated ballast forces are sufficient to restrain the log structures from moving under the selected design conditions. Methodology for the buoyancy calculations is based on a standard force balance approach and information adapted from the U.S. Bureau of Reclamation (USBR) National Large Wood Manual (USBR and ERDC, 2016).

The USBR's risk-based design guidelines recommend using design hydraulics and factors of safety that are commensurate with the public safety and property damage risks associated with a project (Table 13). Both public safety risk and property damage risk are minimal for this project. These risk factors are often formally assessed using the Bureau of Reclamations risk-based design guidelines for large woody material (BOR, 2014). However, the overall risk in the case of this project is very low and does not warrant the level of detail included in that approach as there is no public access to the site, and if wood were to mobilize from a structure it would either rack into an existing or constructed structure further down the slough, or move into Multnomah Channel, below which there are no bridge openings small enough to rack the designed wood members.

Table 13. Recommended Stability Design Criteria for Hydrology and Factors of Safety (USBR and ERDC, 2016)

Public Safety Risk	Property Damage Risk	Stability Design Flow Criteria	$FOS_{sliding}$	$FOS_{bouyancy}$	$FOS_{rotation}$ $FOS_{overturning}$
High	High	100-year	1.75	2.0	1.75
High	Moderate	50-year	1.5	1.75	1.5
High	Low	25-year	1.5	1.75	1.5
Low	High	100-year	1.75	2.0	1.75
Low	Moderate	25-year	1.5	1.75	1.5
Low	Low	10=year	1.25	1.5	1.25

A simplified, conservative approach is taken for wood structure analysis. Instead of analyzing the entirety of large structures individually and in the context of the hydraulics that occur at the design location of that structure, a group of weakest link elements is identified among the design members and those are designed to withstand the maximum hydraulic forces observed in the region where structures are implemented. Three groups of logs were selected to represent the wood structures for this project:

- Single keyed log,
- An unembedded log secured by four pier logs, and
- A basking log (partially embedded and secured by two pier members).

These groups of logs constitute the least secured groups that occur in the design, so finding that they are stable under anticipated hydraulic conditions indicates stability for all the structures in the design. Factors of safety for each of the groups selected for analysis are presented in Table 14.

Table 14. Wood Habitat Structure Factor of Safety (FOS) Summary

Analysis Group	FOS Buoyancy	FOS Sliding	FOS Rotation	FOS Overturning
Single Keyed Log	2.29	34.07	14.84	NA
Unembedded log with 4 piers	2.46	22.12	8.75	NA
Basking Log	1.77	NA	NA	NA

3.6.2 BRIDGES

A need for bridges in place of the water control structures to maintain site access has not been identified by project stakeholders so no bridges are planned for construction as part of this project. METRO coordinated with PGE and a direct need for PGE to be able to drive over the slough in the WCS locations was not reported.

3.7 DESCRIPTION OF HOW PRECEDING TECHNICAL ANALYSIS HAS BEEN INCORPORATED INTO AND INTEGRATED WITH THE CONSTRUCTION – CONTRACT DOCUMENTATION.

Subsections in section 3 of this document include technical analyses associated with the project reach. Data collection of in situ site information included: topographical survey, hydrology analysis, hydraulic modeling, and stability analysis. The collection of survey data combined with LiDAR provides base map information for the existing terrain utilized for the proposed design and hydraulic modeling.

Hydrologic analysis provides the design team with expected hydrologic patterns for the MCMNA project site including the Columbia River tidal datum analysis, Columbia River flood analysis, Peak and typical discharges for the input tributaries. Expected annual and bank full discharge flows as well as flood events aid design of channel and floodplain design, large wood stability analysis, and flood risk evaluation.

Hydraulic modeling informs channel and floodplain design with velocities, shear, and water surface elevations, critical to optimize flow spreading and floodplain connectivity while minimizing additional flood risks to adjacent property and infrastructure.

3.8 FOR PROJECTS THAT ADDRESS PROFILE DISCONTINUITIES (GRADE STABILIZATION, SMALL DAM AND STRUCTURE REMOVALS): A LONGITUDINAL PROFILE OF THE STREAM CHANNEL THALWEG FOR 20 CHANNEL WIDTHS UPSTREAM AND DOWNSTREAM OF THE STRUCTURE SHALL BE USED TO DETERMINE THE POTENTIAL FOR CHANNEL DEGRADATION.

Profiles of the sloughs include 20 channel widths distance upstream of the WCS; downstream distances may be shorter due to proximity to confluence with the Multnomah Channel. The slopes are very flat (~0.1% in both the North and South sloughs) and while there is some buildup of material that forms a grade break across the North structure (~0.5 to 1.0 ft high) mobilization of this material would simply increase the frequency of inundation for the aquatic habitat in that portion of the site. Due to the low slopes the potential for channel degradation to propagate into the interior of the site is low.

3.9 FOR PROJECTS THAT ADDRESS PROFILE DISCONTINUITIES (GRADE STABILIZATION, SMALL DAM AND STRUCTURE REMOVALS): A MINIMUM OF THREE CROSS-SECTIONS (ONE DOWNSTREAM OF THE STRUCTURE, ONE THROUGH THE RESERVOIR AREA UPSTREAM OF THE STRUCTURE, AND ONE UPSTREAM OF THE RESERVOIR AREA OUTSIDE OF THE INFLUENCE OF THE STRUCTURE) TO CHARACTERIZE THE CHANNEL MORPHOLOGY AND QUANTIFY THE STORED SEDIMENT.

The contributing upstream watershed does not supply course sediment to the lower sloughs in the site and the landforms are similar upstream and downstream indicating limited sediment storage by the WCS's.

3.10 CARBON DIOXIDE EMISSIONS

A preliminary estimate was made of carbon emissions that would result from construction. This estimate was based primarily on the carbon emissions associated with the most carbon intensive project activities. Emissions were estimated for the earthwork and installation of the proposed habitat features along with a contingency factor intended to account for other externalities associated with the project.

Table 15. Summary of major carbon dioxide emissions sources during construction. All units are in metric tons of emitted CO_2.

Emissions Source	**CO_2 Emissions (TN)**	**Notes**
Earthwork	45	Includes all excavation activity on an in bank CY basis
Habitat Features	30	Import of large wood and construction of habitat features
WCS and Concrete Pad Removal	5	Machine time for demo and onsite handling of reused rock and concrete materials
Contingency (50%)	39	Contingency to account for embedded carbon in erosion control materials, electricity used during design and construction, mobilization/demobilization of equipment, etc.
Total	118	

These values account separately for:

- Permanent excavation of the marshplain lowering and breach grading includes hauling, finish grading, and compaction of this material in fill areas.
- Import of large wood materials and machine time for installation of large wood habitat structures throughout the project site.
- Machine time for demolition of both water control structures and the concrete pad at the site entrance, as well as machine time for haul WCS demo material and construction of the hibernacula.
- Contingency to incorporate externalities (emissions associated with the project across a range of activities and materials not otherwise accounted for).

The project design is intended to limit carbon emissions in a few specific ways. Demolished concrete materials will be reused on site to construct hibernacula or buried in fill placement areas (after being broken up to prevent detrimental effects on revegetation). To the extent possible, excavation areas are paired with fill placement areas that are balanced on a volume basis to limit haul distance.

Wetland and upland revegetation efforts at the site are also expected to sequester significant atmospheric carbon as accumulated biomass. Future revisions to this analysis will include assessment of time required for site revegetation efforts to recapture the carbon emitted during construction.

4.0 CONSTRUCTION – CONTRACT DOCUMENTATION

4.1 INCORPORATION OF HIP IV GENERAL AND CONSTRUCTION CONSERVATION MEASURES

The MCMNA project will be implemented using the HIP IV general and construction conservation measures for erosion and sediment control, work area isolation and fish salvage, turbidity monitoring, and revegetation. Erosion and sediment control measures will follow the Best Management Practice (BMPs) per the Oregon Department of Environmental Quality (DEQ) 1200-C Construction Stormwater Permit. Construction of project elements below OHW will be carried out during the summer in-water work window for Multnomah Channel, July 1st through October 31st, (ODFW, 2008). In-water work will comply with NMFS guidelines for work isolation and fish salvage. Necessary temporary stream crossings will use whole, untreated logs and steel plates. No treated wood will be used for temporary stream crossings.

Existing access roads will be utilized to the greatest extent possible to minimize impacts to vegetation. Temporary access roads will be necessary to reach portions of the site, but these roads will not be thoroughly cleared, grubbed, or developed. There will be impacts to vegetation during construction; however, impacts to existing trees and vegetation will be minimized to the maximum extent practicable and all access routes will be restored to pre-construction conditions after construction is completed.

HIP Construction Conservation Measures are included in the design drawings in Appendix D.

4.2 DESIGN – CONSTRUCTION PLAN SET INCLUDING BUT NOT LIMITED TO PLAN, PROFILE, SECTION AND DETAIL SHEETS THAT IDENTIFY ALL PROJECT ELEMENTS AND CONSTRUCTION ACTIVITIES OF SUFFICIENT DETAIL TO GOVERN COMPETENT EXECUTION OF PROJECT BIDDING AND IMPLEMENTATION.

- The design plan set, including plan, profile, sections, and detail sheets for the design elements has been included in Appendix D.

4.2.1 70% DESIGN

- **Water Control Structure (WCS) Removal** *(Category 1a)* **–** Both water control structures (North and South) will be removed. To limit cost and carbon emissions, large rock and chunks of concrete will be reused for construction of loose stable piles that will serve as hibernacula for reptiles and small mammals. Separable metals will be disposed of off-site. Removal of the WCS will improve fish access to the site throughout the year (given sufficient water quantity and quality) and improve water quality in the flooded portions of the Marsh (especially in the tidal range).
- **Lower Levee Breach Notches** *(Category 2a)* **–** The existing breaches will be lowered from approximately 16 feet NAVD88 to approximately 12 feet NAVD88 to improve freshet connection. These lowered notches mimic the effect of a crevasse splay breaching a natural levee and increasing the frequency and duration of backswamp flooding. This in turn improves salmonid access during the freshet and enhances water quality in the site.

  The breach connection elevations were selected to maximize connection frequency by using the minimum adjacent interior elevation. Preliminary water level analysis of WSE data collected from April 2016 through December 2018 indicates that this will result in surface water connection from Multnomah Channel approximately 30% of the time during the observed period, compared with approximately 13% of the time under the existing breach configuration. This connection elevation is higher than the measured lidar surface for the current primary flow path for Crabapple Creek, and model output indicates that low flows in Crabapple Creek will not re-route to drain through the breaches.

- **Construct Low Water Access Fords** *(Category 1h)* – An 8-foot-wide hardened travel lane will be constructed in each of the levee breaches using an 18-inch-thick layer of compacted 3-inch round rock. This placement will maintain accessibility for maintenance along the existing power lines without compromising restoration outcomes at the site.

- **Marshplain Lowering and Strategic Fill Placement** *(Category 2a)* **–** There will be approximately 4.3 acres of marshplain lowering in select areas to hydrologically suppress RCG and expand wetland areas available for amphibian breeding and juvenile salmonid rearing throughout the year. The material generated by this excavation will be strategically placed over approximately 4.1 acres of lowland to raise other portions of the landscape above the optimal RCG growing elevation band and improve opportunities for bottomland forest expansion. Where possible, cut and fill are balanced in close proximity to minimize haul distances. Fill is preferentially sited to fall on the southerly aspect of existing or proposed wetlands to provide shade and improve water quality. Excess fill will be placed in uplands as indicated on the plans in Appendix C.

  Marshplain lowering elevations are selected based on location specific hydrology. The excavations immediately adjacent to the lower Sloughs in the North and South are targeted to lower the ground surface into the tidal range with finish grade elevations at or slightly below 8.5 feet NAVD88. This target is consistent with successful marshplain lowering projects in the vicinity of MCMNA. Excavation areas that are further up the gradient of crabapple creek or supported by the observed groundwater table (site observation) are targeted between elevation 9.5 and 13.5 ft NAVD88 for reliable conversion to emergent marsh based on observed conditions adjacent to the MPL areas. Design targets are based on reference sites and literature summarized below in Table 16.

Table 16. Wetland elevation reference table

Location	Target Wetland Elevation (ft NAVD88)	Multnomah Channel RM	Year Constructed	Notes
Ruby Lake Restoration	7 to 7.5	2.8	2013	Targeted nearby reference wetland conditions. Challenging working conditions due to wet material and early fall rains Performing Well
Flight's End Restoration	7.5 to 8	6.7	2017	Expanded reference wetland conditions. Performing Well
Palensky Restoration	10.5 to 11 (and up)	17.5	2021	Expanded reference wetland conditions. Performing Well.
LCRE Zone 4	7.2 to 12.1	NA	NA	Emergent wetland elevation band per Borde et al, 2012. Should be constrained to ~8.5 or below to limit opportunity for RCG colonization.

- **Connective MPL** *(Category 2a)* **–** In addition to enhancing wetland characteristics in place, earthwork is targeted along five alignments to improve connectivity from the Multnomah Channel to a relict slough along the northwest portion of the site via the north distributary of crabapple creek. The connection elevations are selected to tie into the bottom of the existing sloughs at either end. Two of these alignments breach a high embankment and substantially improve connectivity between the floodplain and lower slough.

- **Wood Habitat Structures** *(Category 2d)* **–** Large wood will be added in continuous log complex structures to roughen the North and South sloughs around the removed WCS to provide complexity and cover for aquatic species and anchor points for beaver dam establishment.

  Discrete habitat log placements are intended to add complexity and cover in newly excavated areas and opportunistically in the main sloughs where grading is performed adjacent to them. Significant wood loading is designed for opportunistic placement in the lower portions of the tidal sloughs. Wood habitat structures will be installed using large number of keyed logs and pier logs along with significant slash and channel margin live stake plantings. These structures do not contain continuously channel spanning grade control elements and are permeable to fish while providing a high density of anchor points for beaver to establish numerous low dams in the slough.

  Previous versions of the design included much higher wood loading in the slough which was intended to help limit drainage in the wetlands due to roughness and opportunity for beaver dam construction. This design intent does not bear out in the model as noted, and water retention function was not observed in recently available water level data from the nearby Palensky site. While that may be reversed in time as beavers continue to operate in the Palensky slough it is not a strong indicator that the expense of a high density of these structures is justified so the quantity of wood placement has been significantly reduced for this design.

- **BDA Structures** *(Category 2d)* **–** BDAs are included in the design but will not be included in the main construction contract. As shown by the modeling, the BDAs do increase the wetted area, depths, and inundation of the site, but they will be field fit as needed for adaptive management of the site. They may be placed in the approximate locations indicated throughout the primary conveyance channels to enhance and extend seasonal ponding, supplementing the many existing natural beaver dams throughout the site. These structures will be constructed with hand tools to limit site disturbance but will require (and be eligible for) an expedited fish passage approval from ODFW (ODFW, 2023).

  Structures are designed in keeping with the guidelines documented in the Low-Tech Process-Based Restoration of Riverscapes Design Manual (Wheaton et al, 2019). BDAs in the sloughs will slow flows and mediate sediment transport by both retaining sediments at times and initiating bank erosion at others. On site beaver populations will be relied upon to maintain (or not maintain) individual

4.3 LIST OF ALL PROPOSED PROJECT MATERIALS AND QUANTITIES.

Material quantities for excavation are estimated in units of bank cubic yards (calculated in place prior to removal). Material quantities for excavation are estimated in units of bank cubic yards (calculated in place prior to removal). This quantity does not include increases in volume due to “swell” and “loose” factors that are important to contractors when estimating haul and other costs. It is often preferred by contractors for excavation quantities to be specified on a bank cubic yard basis to eliminate discrepancies between the engineers and contractor estimates of the swell and loose factors. Volumes of planned site excavation are included as unit quantities in Table 18.

The total number of logs and the log length/DBH are summarized in below:

Table 17. Wood Habitat Structure Summary Table.

Log Piece	Min Diameter (in)	Min Length (ft)	Quantity per structure			Number of structures			Log Piece Total
			CLC	*Hab Log*	*Basking Log*	*CLC*	*Hab Log*	*Basking Log*	
Large Log with Rootwad	18	40	5	1	0				45
Small Log With Rootwad	10	20	9	0	0				36
Large Log Without Rootwad	18	40	4	0	1	4	25	15	31
Small Log Without Rootwad	10	20	15	0	0				60
Pier Log	10	20	14	0	2				86
		Log Pieces Per Structure	47	1	3	Total Logs			258

The estimate of probable cost shown in Table 18. This table does not include estimated project costs for permitting design, monitoring, and/or ongoing maintenance. Estimated costs are presented in 2026 dollars and would need to be adjusted to account for price escalation for implementation in future years.

Note that the actual cost of construction may be impacted by the availability of construction equipment and crews and fluctuation of supply prices at the time the work is bid. W2r makes no warranty, expressed or implied, as to the accuracy of such opinions as compared to bids or actual costs.

Primary assumptions of the cost estimate include:

- Unit costs – include contractor markup, profit, and overhead.
- Mobilization/demobilization – Assumed to be 12% of all other fixed costs.
- Temporary Erosion & Sediment Control (TESC) & Water Management – Each assumed to be 1% of all other fixed costs each.
- Logs for the Wood Habitat Structures (WHS) are procured, hauled and installed as part of the construction contract.
- Levee notch and marshplain lowering excavation – excavation costs assume low pressure excavator, bulldozer, and dump truck equipment.
- On-site Disposal – the cost estimate assumes that natural material excavated from the levee and marshplain lowering and swales will be placed as fill in designated areas on site.
- Fuel escalation – prices for excavation have been escalated compared with previous estimates to account for significant escalation of excavation observed in recent bids. These escalations are likely due to fuel price volatility which will continue to be a significant source of uncertainty in the future.
- WCS demolition – the cost estimate assumes that all metal will be removed and disposed of offsite by the contractor, but that concrete and rock will be placed on site as specified.
- Contingencies – 20% construction contingency is included in the total bid estimate to account for future design changes and unforeseen conditions.

Table 18 Estimated Construction Cost based on the 70% design.

ITEM NO.	Item	SPEC. #	Costs Qty	Unit	Unit Cost	Total	Notes
	SITE PREPARATION						
1	MOBILIZATION	00210	1	LS	[redacted]	[redacted]	12% OF ALL OTHER DIRECT COSTS ROUNDED UP
2	EROSION CONTROL	00280	1	LS	[redacted]	[redacted]	1% OF ALL OTHER DIRECT COSTS ROUNDED UP
3	WORK ISOLATION & WATER MANAGEMENT	00245	1	LS	[redacted]	[redacted]	1% OF ALL OTHER DIRECT COSTS ROUNDED UP
4	CLEARING AND GRUBBING	00320	14	AC	[redacted]	[redacted]	DISPERSED/IRREGULAR SHAPE, SOME HEAVILY WOODED
	EARTHWORK				[redacted]	[redacted]	
5	EXCAVATION - N1	00330	1,680	CY	[redacted]	[redacted]	INCL EXCAVATION, HAUL, FINISH GRADING
6	EXCAVATION - N2	00330	1,130	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
7	EXCAVATION - N3	00330	1,060	CY	[redacted]	[redacted]	INCL EXCAVATION, HAUL, FINISH GRADING
8	EXCAVATION - N4	00330	1,090	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
9	EXCAVATION - N5	00330	790	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
10	EXCAVATION - N6	00330	790	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
11	EXCAVATION - NORTH LEVEE BREACH	00330	970	CY	[redacted]	[redacted]	INCL EXCAVATION, HAUL, FINISH GRADING
12	EXCAVATION - NORTH BEAVER DAM BREACH	00330	250	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
13	EXCAVATION - S1	00330	1,730	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
14	EXCAVATION - S2	00330	840	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
15	EXCAVATION - S3	00330	2,060	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
16	EXCAVATION - S4	00330	1,560	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
17	EXCAVATION - SOUTH LEVEE BREACH	00330	930	CY	[redacted]	[redacted]	INCL EXCAVATION, LOCAL HANDLING, FINISH GRADING
18	REMOVAL OF STRUCTURES AND OBSTRUCTIONS	00310	1	LS	[redacted]	[redacted]	INCL. REMOVAL OF 2 WCS, 50x100 FT CONCRETE PAD
19	LOW WATER ACCESS	00250	2	EA	[redacted]	[redacted]	
	HABITAT FEATURES				[redacted]	[redacted]	
20	LARGE LOG WITH ROOTWAD	01042	45	EA	[redacted]	[redacted]	INCL FURNISHING MATERIAL ONLY
21	SMALL LOG WITH ROOTWAD	01042	36	EA	[redacted]	[redacted]	INCL FURNISHING MATERIAL ONLY
22	LARGE LOG WITHOUT ROOTWAD	01042	31	EA	[redacted]	[redacted]	INCL FURNISHING MATERIAL ONLY
23	SMALL LOG WITHOUT ROOTWAD	01042	60	EA	[redacted]	[redacted]	INCL FURNISHING MATERIAL ONLY
24	PIER LOG	01042	86	EA	[redacted]	[redacted]	
25	WHS TYPE 1 - HABITAT LOG	01042	25	EA	[redacted]	[redacted]	INCL CONSTRUCTION OF HABITAT LOG AS SPECIFIED
27	WHS TYPE 2 - CONTINUOUS LOG COMPLEX	01042	4	EA	[redacted]	[redacted]	INCL CONSTRUCTION OF CLC AS SPECIFIED
26	WHS TYPE 3 - BASKING LOG	01042	15	EA	[redacted]	[redacted]	INCL CONSTRUCTION OF BASKING LOG AS SPECIFIED
28	BDA	01042	18	EA	[redacted]	[redacted]	INCL FURNISHING, PLACING ALL MATERIALS AS SPEC'D
29	MARSHPLAIN REVEG	01040	4.3	AC	[redacted]	[redacted]	MPL AREAS
30	WETLAND REVEG	01040	62.4	AC	[redacted]	[redacted]	NOTCHES, WHE, PLANTING, TEMP ACCESS
31	UPLAND REVEG	01040	1.0	AC	[redacted]	[redacted]	UPLAND FILL AREA
DIRECT ITEM TOTAL (ROUNDED)					[redacted]	[redacted]	
ALLOWANCE FOR INDETERMINANTS					[redacted]	[redacted]	
TOTAL ESTIMATE (ROUNDED)					[redacted]	[redacted]	

4.4 DESCRIPTION OF BEST MANAGEMENT PRACTICES THAT WILL BE IMPLEMENTED AND IMPLEMENTATION RESOURCE PLANS INCLUDING:

The design plan set includes HIP General Aquatic Conservation measures to follow during and post construction, which includes TESC measures as well as best management practices (BMP's). Use of erosion control measures such as seeding, wattles, and silt fencing will aid in addressing the stockpiling of spoil material and associated storm water runoff from leaving the site or entering adjacent waterbodies. Temporary access routes will assist with runoff and roadway rutting, while erosion control around stockpiles and staging areas assists with runoff and run-on associated with precipitation events. The stabilized construction entrance helps to prevent erosion associated with heavy equipment entering the site and provides an area for washout prior to construction equipment leaving the site.

Access and staging locations are shown in the design drawings provided in Appendix C. Vehicular access points are strategically located throughout the project area. Access routes follow existing roads and avoid sensitive areas such as wetlands to the highest extent possible. Key entrance points are shown based on land type and access from existing roadways. While keeping equipment and staging areas 150 feet from delineated wetland and Ordinary High Water (OHW) limits is preferred keeping those buffers would require very long travel times to get equipment to and from work areas and the beginning and end of each day, as well as each time they refuel. The current design includes staging areas within 150 feet of wetlands as well as within wetlands themselves. Staging areas within Given significant cost (and carbon emission) savings are available as designed a variance for this requirement may be sought at a later phase to improve constructability by staging equipment closer to work areas.

Excavated material from the marshplain lowering will be placed on site. All in-water grading will occur within the ODFW approved in-water work window for the Multnomah Channel and take place only after isolation measures are installed and fish salvage has taken place.

2. WORK AREA ISOLATION AND DEWATERING PLAN.

Removal of water details for temporary isolation of the WCS work areas and channels for wood structure installations will be required and are shown in the plans.

3. EROSION AND POLLUTION CONTROL PLAN.

The design drawings in Appendix D include HIP General Aquatic Conservation Measures applicable to erosion control, stockpiling, dust abatement, spills, and invasive species control measures. Subsequent design submittals will include the location of specific BMP measures to be incorporated during construction. Specific measures proposed for the project include use of straw wattles to control erosion of placed fill materials. All work is contained to the site and the dense vegetation surrounding temporary access roads and work areas will limit problems associated with storm runoff during construction.

4. SITE RECLAMATION AND RESTORATION PLAN.

Native seeding of all disturbed areas including access routes and staging areas will be completed immediately following construction. The bulk of the project area revegetation including tree and shrub planting will occur after the following phase(s) of the project. A site revegetation and seeding plan is included in the design drawings in Appendix D.

5. LIST OF PROPOSED EQUIPMENT AND FUELS MANAGEMENT PLAN.

Sheet G2.0 & G2.1 of the design drawings in Appendix D include HIP General Aquatic Conservation Measures applicable to construction equipment and spill prevention, control, and counter measures. Section 5 – Equipment of these notes includes conservation measures addressing the use, staging, maintenance and refueling of equipment. Section 9 – Spill, Prevention, Control and Counter Measures of these notes include procedures and precautions for storing, handling any hazardous materials onsite.

4.5 CALENDAR SCHEDULE FOR CONSTRUCTION/IMPLEMENTATION PROCEDURES.

Construction has not been scheduled yet.

4.6 SITE OR PROJECT SPECIFIC MONITORING TO SUPPORT POLLUTION PREVENTION AND/OR ABATEMENT.

Site and project specific monitoring details are TBD.

5.0 MONITORING AND ADAPTIVE MANAGEMENT PLAN

5.1 INTRODUCTION

The monitoring and adaptive management plan will be developed in coordination with Metro and EP at a later design phase.

5.2 PROJECT REVIEW TEAM TRIGGERS

Adaptive management triggers and actions will be added to the table below at a later design phase.

Project Type	Objective	Trigger/Event/Risk	Management Response
Bridges			
WHS			
BDAs			
Levee Breach Lowering			
Riparian and Wetland Revegetation.			

5.3 MONITORING FREQUENCY, TIMING, AND DURATION

BASELINE SURVEY

LiDAR was collected in November 2019 by Quantum Spatial, Inc. Additional supplemental survey to verify the LiDAR was conducted in 2018, 2020, and 2023 by both EP and W2r using RTK GPS and Total Station.

AS-BUILT SURVEY

As-built survey will be conducted post construction.

MONITORING SITE LAYOUT

The monitoring site layout will include the entire MCMNA property. LiDAR coverage for the project area covers the entire project area and adjacent properties.

POST-BANKFULL EVENT SURVEY

To be determined at a later design phase

FUTURE SURVEY (RELATED TO FLOW EVENT)

To be determined at a later design phase

5.4 MONITORING TECHNIQUE PROTOCOLS

To be determined at a later design phase.

6.0 References

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APPENDICES

A MCMNA FEASIBILITY ASSESSMENT REPORT

B ALTERNATIVE FIGURES

C 70% DESIGN ENGINEERING PLANSET

D MODELING RESULTS FIGURES

E BOR RISK ASSESSMENT (OMITTED)

F WOOD STABILITY CALCULATIONS

G DESIGN SPECIFICATIONS

H “NO-RISE” TECHNICAL MEMORANDUM