

Ross Island HAB Final Report

Design team 4

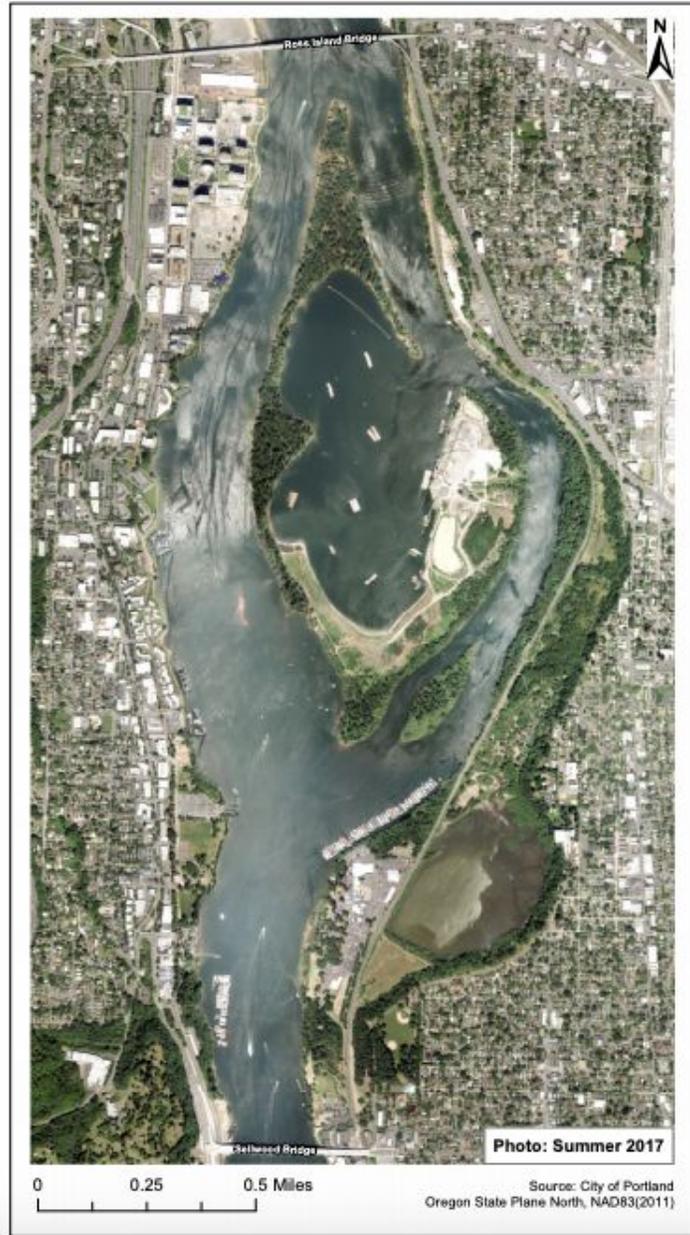


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1.0 Objectives

Our team was hired by the Human Access Project, a non-profit organization in Portland, to determine solutions that reduce the frequency and duration of harmful algal blooms (HABs) in the Ross Island Lagoon. We were tasked with analyzing three different alternatives: no action, a hydraulic solution, and a microbial solution. Our hydraulic solution involved removing a section of land from both sides of the lagoon entrance and adding it to the outside of the river channel, whereas the microbial solution was to add barley straw, an algistat that inhibits algal growth (Waybright, Terlizzi, and Ferrier 2008). Major constraints include the need to maintain or enhance existing habitats and to protect CAD cells in the south side of the island. HEC-RAS and GIS modeling softwares were used to simulate our solutions and come up with the best way of mitigating HABs in the Ross Island Lagoon.

2.0 Methods

2.1 Hydraulic Model

A two-dimensional hydraulic model was developed using the Army Corps of Engineers software HEC-RAS 2D. This software was utilized to simulate the Willamette River near Ross Island in Portland Oregon under existing hydraulic conditions and after altering the landscape with hydraulic design alternatives. A two-dimensional unsteady model was necessary because the river reach is tidally influenced (non-steady) and is not spatially uniform. The model was developed using georeferenced elevation and bathymetry data that was imported from a .tif terrain file. Boundary conditions were established upriver and downriver of the Ross Island site at relatively uniform river cross sections. A flow hydrograph and stage hydrograph were selected for the upstream and downstream boundary conditions respectively. Data for these locations were accessed from USGS gage 14211720 during March 26-28th to develop and calibrate the initial conditions model. After calibration, the river reach was simulated using boundary conditions for a summer baseflow event (August 23-27, 2018), a winter high flow event (December 15-24), and an April flood event (April 9-15, 2019). These three scenarios were chosen to assess the hydraulic alternative at representative seasonal river flows and at a peak flood.

The model was computed in 75' by 75' two dimensional grids at a time step adjusted by the Courant number which ranged from 1 to 0.45 as suggested by the HEC-RAS 2D manual. The computation ran on an initial one-minute time step for all existing condition scenarios, but had to be ran at an initial 30 second time step after culverts were added to avoid model instability. Allowable error was specified as 0.01' for both the water surface elevation (WSE) and volume, but after the simulation was computed, the maximum model error was reported as approximately 0.2'. Our team implemented a hydraulic alternative that widened the lagoon entrance on the downstream side by removing 12,149,742 cubic feet of material. The east bank of the Holgate Channel was built out by 242 ft into the existing channel and adjacent to the lagoon entrance (Figure 3). This expansion utilized 10,303,412 cubic feet of the excavated material from the widened entrance and was expected to funnel flow into the lagoon. A 200' wide 25' tall concrete box culvert was also added to the west side of Ross Island to connect the lagoon to the main river channel. This culvert was 280' long, had flanged wing-walls at 35 and 70 degrees and was simulated at an invert elevation of -10' (~20' below WSE). This culvert essentially functioned as an open channel as it never was completely full. The hydraulic alternative was computed with and without the culvert to determine if it was necessary to cause mixing.

Mixing was assessed using the location of highest velocity at the lagoon entrance from a profile line. Mixing was estimated using the gradient Richardson number which is a numeric approximation for water parcel stability. A water column was considered to be mixed when the Richardson number equaled 0.25. This required an approximate surface velocity of 2.2 and 2.6 ft/s for a mixing depth of 10 meters (epilimnion) and 15 meters (metalimnion) respectively. These depths were chosen from field observations which measured the temperature profile of the lagoon during summer flow (Figure 10). Mixing was assessed for two regions within the lagoon: (1) the downstream section of the lagoon (using the lagoon entrance profile line) and (2) the section upstream of the west island abutment (using the middle lagoon profile line) (Figure 5). The Richardson gradient number is not an ideal method to determine mixing from this model because it assumes that the HEC-RAS reported velocity is the surface velocity, and the bottom of the mixed zone is initially stagnant. In reality, the reported velocity from a profile line is depth averaged, meaning that the entire column of water is moving at that speed. Therefore, the surface velocity is likely underestimated and the velocity at 10 or 15m is most likely not completely stagnant. This should cause considerably more mixing compared to our estimations.

Because the estimated mixing is uncertain and likely underestimated, we decided to approximate the residence time of water within the lagoon under the hydraulic alternative to determine if cyanobacteria would be “flushed” downstream from the increased river-flow into the lagoon. Our team assumed that only the downstream section of the lagoon received direct river-flow because of short-circuiting in the section upstream of the west abutment. The total water volume within this section of the lagoon was approximated as 1,600 million gallons from lagoon cross sections. The flow into the lagoon was determined by the sum of constant river flow into the lagoon entrance and the flow into the lagoon from tidal processes. A profile line on the upstream half of the lagoon entrance was used to determine riverine inputs while a profile line on the downstream half of the lagoon entrance approximated tidal inputs. This was appropriate because water flowed into the lagoon from the upstream side of the entrance and flowed out from the downstream section.

2.2 GIS Analysis

We first analyzed the historical change of flood characteristics in the Ross Island Lagoon and its surrounding channels by overlaying aerial photos from 1948, 1975, and 2015. We observed trends in the lagoon area, the lagoon entrance, and the channel width at the Sellwood bridge upstream from these photos. The team then edited the Ross Island Lagoon terrain to test how our hydraulic solution impacted stratification. The island’s northern peninsula was removed to 30 feet deep, tapering the entrance off slightly to reduce scour. The southern abutment was removed to 20 feet deep, and some of the removed land was added to the east side of the Holgate channel to further funnel water into the lagoon. This process was done in GIS by modifying the elevation of data points on a terrain file, creating a TIN, changing the TIN to a raster, and merging the edited terrain to the original file by using a mosaic to raster tool. The terrain file was then used in HEC-RAS to analyze the impact of altered flows on the system.

2.3 Alternatives Analysis

Each alternative was evaluated on the following criteria; Capital costs, operational and maintenance costs, expected effectiveness at controlling harmful algal blooms, area of created and lost habitat, likelihood of failure during flood events, risk to CAD cells, species benefitted, and unintended consequences. Each criterion was evaluated using the methods outlined below.

To estimate the cost of the hydraulic modification alternative, a similar Portland dredging project was used (BBL, 2005). This provided a general cost per CY of dredged material and other project specific costs such as mobilization, site preparation, and disposal. The cost for each individual project component are listed in Table 1. Cost estimate calculations for the Barley Straw alternative was based on the Centre for Ecology and Hydrology - Centre for Aquatic Plant Management (2012). Costs associated with manual labor and equipment rental were estimated using RS means (Hale, 2018). The cost of each individual project component for the barley straw alternative is listed in Table 2. The cost and frequency of maintenance will be specific to each alternative. The hydraulic modification was assumed to require annual monitoring for erosion and water quality. This was estimated to be 19,000 per acre from (BBL, 2005). The barley straw alternative requires annual implementation before the HAB occurs. The barley floats are expected to last throughout the entire algal blooming period and will require disposal at the end of the season.

The expected effectiveness of the hydraulic modification was estimated using HEC RAS but has some major uncertainties. The expected effectiveness of the barley straw alternative is also highly uncertain. Research indicates the possible inhibitory effects of barley straw on algal blooms while other studies reveal no change (NEI, 2015). Habitat Loss or creation was determined by the change in shallow water habitat. Shallow water habitat has been defined by the City of Portland as 20 feet below ordinary low water. Acres of impacted habitat will be estimated in ArcGIS using the Ross Island Lagoon datum and measuring the change in area between 0 and -20'. The change in water depth between the two site conditions and varied flows will yield an estimated likelihood of failure. The Barley Straw alternative was assumed to be low likelihood of failure during flood events since it does not affect the hydrology of the system. Each alternative does not impose upon the Ross island CAD cells. Therefore, each alternative was classified as low risk.

A review of literature was conducted to identify the habitat needs and limiting factors for important species of the Lower Willamette. The project impacts were compared to habitat needs and limiting factors as summarized in Table 1 (with references) to identify how the project benefits each aquatic organisms. The number of benefitted species from each alternative was then recorded. Natural beaches (Shallow water habitat) appeared to be the most important habitat for younger age classes of salmonids (particularly Chinook salmon), Coho salmon, and were not a preferred habitat of large predator fish; enhancements directed at creating beaches will likely provide a benefit to salmonids.

2.4 Failure Modes Analysis

Potential modes of failure were created for the design features of the hydraulic and microbial solutions. A Risk Priority Number (RPN) was calculated from the likelihood, severity, and detention rates of each potential failure mode. The team developed key design features that should be analyzed for each individual design method. The features for each alternative are illustrated in Figures 11 and 12 in the appendix. The PFMA table is included in the appendix with the Risk Priority Number for each key design feature. This is an important part of the design process to determine the best alternative that has the least potential for failure along with being the most cost-effective.

3.0 Existing Conditions

3.1 Historical Alterations and Harmful Algal Bloom

Ross Island has historically experienced a series of anthropogenic land-use changes that have drastically impacted the hydraulic and ecological conditions surrounding the island. These alterations include: (1) the connection of two originally separate islands by a narrow road built from riprap (2) dredging of the space between the two originally separate islands for gravel (this area is now the lagoon) and (3) expanding the island on the downstream end and narrowing the original island through gravel extraction. This resulted in an increase of the lagoon's surface area by over 5 million ft², the channel width at the Sellwood Bridge by 111 ft, and decreased the width of the lagoon entrance by almost 151 ft between 1948 and 2015. The alterations have created a sheltered lagoon area in the middle of the Willamette River that is highly stratified and stagnant. These are prime conditions for bacterial species to thrive and have been the cause for the HAB.

3.2 Hydraulic Conditions

The existing conditions model revealed that maximum velocities occurred adjacent to the middle of the island and at the end of Ross Island in the west channel. The lowest velocities (<0.1 ft/s) occurred in the middle of the lagoon which was also the deepest location (~138') (Figure 3). Flow analyses revealed that the WSE and flow velocities fluctuate regularly with tidal cycles with a max WSE change of about 2' near the lagoon entrance. The tidal fluctuations peaked approximately every 12 hours. The stratification status of the lagoon was determined using the flow accumulation data during a single tidal cycle. The ratio of riverine volume (R) and tidal volume (V) was computed to have an average of 2.4 during the August low flow scenario. This indicates that the lagoon falls in the "salt wedge" category and therefore should have virtually no vertical mixing from tidal velocity shear.

Our team analyzed flood frequency characteristics and the geographic boundaries different flooding zones within the Ross Island river reach. Information was gathered from the Federal Emergency Management Agency (FEMA) flood map database. Ross Island falls into two different map quadrants (4101830181E and 410830182E) and three different flood zoning designations including Zone A and AE, which cover a majority of the island, and Zone X which is present in smaller patches (Figure 1). FEMA has defined Zone A as the flood insurance rate zone that corresponds to the 1% annual chance of flooding. Zone AE is synonymous to Zone A, except BFEs from hydraulic analysis are shown within the zone. In contrast, Zone X areas have a 0.2% annual chance of flooding. These zones were mapped on Ross Island and the adjacent river boundary most recently on 10/19/2014 and there have been a few letters of map revision (LOMRs) that were approved to alter the flood map since then. The most notable of these is the Tilkum bridge construction in 2016, this LOMR decreased the size of Zone A and Zone X. Aerial photos provide evidence that the Ross Island topography, and the resulting flood hazards, have changed significantly since 2004 because of land modifications to the island (Figure 2). Given that any hydraulic solution for project will be located within the floodplain non-encroachment zone, a no-rise certification will need to be obtained for any proposed solution.

A flood frequency analysis was completed using peak streamflow data between 1972-2016 at USGS gauge 14211720. The log-Pearson analysis method was utilized to convert this peak flow data into a statistical distribution that predicts the magnitude of river discharge during different peak flood frequency events (Figure 2). This analysis revealed that the predicted river discharge for the 1, 10, and 100-year storms were 67,901, 245,164 and 354,605 cubic feet per second respectively.

4.0 Alternatives

4.1 Hydraulic Modification Alternative

The hydraulic alternative consisted of (1) a widened lagoon entrance through excavation of the downstream peninsula, (2) funneled flow into the lagoon by building out the east river bank, and (3) installation of a conveyance channel on the downstream west side of the lagoon to improve mixing (Figure 4). The model was simulated under a high flow (December), low flow (August) and flood event (April). The low flow event was analyzed most extensively because HAB's are only a concern during the summer months when warm temperatures stimulate microbial growth.

We ensured that the modified terrain gradually led into the river rather than created a cliff because this makes it less susceptible to erosion. The peninsula was tapered off rather than removed entirely to prevent scour. These modifications are shown in Figure 13 of the appendix. By modifying the land, we decreased the shallow water habitat by 4.13 acres, as well as displacing land habitat from the island to the side channel. This is something we need to consider when recommending which solution to use.

The hydraulic model determined that the west side culvert had little to no impact on mixing within the lagoon during the August low flow event. The maximum culvert velocity was ± 0.02 ft/s and maximum flow was ± 200 cfs. This is minimal for a 200' wide and 20' deep channel. During the high flow and flood events the culvert had a more significant impact on mixing. However, since the low flow event is the only important flow for HAB prevention, we determined that the culvert would not be a viable alternative. After this finding, the simulation was computed without the culvert for all flow events.

The maximum reported velocities at the lagoon entrance were 0.16, 0.75 and 1.62 ft/s for the low flow, high flow, and flood events respectively. These were the reported velocities for the hydraulic alternative excluding the culvert. This corresponds to a Richardsons gradient number of 45.0, 2.05 and 0.45 for a 10m mixing depth. The high flow and flood events both visually mixed and flushed out the downstream section of the lagoon and the upstream section to an extent. Maximum velocities in the middle of the lagoon were reported as 0.01, 0.04 and 0.09 ft/s for the same flow events. These results indicate that only the downstream section of the lagoon received a majority of the riverine and tidal flow. This was supported by the HEC-RAS animations which displayed very little circulation upstream of the west Ross Island abutment (Figure 5). The April flood event was the only exception to this finding and visually seemed to circulate the entire lagoon (Figure 6).

Two profile lines separating the lagoon entrance were used to quantify the volume of direct riverine and tidal water entering the lagoon during the low flow event. Averaged over three days (August 23-26), the lagoon exchanged approximately 780 million gallons per day (MGD) from a combination of tidal inflow and riverine inputs. Riverine inputs accounted for a 2.4 times greater proportion of the total water exchange. Assuming that the average lagoon depth is 80' (from HEC-RAS approximation) and a measured downstream lagoon area of 62 acres (from Google Earth pro), this results in an average hydraulic residence time of 2.1 days. This calculation assumes that influent water completely exchanges with the resident lagoon water, which is clearly a false assumption. Therefore, the actual residence time may be much greater because water is not completely mixed. On the other hand, this effect could cause the surface water zone (0-15m) to have a shorter residence time than the estimated 2.1 days because it would be preferentially transported downstream. This is the zone of interest

for cyanobacterial growth and therefore HAB treatment. We believe that advective transport of cyanobacteria out of the lagoon through water exchange may be a more significant mechanism for HAB treatment than breaking up stratification. To be clear, there is a lot of uncertainty in this residence time assumption because the degree of mixing is not clear. Furthermore, we assumed that only the downstream portion of the lagoon would be mixed by this influent flow because the model revealed very little mixing in the upstream lagoon section.

4.2 Barley Straw Floats

Barley straw floats have been shown to be a cost-effective, environmentally sustainable method of controlling harmful algae blooms (NEI, 2015). Laboratory studies have suggested its algastatic effects on both green algae and cyanobacteria through the release of phenolic compounds (NEI, 2015). Large scale application of barley straw has been shown to have variable results and requires experimentation with site specific conditions to determine optimal dosing rates and efficiency (NEI, 2015).

The optimal application method of barley straw is through the construction of barley straw bundles (PRF, 2012). The amount of barley straw required to treat the given algal bloom was dependent on the project site water surface area and the chosen dosage rate of 25g/m². The bundles will be constructed using tubular netting wrapper. Each float will be 20m long and weigh around 50 kg. Once the floats are constructed, they will be towed to the desired area and anchored. Each float was calculated to have a given treatment radius of 22.5m and a recommended bale spacing of 45m. Calculations of the required materials and treatment area are listed in the calculation section of the appendix.

4.3 Alternatives Analysis

Table 4 shows each alternative and its corresponding criteria evaluation. Each criterion was evaluated using the methods outlined in section 2.3.

5.0 Failure Modes

5.1 Hydraulics Failure Modes

From the potential modes of failure analysis it was determined that the surface channel or culvert on the west side of Ross Island had the highest risk of failure (RPN) during a flood scenario. The following key potential failures of a hydraulic solution were analyzed: HAB treatment, west downstream surface channel concrete, east side bank expansion, lagoon entrance widening, and west downstream surface channel gate (Figure 12). The culvert and land excavation at the lagoon entrance were analyzed for potential failures separately, but the east side expansion was chosen as the sole hydraulic method because of the lower RPN and findings from the HEC-RAS model. We decided to not include the culvert or channel in our final recommendation to reduce the number of possible design failures.

The overall failure severity is higher for the hydraulic solution relative to the biological alternatives because the cost of construction to modify the lagoon is a large initial expense and there is a larger possibility for loss of shallow water habitat. The detection of a failure scenario is more likely for the hydraulic alternative because it is easier to identify failures before they occur using the hydraulic model. The expansion and lagoon entrance widening can cause erosion and loss of habitat, which can be prevented with monitoring and armored banks. As discussed in section 4.1, the alternative analysis revealed that the hydraulic solution has a high likelihood of

failure for HAB treatment. Lagoon entrance velocities were too low for the Richardson's value to meet its criteria for mixing, so stratification may not be solved by the land modifications.

5.2 Biological Alternative

The following key potential failures of the biological solution were analyzed: HAB treatment, impact to aquatic species, microbial response and treatment timeline (Figure 11). The overall cost of barley is low compared to other alternatives. If HABs treatment fails, the severity of economic loss will be lower. However, the overall likelihood of failure is high because only research can support this alternative. A literature review of barley straw indicates conflicting evidence of HAB treatment efficiency. High amounts of barley straw may decrease the dissolved oxygen and adversely affect habitat quality. To confirm the RPNs, a physical model would need to be created to determine HAB treatment effectiveness.

6.0 Discussion and Conclusions

6.1 Error and Uncertainty

The recommended dosage rate of barley straw is not well understood and will require experimentation with site specific conditions. Barley straw also lowers dissolved oxygen content of the water as it decomposes. This could pose a risk to the surrounding organisms. It is suggested to use the lowest dosage rate possible to attain desired effects. Barley straw is a long-term preemptive solution to HAB control (full season) and will not be effective once bloom has already occurred. Barley straw will require implementation in the early spring and will likely last throughout entire blooming season. (CEH, 2004)

Mixing within the Ross Island Lagoon is fundamentally a three dimensional process because surface flows at the lagoon entrance will disperse and mix lower stratified water layers. A 3D simulation is necessary to model this process accurately, but because of time and resource constraints we were forced to utilize a two dimensional model. Therefore despite our modeling efforts, the magnitude of mixing within the lagoon is fairly uncertain. We were forced to approximate mixing using the gradient Richardson number assuming that the model output velocities were at the surface. However, the output velocities were depth averaged by the model so are likely underestimated. Furthermore, we are uncertain how much mixing is even necessary to inhibit cyanobacterial blooms, and do not know the degree to which advection of water downstream will adversely impact bacterial populations. We can conclude with relative certainty the average velocities within the Holgate Channel and Lagoon entrance, and the approximate volume of water flowing into and out of the lagoon during the low flow scenario. But, we cannot conclude whether this will be effective at treating the HAB problem at Ross Island.

6.2 Recommendations

The barley straw solution was significantly cheaper compared to the hydraulic solution. However, previous experiments yield inconsistent treatment effectiveness (NEI, 2015). Scalable experiments with site specific conditions must be performed to better understand the barley straw treatment efficiency. The hydraulic model provided results that visualize the impact of our solution on the lagoon. However, it was much more expensive, and still did not fully mix the lagoon even during the April flood event. We recommend doing more research into what degree of mixing is required to dismantle the HABs, and if we are capable of flushing the bacteria downstream rather than mixing the lagoon. We came to the conclusion that a more detailed model is required to

determine the optimal HAB solution, such as a HEC-RAS 3D model. This would allow us to analyze the water velocities at different depths of the lagoon.

References

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- ❑ PRF, B. & Newman, J. (2012). *Centre for Aquatic Plant Management INFORMATION SHEET 1: CONTROL OF ALGAE WITH BARLEY STRAW*.
- ❑ NEIWPC. (2015). Harmful Algal Bloom Control Methods.
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Appendix



Figure 1. FEMA flood insurance rate map of Ross Island

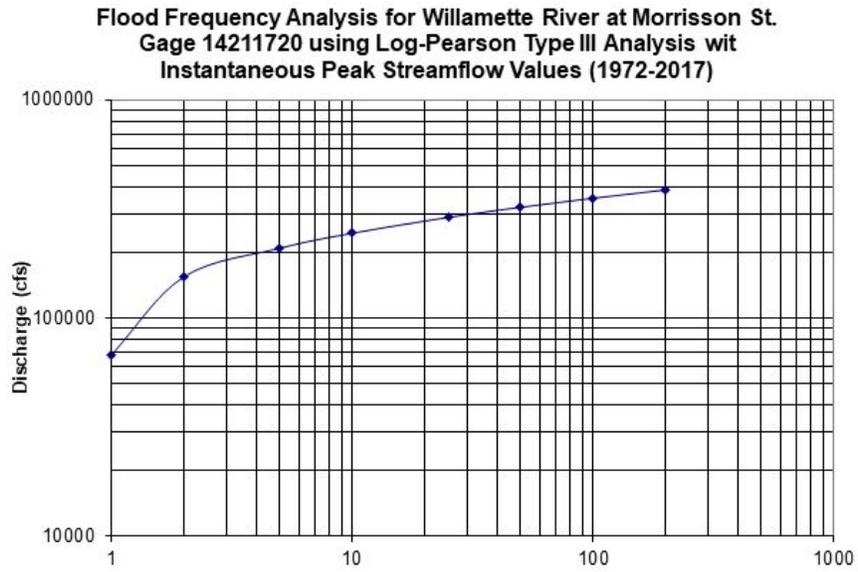


Figure 2. Flood frequency analysis for Willamette River at Morrison St. Gage using Log-Pearson Type III Analysis With Instantaneous Peak Streamflow Values (1972-2017)

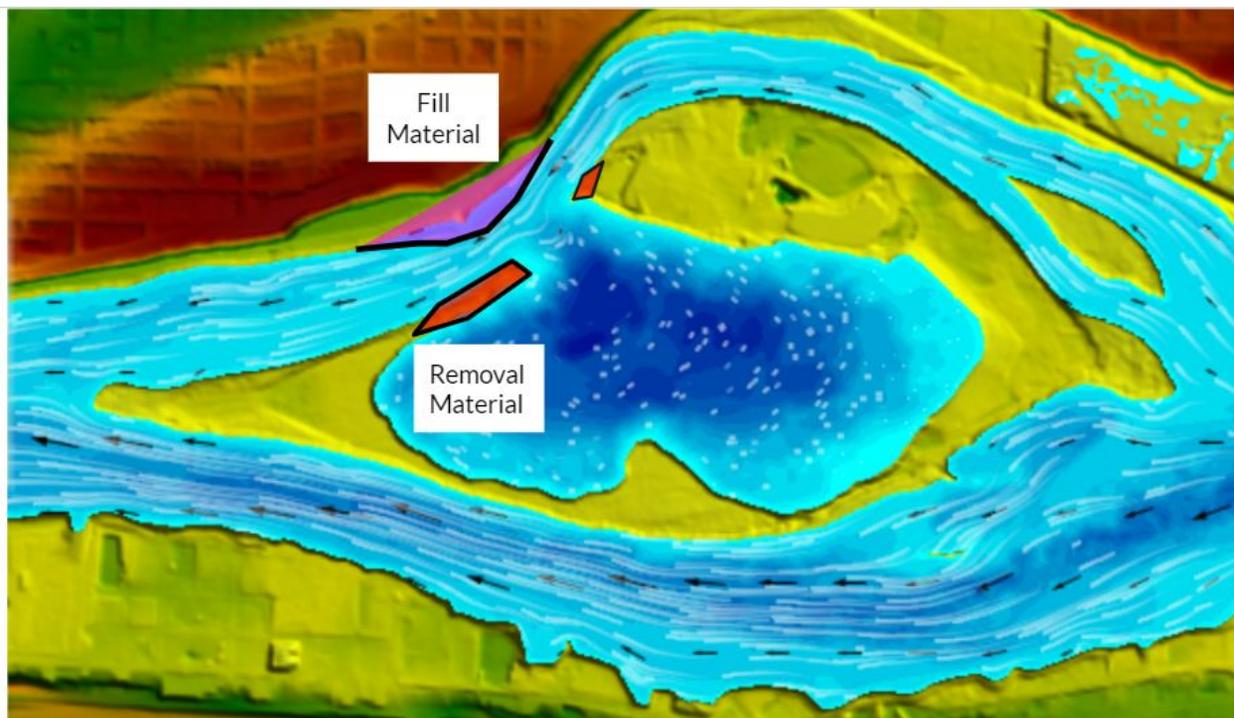


Figure 3. HEC-RAS existing conditions model with proposed terrain modifications to Ross Island and the east riverbank

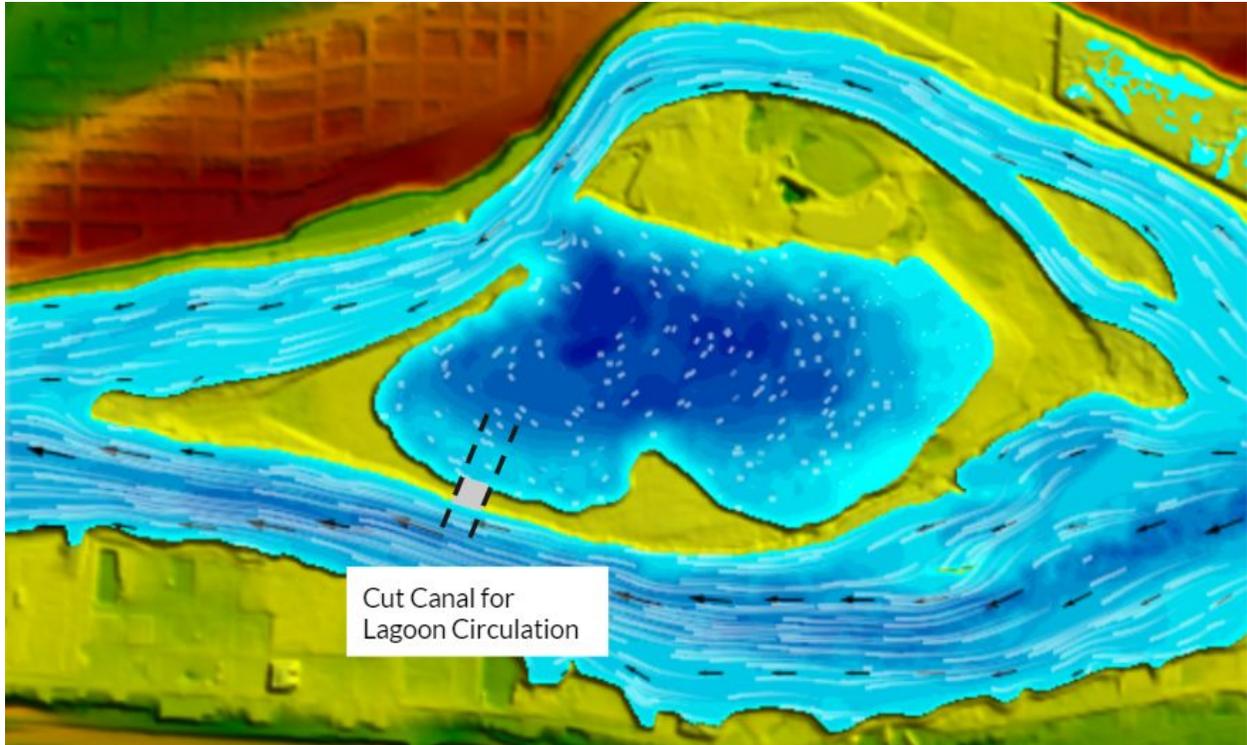


Figure 4. HEC-RAS existing conditions model with proposed culvert in the west downstream side of Ross Island. This culvert was implemented in conjunction with the terrain modifications.

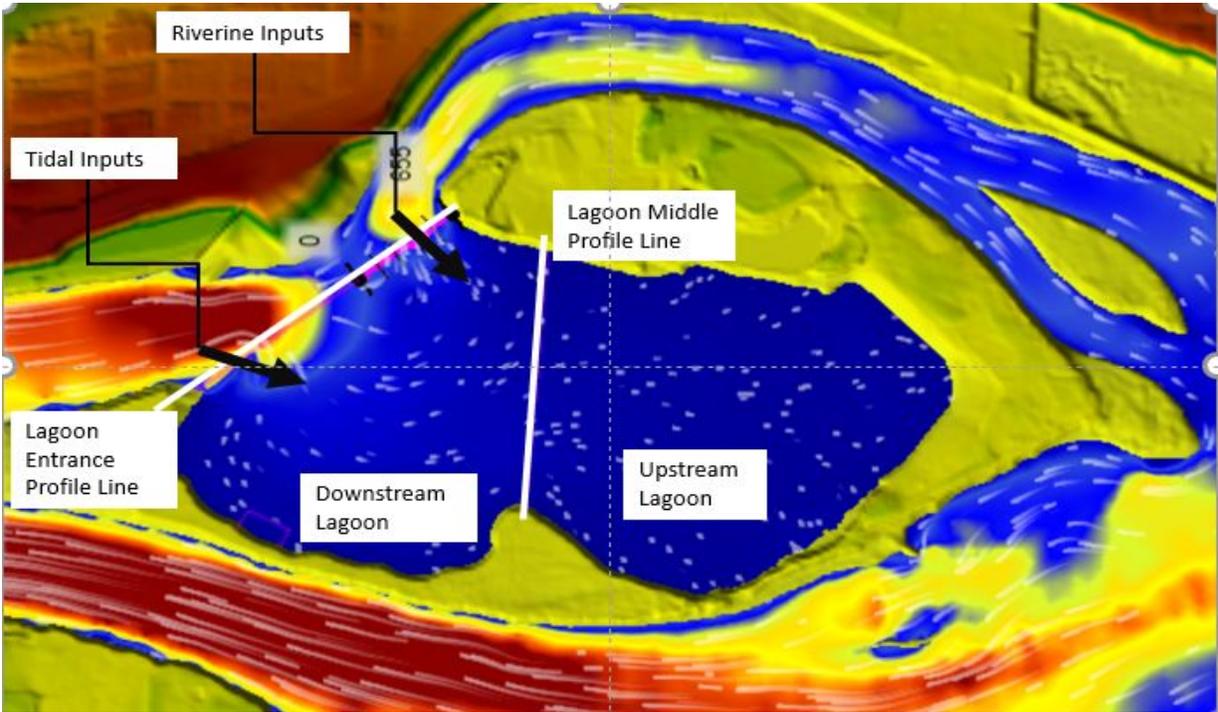


Figure 5. HEC-RAS hydraulic alternative velocity output (ft/s) for low flow August scenario without proposed culvert. Output geometries and regions are labeled consistent with hydraulic alternative report section.

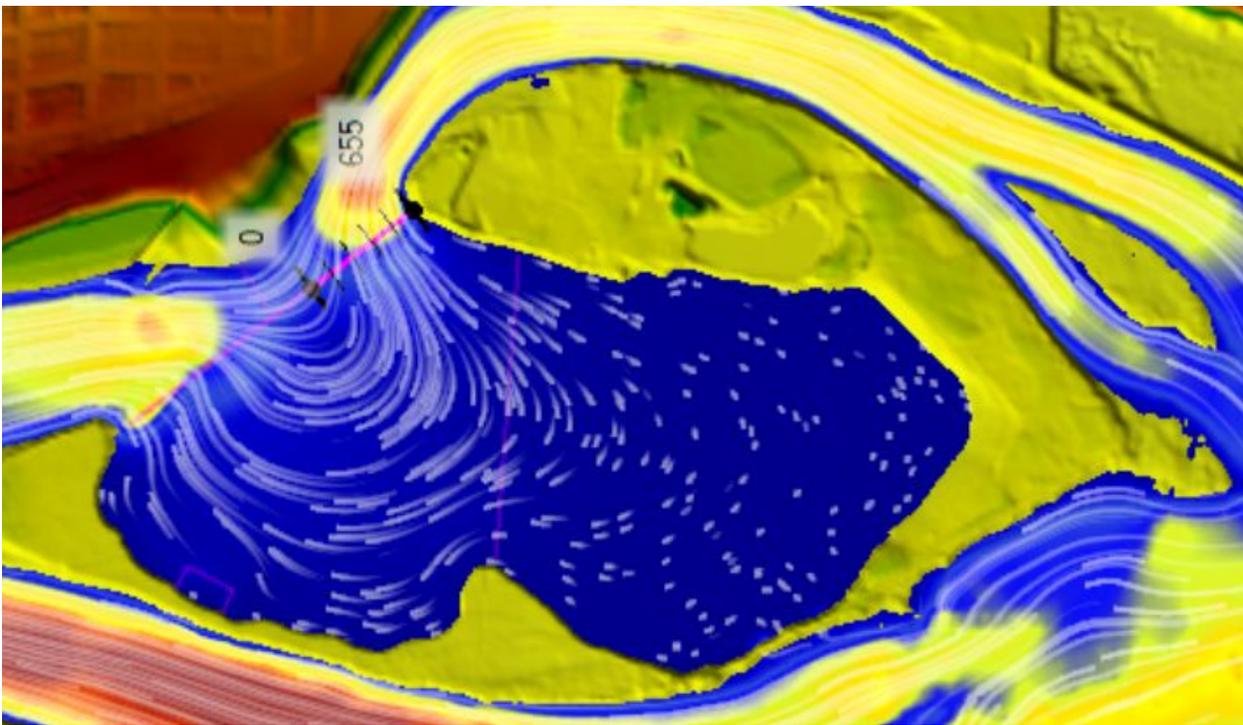


Figure 6. HEC-RAS hydraulic alternative velocity output for April Flood scenario with proposed culvert.

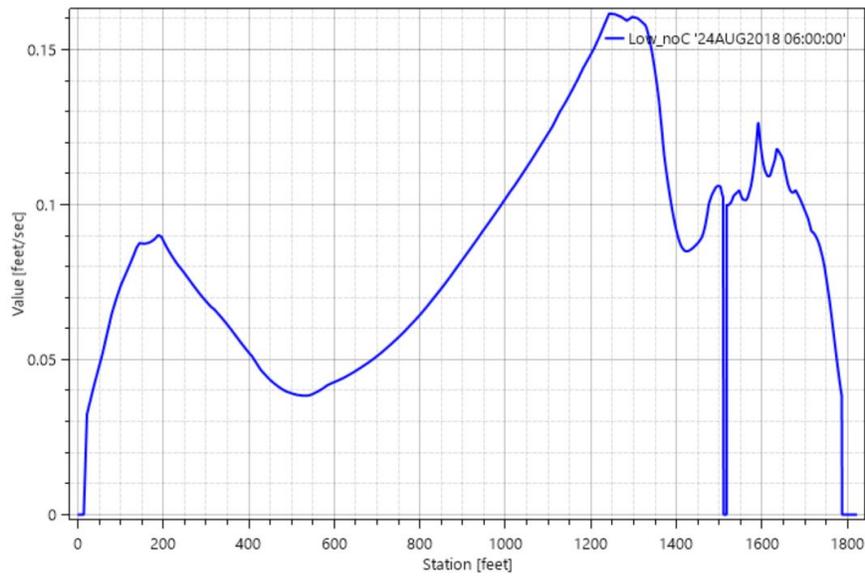


Figure 7. Lagoon entrance velocity profile line during August flow event. This profile line displays the time of maximum velocity.

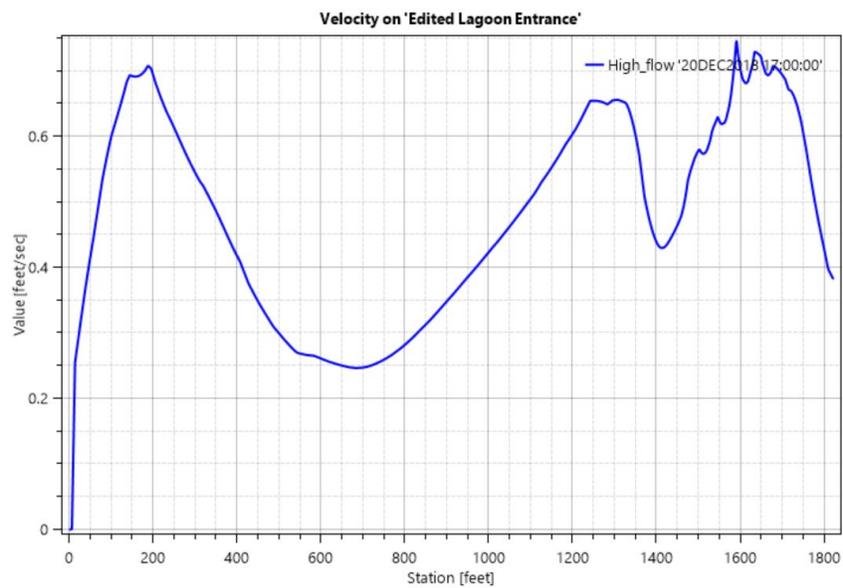


Figure 8. Lagoon entrance velocity profile line during December flow event. This profile line displays the time of maximum velocity.

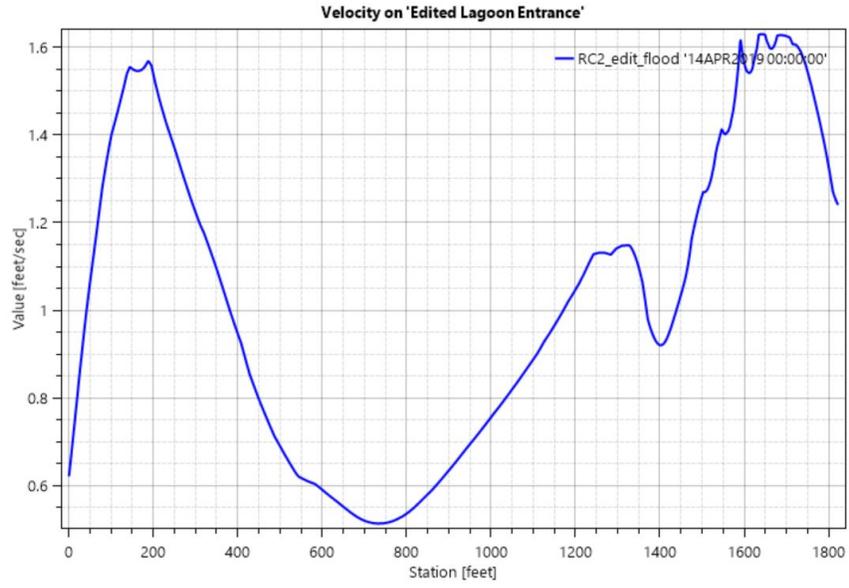


Figure 9. Lagoon entrance velocity profile line during April flood event. This profile line displays the time of maximum velocity and is for the alternative with the culvert included.

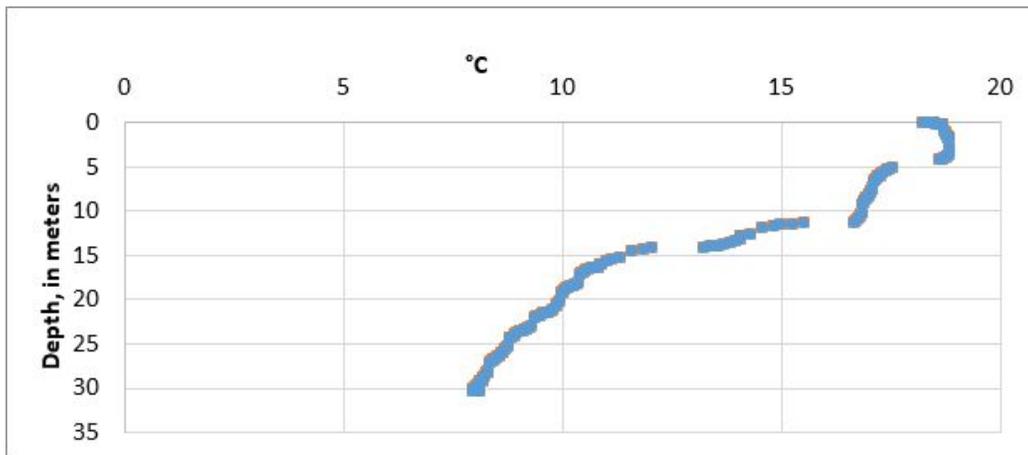


Figure 10. Lagoon Temperature profile

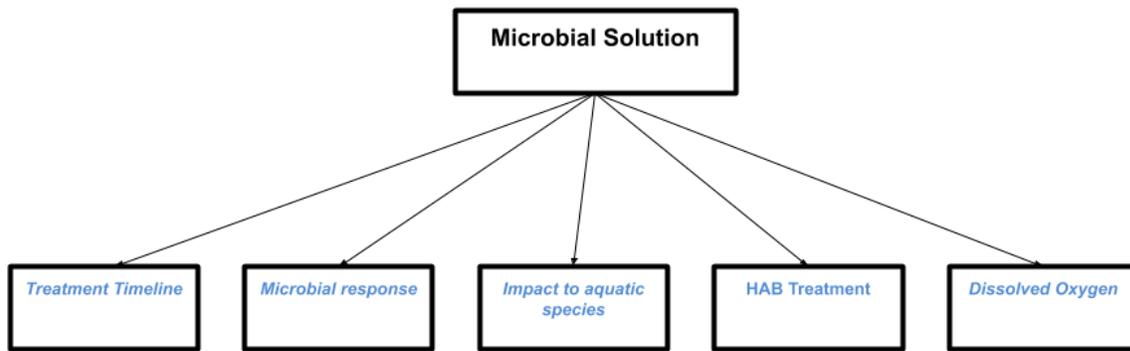


Figure 11. PFMA alternative key features for the microbial solution.

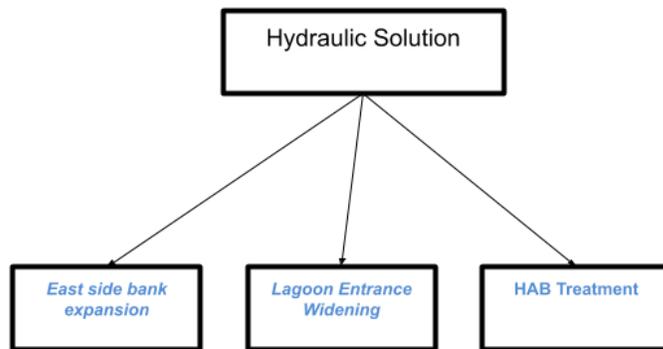


Figure 12. PFMA alternative key features for the hydraulic solution.

Hydraulic Modification of the Ross Island Lagoon

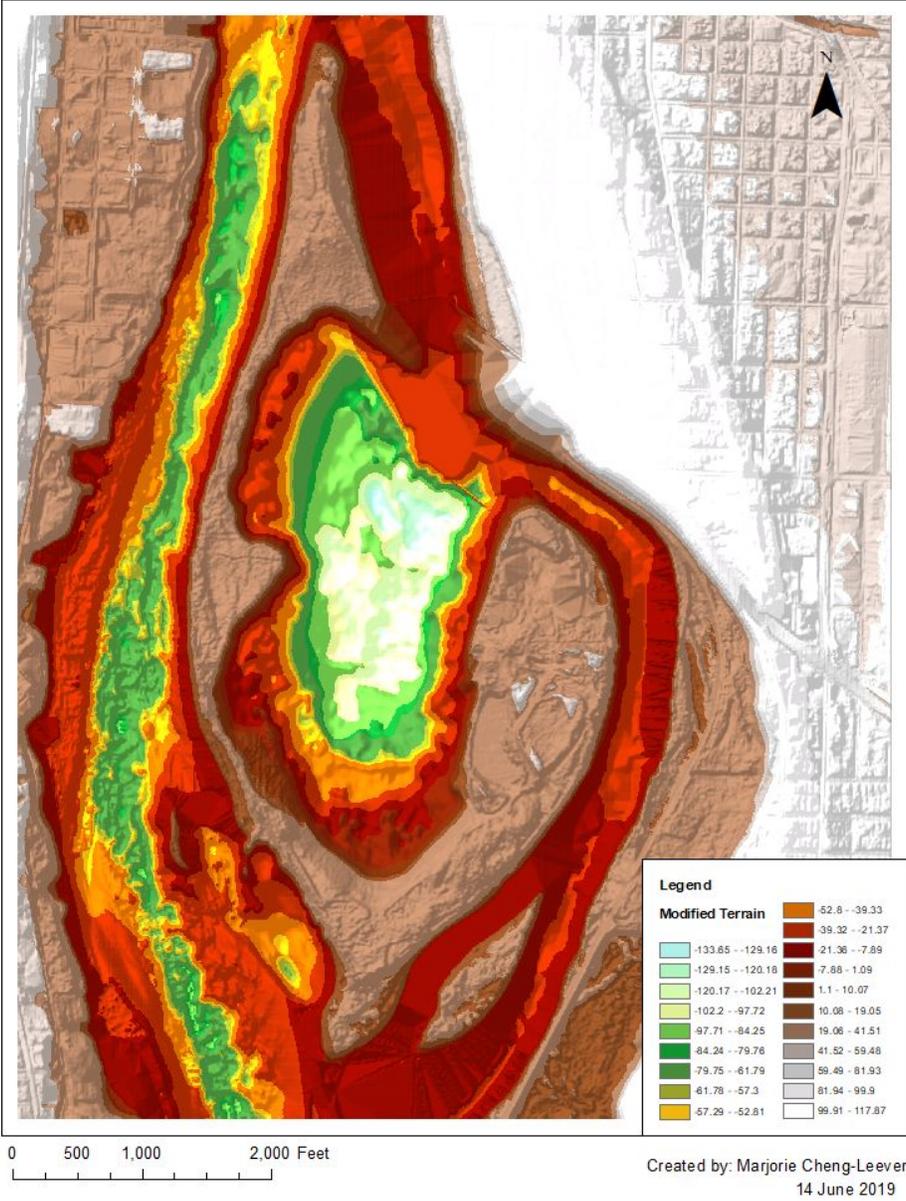


Figure 13. ArcMap Hydraulic modification to the Ross Island Lagoon

Table 1. Hydraulic alternative cost estimate.

Alternative: Hydraulic Modification				
<u>Description</u>	<u>Price per Unit</u>	<u>Units</u>	<u>Total</u>	<u>Source</u>
Capitol Costs				
<u>Mobilization and Demobilization</u>				
Mobilization and Demobilization			\$ 1,000,000.00	(BBL, 2005)
Contractor Work Plans			\$ 250,000.00	(BBL, 2005)
			Subtotal = \$ 1,250,000.00	
<u>Site Preparation</u>				
Sediment Transload Facility			\$ 920,000.00	(BBL, 2005)
			Subtotal = \$ 920,000.00	
<u>Dredging and Sediment Disposal</u>				
Dredging				
Cost per CY	\$ 8.00	CY	\$ 3,608,337.36	(BBL, 2005)
Landfill disposal	\$ 30.00	CY	\$ 2,056,254.60	(BBL, 2005)
DEQ Disposal	\$ 1.24	CY	\$ 84,991.86	(BBL, 2005)
Metro Disposal	\$ 3.50	CY	\$ 239,896.37	(BBL, 2005)
			Subtotal = \$ 5,989,480.19	
<u>Project Development Construction</u>				
Construction Management and Oversight			\$ 950,000.00	(BBL, 2005)
Engineering Support During Construction			\$ 350,000.00	(BBL, 2005)
Special Insurance, Bonding, Permitting			\$ 400,000.00	(BBL, 2005)
			Subtotal = \$ 1,700,000.00	
<u>Micellaneous Construction-Related Direct Costs</u>				
Short Term water quality monitoring	\$ 12,000.00	ACRE	\$ 83,640.00	(BBL, 2005)
			Subtotal = \$ 83,640.00	
			Total Capitol Cost = \$ 10,820,623.01	
O&M Costs				
1 Year Monitoring and Control	\$ 19,000.00	ACRE	\$ 132,430.00	
			Subtotal = \$ 132,430.00	
			Total O&M Cost = \$ 216,070.00	
Notes				
Volume of Sediment Removal	344307	m3	451042.17	CY
Volume of Sediment Disposal	52322	m3	68541.82	CY
Area of Sediment Movement	6.97	Acre		

Table 2. Microbial Barley straw alternative cost estimate.

Alternative: Barley Straw				
<u>Description</u>	<u>Price per Unit</u>	<u>Units Required</u>	<u>Total</u>	<u>Source</u>
Capitol Costs				
Materials				
Barley Straw	\$ 7.70	14165	\$ 109,070.50	https://www
Tree Wrapping	\$ 119.00	5	\$ 595.00	https://shee
Baler	\$ 325.00	5	\$ 1,625.00	https://shee
Anchor System	\$ 19.99	354	\$ 7,076.46	https://www
		Subtotal =	\$ 118,366.96	
Labor				
Common Building Laborers	\$ 41.05	70.8	\$ 2,906.34	RS Means
Tug Boat Captain	\$ 55.10	23.6	\$ 1,300.36	RS Means
Tug Boat Hand	\$ 41.05	23.6	\$ 968.78	RS Means
Tug Boat, 250 HP		1	\$ 710.07	RS Means
		Subtotal =	\$ 5,885.55	
Total Capitol Cost =			\$ 124,252.51	
O&M Costs				
Materials				
Barley Straw	\$ 7.70	14165	\$ 109,070.50	https://www
		Subtotal =	\$ 109,070.50	
Labor				
Common Building Laborers	\$ 41.05	70.8	\$ 2,906.34	RS Means
Tug Boat Captain	\$ 55.10	23.6	\$ 1,300.36	RS Means
Tug Boat Hand	\$ 41.05	23.6	\$ 968.78	RS Means
Tug Boat, 250 HP		1	\$ 710.07	RS Means
		Subtotal =	\$ 5,885.55	
Total O&M Cost =			\$ 114,956.05	
Notes				
Surface Area	56.66 Ha			
Dose Rate	25 g/m2			
Straw Required	14165 kg			
Bales needed	354 bales			
Treatment area	1600 m2			
Bales per hour (Constructic	5			
Workers	3			

Table 3. Species benefited from alternatives

Species	Hydraulic Modification (Tiffan, 2002).	Barley Straw (PRF, 2012)
Chinook salmon (<i>O. tshawytscha</i>)	<ul style="list-style-type: none"> Juvenile Chinook select for sandy substrate and submerged willow or tall riparian canopy (Freison, 2000) Modification would likely have no effect. 	<ul style="list-style-type: none"> Increased food supply and health from increased growth of invertebrates.
Coho salmon (<i>O. kisutch</i>)	<ul style="list-style-type: none"> Prefer beach habitat. Could increase water velocity and slope erosion which negatively impacts habitat quality. 	<ul style="list-style-type: none"> Increased food supply and health from increased growth of invertebrates
Steelhead (<i>O. mykiss</i>)	<ul style="list-style-type: none"> Prefer beach habitat. Could increase water velocity and slope erosion which negatively impacts habitat quality. 	<ul style="list-style-type: none"> Increased food supply and health from increased growth of invertebrates.
Cutthroat Trout	<ul style="list-style-type: none"> Prefer beach habitat. Could increase water velocity and slope erosion which negatively impacts habitat quality. 	<ul style="list-style-type: none"> Increased food supply and health from increased growth of invertebrates.
Waterfowl	No effect.	<ul style="list-style-type: none"> Provides habitat for roosting and nesting.
Aquatic Invertebrates	<ul style="list-style-type: none"> Could change habitat to increase or decrease invertebrate populations which affect the entire food chain. Beach habitat support high invertebrate species diversity. (Freison, 2000) 	<ul style="list-style-type: none"> Decaying straw provides good habitat for numerous water invertebrates such as water shrimp (<i>Gammarus</i> spp.) which benefit the entire food chain.

Table 4. Alternative analysis criteria checklist

Alternative	Capital costs (\$)	O&M (\$, frequency)	Habitat: loss and creation of shallow water habitats (acres)?	Expected effectiveness at controlling HAB (unknown, low, med, high)?	Likelihood of failure during flood events (unknown, low, med, high)	Risk to CAD cells (USACE likelihood scale)	Likely benefit to widest range of aquatic taxa	List any unintended impacts
Hydraulic Modification	\$10,820,623	\$216,070 per year	-4.13	Low	Low	0	None	Fish Passage
Barley Straw Floats	\$124,252.51	\$114,956 per year	0	unknown	Low	0	Steelhead, Trout, Salmon, Invertebrates, Waterfowl	Dissolved Oxygen Depletion, Increased boat traffic.

No Action	0	0	0	none	Low	0	none	none

Barley Straw Calculations

$$SA = 56.66 \text{ HA } (566600 \text{ m}^2)$$

$$\text{Dose Rate} = 25 \text{ g/m}^2$$

$$\text{Bundle Weight} = 40 \text{ kg}$$

$$\text{Straw Required} = 25 \text{ g/m}^2 \times 566600 \text{ m}^2 = 14165 \text{ kg}$$

$$\text{Bales Required} = \frac{14165 \text{ kg}}{40 \text{ kg}} = 354 \text{ Bales}$$

$$\text{Treatment Area of each bale} = 25 \text{ g/m}^2 \times 40000 \text{ g} = 1600 \text{ m}^2$$

$$\text{Treatment radius of each bale} = \pi r^2 = 22.5 \text{ m} = r$$

$$\text{Spacing between each bale} = 2r = 45 \text{ m}$$

Table 5. PFMA and Risk Number Priority

FMEA

Process/Product Name: Team 4

Prepared By: Bridgette Medeghini

Responsible: Ross Island Portland, Oregon

FMEA Date (Orig.):

28-May

Alternative	Process Step	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 5)	Potential Causes	LIKELIHOOD (1 - 7)	Current Controls	DETECTION (1 - 6)	RPN (S * L * D)	Action Recommended	Resp.
	What is the process or feature under investigation?	In what ways could the process or feature go wrong?	What is the impact if this failure is not prevented?		What causes the process or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed?
Hydraulic Solution	East Side Bank Expansion	Widened bank could fail and erode during flood events	Erosion, loss of functionality, sediment transport, monetary loss	4	Undersized rock material causes entrainment, large velocities in Holgate channel.	3	Monitoring the channel, sizing rock with a factor of safety, adding vegetation to prevent erosion.	3	36	Monitoring bank, overdesign features	River engineers, construction companies
	Lagoon Entrance Widening	Increase flow through entrance could erode island	Erosion, sediment transport, infrastructure damage, loss of habitat	4	Increased flow and velocities from channeling river could cause entrainment	3	Armoring of bank, depth of lagoon limits velocities	3	36	Armor bank effectively and monitor	River Engineers, construction companies
	HAB Treatment	Mixing not sufficient to break up stratification and inhibit microbial growth.	HAB is persistent, toxic cyanobacteria, wasted money	4	Mixing velocities necessary are underestimated or flow does not get routed into lagoon effectively	6	HEC-RAS model with overestimation of necessary velocities	2	48	Use multiple methods to determine mixing velocities	River engineering, maintenance workers
Barley Straw	HABs treatment	Cyanobacteria won't be treated or removed	Problem will continue to occur	3	Not enough barley or improper maintenance	5	Confirming calculations and further research on correct area of barley barrels	3	45	Monitoring algal biomass	River engineers, maintenance workers
	Impact to Aquatic Species	The barley decreases water dissolved oxygen content	Death of organisms, decrease in ideal fish habitat	3	Too much barley, unfavorable conditions for certain fish species, not monitoring the DO levels	4	Monitoring the nutrient and algal levels in the lagoon, making consistent observations, adding mixing or diffusers in the lake to increase dissolved oxygen	3	36	Monitoring fish populations, DO monitors in lake, increase mixing	River engineers, maintenance workers, Fish & Wildlife Services
	Microbial Response	Barley straw causes unexpected microbial response that has a similar bloom effect	Increases the severity of the algal bloom, further degrading the ecosystem	3	Unintended conditions created	1	Monitoring the nutrient and algal levels in the lagoon	4	12	Continually monitoring the nutrient and algal biomass trends	River engineers, maintenance workers
	Treatment Lifetime	Barley straw quickly flows out of lagoon and disperses downstream	Loss of materials, HABs continues to occur	3	Existing conditions cause variance in barley straw treatment capability, improper amount of barley straw used	3	Controlling the flow and having supporting structure for the barley	4	36	Researching similar study areas with implemented barley straw and scaling properly.	River engineers, maintenance workers