Portland, Oregon

Ross Island Analysis Report

June 14, 2019

Design Team 3

Abstract
Harmful algal blooms (HABs) are occurring at Ross Island and are currently threatening recently reclaimed and protected habitats. Continual nonpoint sources of agricultural fertilizer are likely to blame for the recurrence of HABs in the lagoon. Hydraulic and non-hydraulic solutions for reducing the frequency of HABs were identified in this report. The river modeling program HEC-RAS was used to simulate the hydraulic conditions created by implementing cuts to the lagoon made in the existing terrain files. ArcGIS was used to modify the terrain files used in the HEC-RAS model. It is suggested that the second hydraulic alternative of breaches in the Southwest and Northwest regions of the island be implemented. The HEC-RAS model computed that both hydraulic alternatives achieved the same mixing; however, the model did not properly quantify mixing at the Northwest breach. By utilizing two cuts to the lagoon, maximum mixing will be achieved. The second alternative will be significantly more expensive because of increased excavation costs. The worst solution was determined to be the alum alternative. Although it can be effective in mitigating algae blooms, it is a short term option and continual application would lead to economic infeasibility. It is recommended that the second hydraulic alternative be implemented on the Ross Island Lagoon.

Problem Statement and Objectives

The project objective is to identify solutions to reduce the frequency and duration of (HABs) at Ross Island Lagoon while protecting the Confined Aquatic Disposal (CAD) cells, avoiding capture of mainstem river by the lagoon, maintaining or enhancing existing wetland habitats and the aquatic ecosystem, and considering the cost associated with a given solution.

Introduction

Background

Between 1926 and 1927, an earthen dike constructed between Ross and Hardtack islands formed the Ross Island Lagoon. Starting in the 1920s, Ross Island Sand & Gravel (RISG) extracted materials from the site until 2001. In 1979, CoP required RISG to start reclaiming areas that had been mined. In 2002, the final reclamation plan was negotiated, including the creation of a mosaic of habitats (Brennan et al. 2019). New habitats included 22 aces of riparian/emergent wetlands, 14 acres shallow water, and 118 acres of upland forest.

Existing Conditions

HABs are occurring at Ross Island and are currently threatening these recently reclaimed and protected habitats. HABs typically form in the summer months, when river discharge is low and river temperature is warming. Continual nonpoint sources of agricultural fertilizer (Nitrogen, Phosphorus and Potassium) upstream from Ross Island lagoon create ideal conditions for HABs. The low discharge that occurs in summer is principally responsible for creating conditions which facilitate HABs, as low velocities aid in stratification. Increased river velocities creates water shear and promotes the mixing of stratified water. The HABs persist until the first significant rain events occur, which cause the river discharge to increase and the river temperature to decrease.

Methods

Hydraulic Model

To create an accurate representation of the existing conditions in the lagoon and the surrounding river, a 2-dimensional model in the hydraulic modeling software HEC-RAS was created. The model was created using terrain data gathered from the area. The river discharge data used for the model was gathered from the Morrison Bridge USGS gauge (14211720).

Upon the creation of a stable model, the terrain files were modified and re-entered into HEC-RAS to investigate any changes in the hydraulic conditions inside the lagoon as a result of modified channel geometry. The terrain adjustments were carried out by modifying the terrain file using ArcMap software. Adjustments to the terrain were performed at the Southwest and the Northwest sections of Ross Island lagoon.

Alternatives Analysis Calculations

Because limitations in our 2 dimensional model we had to employ other means to analyze the mixing depth from each of our alternatives. To determine the effectiveness of our various hydraulic solutions on the stratification, we employed the use of the dimensionless Richardson number which describes the stability of a parcel of water (Tullos 2019). The Richardson number was calculated using the velocity directly at the inlet to the lagoon as this velocity is most likely the most representative of actual velocities. To find the effective depth of mixing we assumed a Richardson number of 0.25, which is the minimum number needed for a body of water to be expected to mix. Using this value we then back solved for the depth in the Richardson equation. This process was repeated for each solution for 4 different flow scenarios. For the non-hydraulic solution, a literature review of "Review and Evaluation of Reservoir Management Strategies for Harmful Algal Blooms" was conducted to evaluate the effectiveness at controlling HABs using alum (Herman, et al. 2017). It mentioned that treatment with coagulants like alum were found to be effective in small areas, so the effectiveness at controlling HABs using alum has been rated a medium since it is a relatively small area (Herman, et al. 2017).

Failure Modes and Effects Analysis

A Failure Mode and Effects Analysis (FMEA) was conducted to discover potential failure modes that may exist within the two design alternatives for the Ross Island Lagoon HABs. The Risk Priority Number (RPN) was calculated for each potential failure mode and tabulated in a rating table (Figure 6). The FMEA consists of two alternative solutions: A hydraulic approach and a chemical approach involving alum. Two process step subcategories of the hydraulic solution were identified: Flood events and drought events. The chemical approach involves dosing the lagoon with alum periodically. Three process steps were identified for the chemical approach: Inadequate concentrations of alum, unexpected flows which flush the lagoon, and toxicity to aquatic life.

Alternatives Analysed

The team's main focus was the analysis of 2 hydraulic solutions. The first solution includes an entrance modification into the lagoon at the upstream end of the island. The second solution kept the same upstream modification while adding an additional outlet on the west side of the downstream end of the lagoon. A major hydraulic design consideration is the necessity not to disrupt the CAD cells buried on the upstream side of the lagoon. In addition to the hydraulic solutions, the potential use of alum as a microbial solution to inhibit the HAB growth was also analyzed.

Southwest Breach

A breach was placed on the Southwest portion of the Island (Figure 1). This was the optimal placement of a breach for the following reasons: any opening on the upstream end of the island will be more effective for routing flow into the lagoon and the flow into the lagoon would not disrupt the sealed CAD cells. The location of the CAD cells can be seen in the Appendix Figure 5.

Northwest and Southwest Breach

For the second alternative a second breach to the island on the Southwest side (Figure 2). The addition of this secondary breach serves two purposes. The first was that during times of mid to high flow it allows for a second effluent to the lagoon which helped to mobilize the entire body of water. The second benefit that this had was that during times of low flow, it allowed for an increase in tidal pumping from incoming tides. This aspect of the additional cut is more considerate of low discharge situations when more mixing, created by higher velocities, is needed to inhibit the HAB.

Microbial alternative

The third alternative involves adding a mixture of Phoslock ® and alum to the water to treat the HABs. Alum is commonly used in water treatment to cause organics suspended in the water to settle out of solution by forming pieces of floc. At Ross Island lagoon, alum would be used to cause HAB, which are organic, to settle to the bottom of the lagoon. Phoslock ® , like it's name would imply, binds to phosphate and makes it available for uptake by microorganisms. The use of alum in large stagnant bodies of water experiencing HABs has been an effective method for reducing HABs.

Results and Discussion

As expected, the desired mixing depth of 10 meters in the lagoon was not reached. Mixing to that depth would have required velocities of at least 2 m/s which are not achieved in the main stem of the river. However, the mixing depth was calculated at the upstream breach, the holgate channel, and for the additional breach on the northwest side of the island. The results of this are tabulated below.

Table 1. Results of Richardson numbers for four different flow scenarios using hydraulic solutions 1 (SW Breach) and 2 (SW&NW Breach).

Terrain Adjustment	Flow conditions	Inlet velocity (m/s)	Holgate outlet velocity (m/s)	NW breach velocity (m/s)	Inlet Mixing depth (m)	Holgate mixing depth (m)	NW mixing depth (m)	Ri
SW Breach	Apr (Flood)	0.83	0.298	n/a	11.41	1.47	n/a	0.16
	Dec (HI)	0.43	0.118	n/a	3.06	0.23	n/a	0.57
	Mar (MID)	0.21	0.067	n/a	0.73	0.07	n/a	2.24
	Aug (LOW)	0.094	0.018	n/a	0.14	0.01	n/a	12.10
SW&NW Breach	Apr (Flood)	0.941	0.265	0.338	14.67	1.16	1.89	0.12
	Dec (HI)	0.43	0.107	0.198	3.06	0.19	0.65	0.57
	Mar (MID)	0.21	0.067	0.143	0.73	0.07	0.34	2.42
	Aug (LOW)	0.094	0.064	0.061	0.14	0.04	0.06	12.10

Although our mixing depths don't reach the desired depth (except for the April floods), this does not mean that the design will be ineffective (Table 1). With the addition of both breaches, there is a constant flow throughout the lagoon. While this flow is not enough to break up stratification, it does mobilize the entire body of water. The hope is with the mobilization of the entire lagoon, the existing bacterial colonies may be washed downstream and new colonies will be unable to establish.

Acres of impacted habitat for the southwest cut were estimated in ArcGIS to be around 2.09 acres, and for the combined northwest and southwest cuts, 4.74 acres. The volumetric land needed to be excavated was determined to be 1,539,179.12 ft^3 for the southwest cut and 3,493,041.88 ft^3 for the combined northwest and southwest cuts. These values were calculated using the cut and fill tool in ArcGIS, it worked by totaling the volumetric difference between the original ArcGIS files and the cuts made in the lagoon which represent the hydraulic solution. Shallow water habitats are assumed to be produced from the excavation of land in both scenarios. For the southwest breach, 1.13 acres of riparian habitat were produced and 3.68 acres of riparian habitat were produced for the combined northwest and southwest breach.

The cost estimate for the hydraulic solutions was largely based on current prices for construction found in the 2019 Building Construction Costs with RSMeans Data book (“Building Construction”). The capital cost estimate (Table 4) for making the single cut out of Ross Island came out to be $1,262,280.09. The O&M cost came out to be $126,887.75/year. The capital cost estimate (Table 5) for making the combined cut out of Ross Island came out to be $2,857,790.00. The O&M cost came out to be $286,438.75/year. Excavation costs were estimated using the volumes of 1,539,179.12 ft^3 from the single cut and 3,493,041.88 ft^3 from the combined cut that were found using GIS. The price of armoring the cuts was the same as excavation at $8.48 per cubic yard (“Building Construction”). Skilled labor was assumed to be worth $57.67/hr from RSMeans data (“Building Construction”) and it was assumed that it would take 3 8-hour days for 3 workers to complete the excavation and armoring. Operations and maintenance costs were built around re-armoring the cut every 5 years, so costs are multiplied by ⅕ to account for the yearly cost. A 30% contingency allowance for both capital and O&M costs was used to cover any unanticipated work and/or potential for change in construction costs/needs.

The 30% contingency was carried over to the non-hydraulic solution (Table 6) for consistency. The capital cost estimate for adding alum to the lagoon came out to be $176,749.77. The O&M cost came out to be $22,093.72/year. The price of alum/acre and the need to re-apply the alum dosage every 8 years came from a brochure for Alum treatments to control phosphorus in lakes (“Alum Treatment”). Alum will be applied by 2 laborers over a 4 hour period in boats rented from the Portland Electric Boat Company for $125/hr (“Boat Rentals”). Once the alum is spread over roughly 300 acres of water, the boats will be driven around the lagoon for the remainder of the 4 hours to promote mixing of the alum in the water.

The wetlands at Ross Island Lagoon are integral to bird species (Canada geese, ruddy ducks, northern pintail, bald eagle, and Killdeer), animals (Red-legged frog, Pacific tree frog, river otters, deer, mink, and beavers), and plants (Broad-leafed pondweed, water plantain, American sloughgrass, and Englemans spike-rush) (US Fish and Wildlife Service). The lagoon is home to many aquatic species which are listed as sensitive, threatened or endangered. A brief list of the aforementioned aquatic species include: Oregon Lamprey, Sturgeon, Steelhead, and many salmonid species. The addition of either 1.13 acres of riparian habitat produced from the southwest breach or 3.68 acres of riparian habitat produced from the combined northwest and southwest breach would benefit the bird and animal species since it would provide a larger area for them to inhabit. Both hydraulic and non-hydraulic solutions would benefit all aquatic species listed as each of them would benefit from improved water quality and less toxicity if the HABs are treated.

To create a viable hydraulic solution, an excavation depth of 10 meters will be required. Water will likely need to diverted from the site of excavation (NIWA 2016). Temporary roads will need to be created on the lagoon for excavation equipment (NAP.edu). This will require that more acres land of the lagoon, than that of what is being excavated and relocated on the lagoon, be temporarily converted for transportation. A temporary change in the ecological condition near the site of excavation is expected. Abiotic components likely to be impacted as a result of construction equipment are soil compaction and soil moisture (NAP.edu). Persistent movement of construction equipment will deter birds and animals from occupying wetland areas near the site of excavation on the lagoon. The project impacts will be compared to habitat needs. Limiting factors will be summarized to identify how the project benefits each aquatic organism.

The non-hydraulic alternative of using alum relies on the proper dosing of alum needed for the alum to form flocc with the HAB and settle to the bottom of the lagoon. The presence of aquatic life limits the amount of alum treatment that can be applied in the lagoon. Many studies have concluded that fish and macroinvertebrates are impacted by aluminum if the pH in the water drops below 6, because below that pH a toxic dissolved aluminum (Al^{3+}) forms (Bischoff and Beck). Proper balancing of pH is needed to ensure the success of alum application. Generally, when a mostly stagnant body of water, such as a lake or lagoon, has been dosed with alum, a large initial decrease in benthic macroinvertebrate community is observed. Following the initial decline of benthic species, is a significant increase in water quality, followed gradually by a complete recovery of taxa richness to levels often exceeding pretreatment values (Bischoff and Beck). Aluminum has not been shown to bioaccumulate in algae or fish tissue (Bischoff and Beck). Bioturbation from fish and unusually high flows may cause the resuspension of sedimentmented flocc. If alum worked to control HABs, the aquatic organisms will benefit from increased water quality.

Downstream human health effects will not be impacted as a result of alum dosing, because the average adult ingests roughly 8 milligrams of aluminum per day in their food. The FDA has listed aluminum as a safe food additive.

As the conclusion of the PFMA analysis, three potential failure modes were identified, based on their calculated RPN, as failure modes which presented a greater risk. Excessive scour near site of the proposed hydraulic solution and inadequate flows needed to provide Richardson number destratification tied for the highest RPN with a calculated value of 48. The chemical solution process step which has the highest RNP, with a calculated value of 40, was the potential underperforming efficiency of Phoslock and alum.

There are some uncertainties in the confidence of the ranked RPNs, which come from the inherent variability that arises when working with biological and environmental systems. However, it is reasonable to assume that a likely result of altering the current channel geometry is that scour may occur in regions where the geometry of the river was altered. It is uncertain, but reasonable to assume, given the annual severity variability of harmful algal blooms, the dosing and frequency of a chemical solution may provide less-than-desirable treatment of the HABs.

Conclusion

After analysing our 3 alternatives, it was determined that the second hydraulic alternative with both of the terrain modifications will be the most effective. 3.68 acres of new riparian habitat would be produced by using this alternative that will benefit birds and land animals. Increased water quality will benefit aquatic life once algal blooms are treated. The opening of the island on both ends allows for more effective mobilization of the entire body of water and for an increase in the influence of tidal pumping during the low flows. Because of the approximate locations of the CAD cells, further research needs to be done on the safety of the southwest breach. However, assuming that it is safe and the CAD cells will not be breached, this design will have a large beneficial effect on the HABs in the lagoon.

Appendix

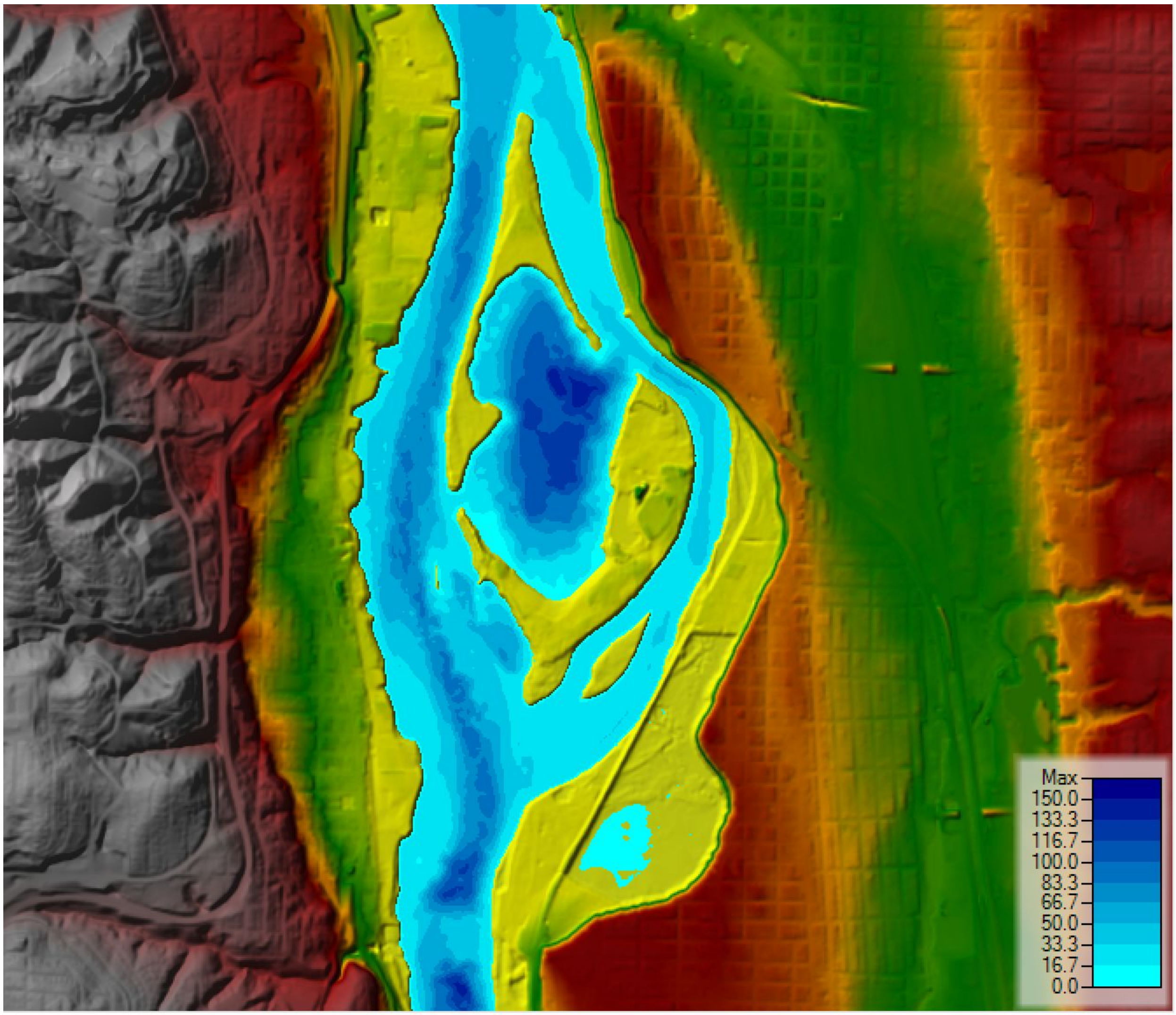

Figure 1 : Southwest breach to the island, hydraulic alternative 1.

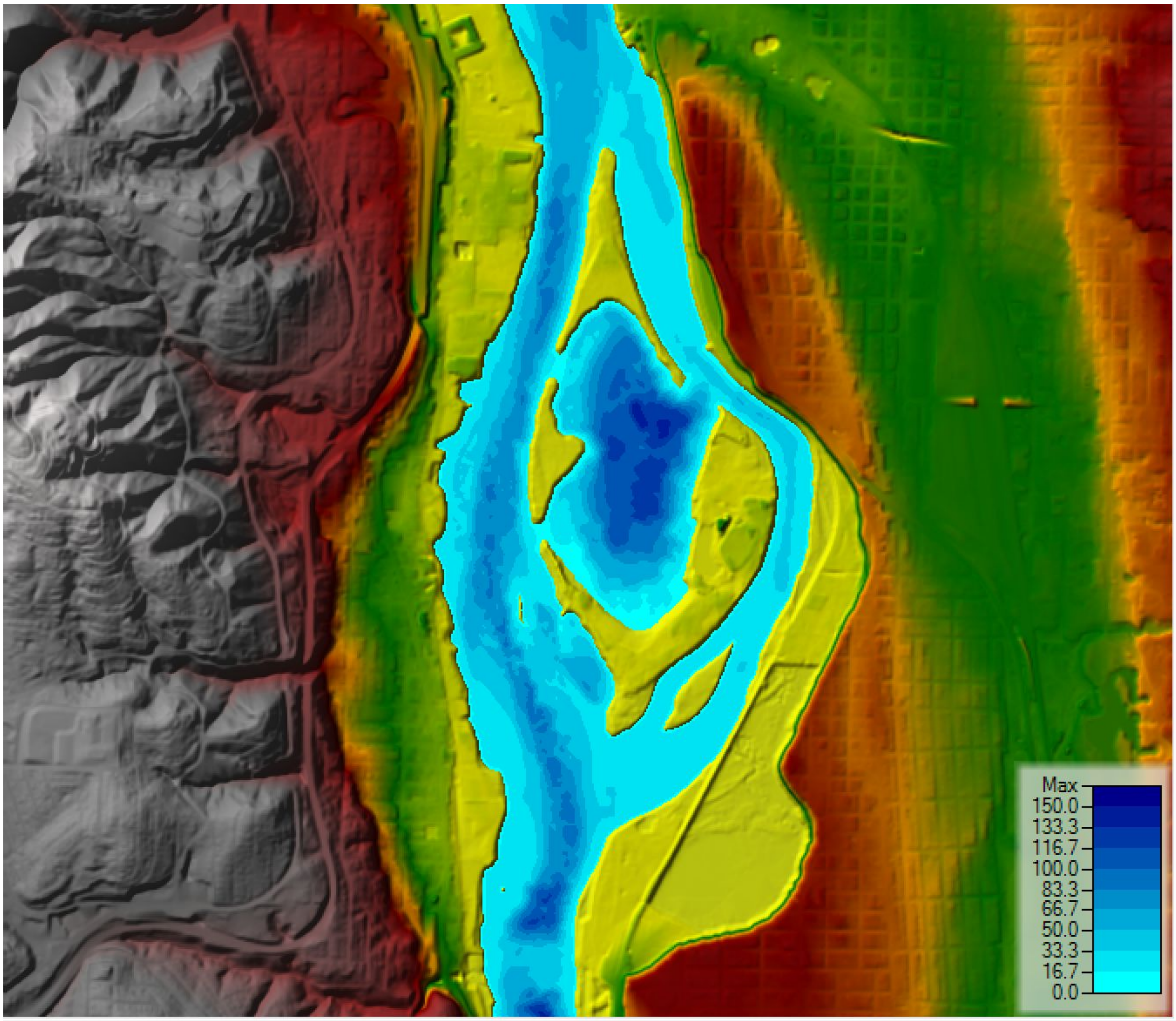

Figure 2: Southwest and Northwest breach, hydraulic alternative 2

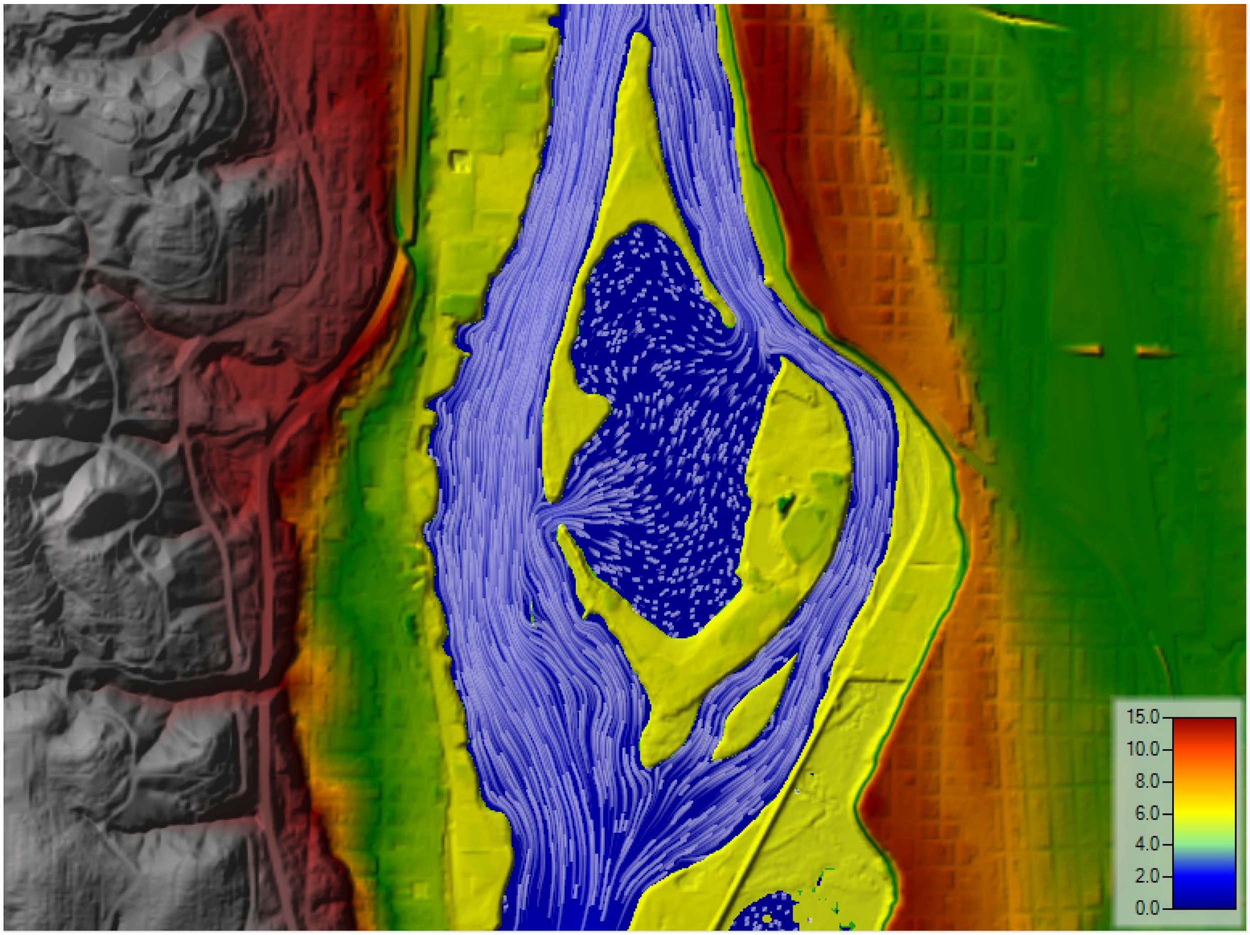

Figure 3: hydraulic alternative 1 flow lines.

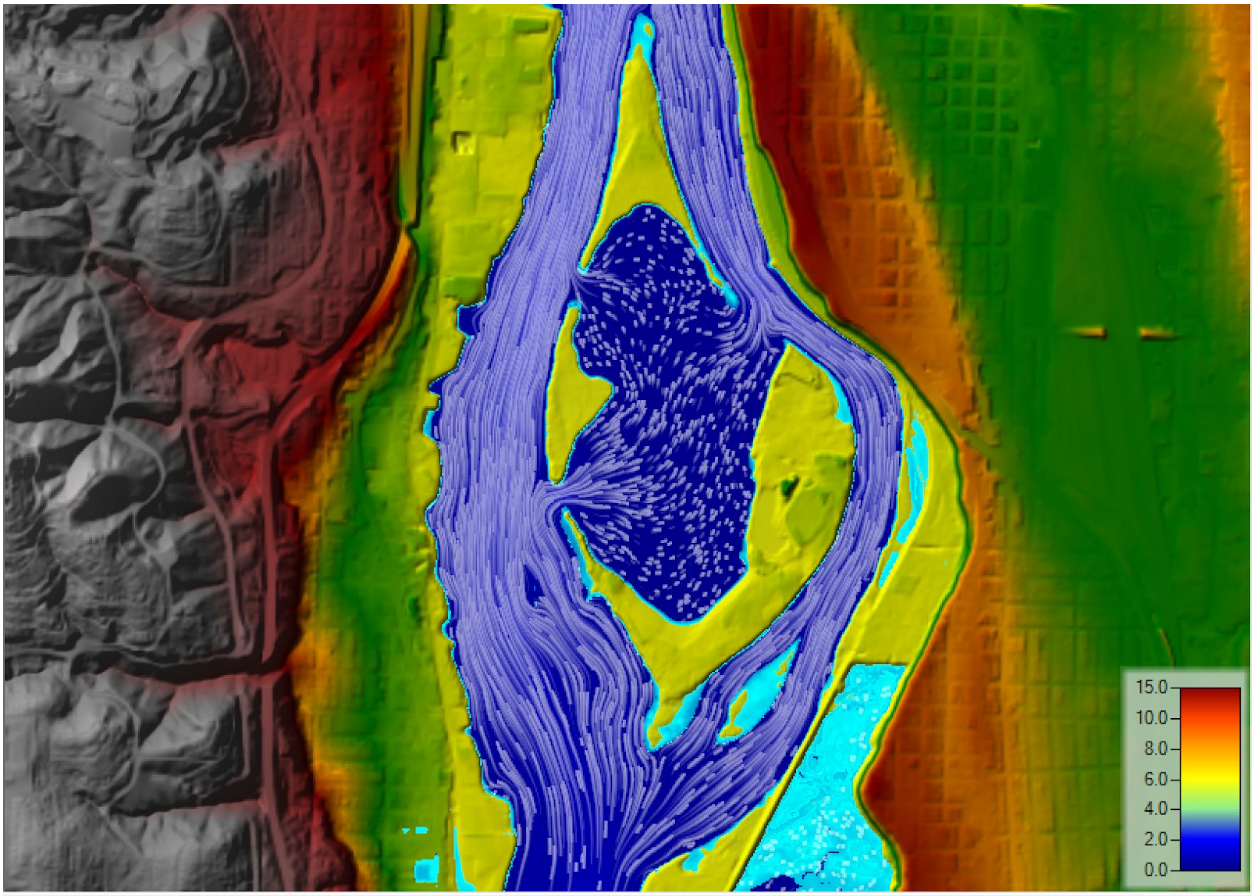

Figure 4: Hydraulic alternative 2 flow lines.

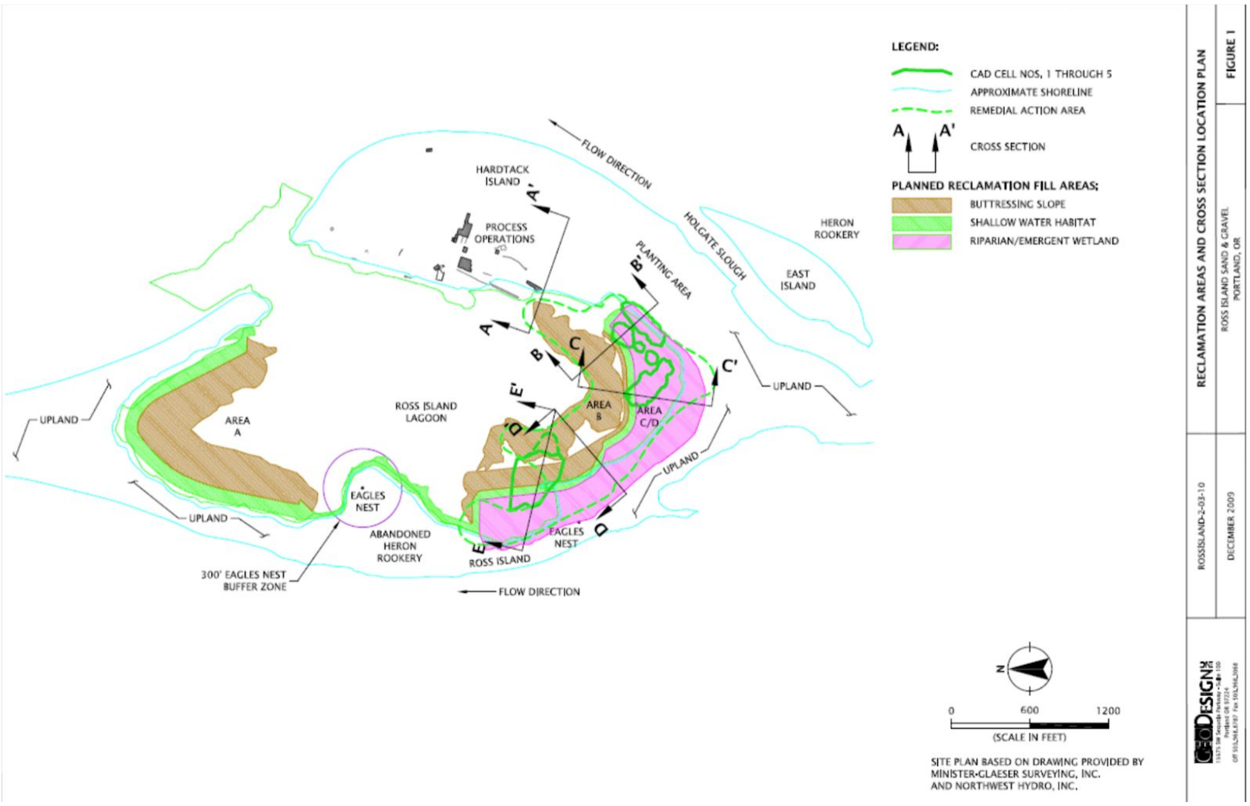

Figure 5: Approximate location of the CAD cells.

Table 2. GIS outputs from Southwest breach, hydraulic alternative 1.

1 cut		
total area removed	91,071	ft^2
Riparian area added	49,055.87	ft^2
Total volume removed	1,539,179.12	ft^3

Table 3. GIS outputs from combined Southwest and Northwest breach, hydraulic alternative 2.

2 cut (combined)		
total area removed	206,678	ft^2
Riparian area removed	111,328.31	ft^2
Total volume removed	3,493,041.88	ft^3

FMEA

Process/Product Name: Ross Island Lagoon | Prepared By: Matthew Huckins

Responsible: | FMEA Date (Orig.): 29-May

Alternative	Process Step	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 5)	Potential Causes	LIKELIHOOD (1 - 7)	Current Controls	DETECTION (1 - 5)	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	*Increased frequency of high flow events*	*Excessive scour at site of hydraulic solution*	*Decrease in Acrage of lagoon wetland at site of erosion*	*2*	*Hydraulic processes*	*6*	*Proper sediment size choice*	*4*	*48*	*design with a factor of safety*	
		Flooding of downstream side of lagoon wetland	*Damage to sensative ecosystem and loss of habitat*	*2*	*High flows, terrain characteristics*	*5*	*Willamette River Hydrograph (NOAA)*	*4*	*40*	*Proper hydraulic modeling techniques*	
		loss of constructed hydraulic vena contracta	*Decrease in effectiveness of hydraulic solution to dirvert flow into lagooon. Increase chance in stratification and HAB.*	*3*	*Hydraulic processes*	*3*	*Concrete vena contracta*	*4*	*36*	*Proper hydraulic modeling techniques*	
	Increased frequency of drought events	*River level too low for flow to adequately enter the lagoon*	*Stratifiaction will persist and HAB will continue*	*3*	*Low flow conditions*	*3*	*Proper hydraulic modeling and design*	*4*	*36*	*Ensure adequte depth*	
		moderately Insufficient flows	*Partial destratifiaction and moderate HAB*	*2*	*Lower than needed flow conditions*	*5*	*Phoslock and/or induced flow*	*4*	*40*	*Reshape lagoon to provide more reliable flows*	
		Flow into lagoon inadequate to provide richard # mixing	*Stratifiaction will persist and HAB will continue*	*3*	*Low flow conditions*	*4*	*Proper hydraulic modeling and design*	*4*	*48*	*Flow modification to direct flow*	
Chemical Solution: Phoslock and Alum Solution	*Underperforming efficiency of Alum and phoslock*	*Possible ineffectiveness of phoslock and alum*	*Reapplication costs, hault of aquatic recreation.*	*4*	*Not enough alum and phoslock used*	*5*	*Proper treatments given size of the bloom and the area of application*	*2*	*40*	*Reconsideration of dose and frequency of application.*	
	Unexpected flushing of lagoon	*Transport of concentration down river*	*Loss of aquatic life and unsafe conditions*	*1*	*Unexpected rainfall furing dry season*	*3*	*None*	*5*	*15*	*The solution to pollution is dilution*	
	Aquatic Life Toxicity	*Can be toxic for fish leading to fish mortality*	*Potential death of aquatic life*	*2*	*Water pH rises above 8.2*	*2*	*Proper treatments given size of the bloom and the area of application*	*2*	*8*	*Identify maximum safe concentration for aquatic species*	

Figure 6: Failure Mode and Effects Analysis

Table 4: Capital and O&M cost estimates for the proposed hydraulic solution 1.

Hydraulic Solution 1			
Capital Cost:			
Item	**Units**	**Price**	**Cost**
Excavation	CY	$8.48	$483,416.22
Armoring	CY	$8.48	$483,416.22
Labor	hr	$57.67	$4,152.24
		Contingency 30%	$291,295.41
		Total	$1,262,280.09
Operation and Maintenance Cost Per Year:			
Item	**Units**	**Price**	**Cost**
Re-Armoring Every 5 Years	CY	$8.48	$96,683.24
Labor	hr	$57.67	$922.72
		Contingency 30%	$29,281.79
		Total	$126,887.75/year

Table 5: Capital and O&M cost estimates for the proposed hydraulic solution 2.

Hydraulic Solution 2			
Capital Cost:			
Item	**Units**	**Price**	**Cost**
Excavation	CY	$8.48	$1,097,073.88
Armoring	CY	$8.48	$1,097,073.88
Labor	hr	$57.67	$4,152.24
		Contingency 30%	$659,490.00
		Total	$2,857,790.00
Operation and Maintenance Cost Per Year:			
Item	**Units**	**Price**	**Cost**
Re-Armoring Every 5 Years	CY	$8.48	$219,414.78
Labor	hr	$57.67	$922.72
		Contingency 30%	$66,101.25
		Total	$286,438.75/year

Table 6: Capital and O&M cost estimates for the proposed non-hydraulic solution.

Non-Hydraulic Solution			
Capital Cost:			
Item	**Units**	**Price**	**Cost**
Alum	acre	$450	$135,000
Boat Rental	boat/hr	$125	$500
Labor	hr	$57.67	$461.36
		Contingency 30%	$40,788.41
		Total	$176,749.77
Operation and Maintenance Cost Per Year:			
Item	**Units**	**Price**	**Cost**
Re-Apply Alum Every 8 Years	acre	$450	$16,875
Boat Rental	boat/hr	$125	$63
Labor	hr	$57.67	$57.67
		Contingency 30%	$5,098.60
		Total	$22,093.72

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