Ross Island Harmful Algal Bloom (HAB) Design Project

Clients: City of Portland Oregon and
Ross Island Sand and Gravel

Bee 446/546: River Engineering, OSU
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1. Introduction

Ross Island, one of the main islands within the Willamette River in Portland, Oregon, currently experiences seasonal harmful algal blooms within the island's interior lagoon. Harmful algal blooms, or HABs, occur when colonies of algae grow out of control while producing toxic harmful effects on people, fish, shellfish, marine mammals, and birds (NOAA, 2009). Additionally, HABs usually occur within stagnant waters, making this specific HAB occurrence within the Ross Island lagoon very unique due to the fact that this island is located within a large river.

1.1. Objective

The objective of this analysis is to identify practicable solutions to reduce the frequency and duration of HABs at Ross Island lagoon, while considering the major constraints of the location. These major constraints include protecting current CAD cells located on the island, minimizing conflict with Ross Island Sand and Gravel (RISG) operation, and protecting the existing varied habitat types. The alternatives analyzed within this project include a hydraulic, non- hydraulic, and a no action alternative. Additionally, though this HAB contamination is considered to have no responsible party, the City of Portland and RISG are recognized as the clients for this project.

2. Methods

2.1. Hydraulic Model (Existing Conditions)

A 2-D HEC-RAS model was used to model the existing conditions within the Ross Island lagoon. This modeling was completed by entering a terrain file into HEC-RAS, computing a mesh over the top to represent the calculation grid, then adding the upstream and downstream boundary conditions. These boundary conditions were provided by the flow hydrograph and stage data from USGS, allowing water to flow in and out of the mesh. Additionally, in order to increase the stability of the model, the courant number was adjusted; however, it is noted that this adjustment of the courant number leads to a reduction of model accuracy.

2.2. Alternatives Analysis

Certain calculation and modeling methods were necessary to perform an alternative analysis on the hydraulic alternative. These methods were applied in determining cost, habitat loss, flood event failure, and effectiveness of the alternative design. Cost estimation of the hydraulic alternative was completed using RSMeans 2019, 33rd Edition, as well as comparison with other similar projects. The amount of shallow water habitat impacted by the hydraulic design was calculated using GIS modeling. Using the definition of shallow water habitat within the Lower Willamette river as 20 feet or less of water, along with a provided elevation raster, the measurement tool was used to calculate the area the channel would extend in areas of water that were 0- 20 feet deep (Portland BES, 2016). The total amount of excavated land was also modeled using GIS. To calculate this excavated land, created contours (using 3D analyst) at the ordinary low water line (4-ft contour) were highlighted, as well as the invert elevation of the designed culvert. Results were exported to Excel and integrated into an estimated excavated volume. Additionally, the full design of the hydraulic alternative was modeled using the HEC-RAS 2D model used in Section 2.1. This modeling was completed using the provided Unsteady, 2D HEC- RAS Culvert Tutorial (Spann and Larson, 2019). Alternative analysis of the non-hydraulic design was completed using literature review and information given by a company in industry.

2.3. Failure Modes Analysis

Potential Failure Modes Analyses (PFMA) were conducted for the hydraulic and non- hydraulic alternatives using three main objectives: (1) to identify the design features of each alternative in a functional tree diagram, (2) to identify the potential failure modes of each design, and (3) calculate Risk Priority Number (RPN) using the provided rating tables (as defined by the U.S. Department of the Army Corps of Engineers). As rankings were assigned for each failure mode, each score was multiplied together to receive an RPN. The higher the RPN, the greater the risk for that specific failure.

3. Hydraulic Conditions in Lagoon

Ross Island's existing conditions were modeled within a HEC-RAS 2D Model. Results concluded that the tide has significant effects on the ability of the water to mix and flow easily through the lagoon. This process is due to the backwater process that pushes water back into the lagoon at its entrance, minimizing mixing that is necessary in preventing stratification. Due to the low flows seen in the lagoon, it can be assumed that stratification is surely present, and that lack of mixing is present due to the deep depth of the lagoon. Figure A.1 and A.2 of the Appendix display the 2D HEC-RAS aerial results of the varying velocities and depths of the lagoon, respectively. These results confirm the hypothesis of why HAB blooms are present during the low flow season within the lagoon.

4. Hydraulic Alternative Analysis

4.1. Design

The hydraulic alternative for the Ross Island project involves excavating a concrete channel with a tilting weir gate within the southwest portion of the lagoon. The goal of this alternative is to redirect flow during the low flow season from the river into the lagoon to increase mixing and breakup the lagoon stratification. With the use of the tilting gate, the flow into the channel can be controlled automatically by an operator. Additional benefits in using a tilting weir gate include simple installation and very little maintenance (Aquatic Control Engineering). The functional design tree diagram, shown in Figure B.1 of the Appendix, also presents additional major design features. The proposed channel design is 450 ft. x 25 ft. x. 12 ft., at a proposed located shown in Figure B.2. A conceptual drawing of this design is shown in Figure B.3. The width and depth dimensions were chosen to maximize jet- like flow conditions into the lagoon to enable mixing.

4.2. Cost (Capital and O&M)

Cost estimates for the hydraulic alternative were estimated using RSMeans 2019 and available case studies, as shown in Table B.1 of the Appendix. These cost estimates are broken down into six categories including equipment, labor, mobilization, materials, dewatering systems, and maintenance. Maintenance cost of the hydraulic alternative is estimated at $25,578. The total cost (not including maintenance) of the hydraulic alternative is estimated at $388,420, with the canal lining (polyfiber reinforced shotcrete), tilting gate, and concrete as the greatest cost contributors.

4.3. Habitat Loss

Assuming shallow water habitat is defined as 20 feet or less of water, the amount of shallow water habitat predicted to be threatened by the hydraulic alternative is approximately 0.08 acres (estimated using GIS). Figure B.2 displays the representation of this impacted habitat with the overlying channel area. Additionally, 7.8 acre-ft (341740 ft^3) of land habitat is predicted to impacted by the excavation of the channel (GIS results shown in Figure B.4). This excavated volume is proposed to be moved to the northern tip of the lagoon to create additional shallow water habitat and replace the shallow water habitat impacted by the channel. The goal of replacing the shallow water habitat is to approximately replace every one acre of impacted habitat with two new acres of habitat (2:1 ratio).

4.4. Effectiveness

The HEC- RAS 2D model was used to model to determine the effectiveness of implementing a channel within the SW portion of the lagoon. As previously stated, the goal of this alternative is to create a jet- like flow into the lagoon, increasing mixing and reducing stratification. Effectiveness of the channel can be visually interpreted from observing the modeled velocity vectors, and as presented in Figures B.5 and B.6, this channel design is observed as ineffective. An estimated measurement of velocity vector spreading shows that surface mixing only occurs up to about 300 feet away from the opening of the channel. These results are most likely due to the extreme depths of the lagoon (120+ ft.) and the ability of this depth to quickly absorb all of the forward energy created by the jet. The surface channel design may have more successful results if the channel was deepened or widened, yet doing this will increase excavation and material costs and could potentially draw the main river channel through the lagoon.

Additionally, in determining the effectiveness of the channel design on stratification, an estimation of the Richardson's number was performed. The Richardson number is considered as the ratio of the buoyancy term to the shear term (vertical and lateral mixing). Profile lines were cut along the proposed channel outlet and the outlet of the lagoon for both pre- and post-channel design conditions. The resultant water surface and velocity profiles were observed at these cross sections to determine values for the Richardson number calculations. Table B.2 presents the calculated Richardson numbers for the pre- and post- channel scenarios. It is observed that all Richardson numbers are obscenely high, meaning the buoyancy and vertical mixing in the water profile to break up stratification is very insignificant at each analyzed location. Additionally, the Richardson number is observed to actually increase with the addition of the SW conveyance, meaning the lagoon mixes better in its existing condition than the implemented design, which is certainly not as hoped or expected.

4.5. Flood Event Failure

To determine the durability of our proposed design against various flow events, flow data from USGS for August, December, and April was entered into the HEC-RAS 2D model proposed condition. The model was unable to be fully successfully calibrated. Velocity values were extremely fast, but the water depths appeared slightly more accurate. April had the highest water surface elevation (Figure B.7), and therefore, the highest shear forces to cause bank erosion. The shear forces for the lagoon's regular regime are so low that they can usually be considered inconsequential, but they become relevant as the discharge increases. The sidewalls for our design are high (40ft - Ross Datum) and steep, which keeps our design from being fully submerged and swept downstream, however, the increased shear stress would increase erosive forces and could lead to structural instabilities and increased sedimentation. Exposure of the dangerous CAD cells due to erosion is also of high concern. This only seems to be the case with the April flow event, both the December and August (lowest flow - Figure B.8) events have relatively manageable water surface rise in terms of the proposed channel.

4.6. Aquatic Taxa Benefits

As the purpose of the hydraulic alternative and channel conveyance is to increase flow into the lagoon, this new mixing of the water column is expected to reduce algal blooms (ideally). When these blooms are controlled, competition within the lagoon is reduced, benefiting the development of other phytoplankton species in the water column. With the increased growth of phytoplankton, zooplankton growth will increase, and planktivorous fish and piscivorous fish will be benefited.

4.7. Unintended Impacts

Unintended impacts of the hydraulic alternative include impacting species of the shallow water habitat, as well as threatening the protection the CAD cells. Flow from the channel conveyance may increase scouring near the CAD cells, leading to eventual exposure.

4.8. Failure Mode Analysis

Using the functional design tree (Figure B.1), a PFMA was performed for this alternative. The PFMA analysis, shown in Figure B.9, concluded that the failure of closing the lagoon during high flows (whether due to mechanical or human error) resulted in the highest RPN value (RPN of 15). This failure has the highest severity due to the potential impacts of the lagoon capturing the river, resulting in threatening the protection of the CAD cells, habitat, and navigability. A loss of navigability through the lagoon can greatly impact the operation for Ross Island Sand and Gravel (RISG), resulting in the highest severity ranking due to the potential economic loss. Additionally, failure related to the sealing of the channel and gate, as well as debris blockage, resulted in the next high RPN value of 12.

5. Non- Hydraulic Alternative Analysis

5.1. Design

The non- hydraulic solution for the Ross Island project involves the use of solar- powered ultrasonic technology, located on anchored pontons within the lagoon (shown in Figure C.1 of Appendix). This technology works by sending off ultrasound waves that create a sound layer within the top layer of the water, directly impacting the buoyancy of the algae (LG Sonic, 2017). Algae cells then sink to the bottom and are unable to photosynthesize, eventually dying due to a lack of sunlight (Figure C.2). Though not a well known technology, ultrasound has been recognized as a highly effective blue- green algae removal method within industry, including uses for many drinking water reservoirs and wastewater ponds (Zimba, 2013). The literature contains over 50,000 results on Google Scholar regarding ultrasound technology, though the effectiveness still continues to be researched and further understood.

For this project, SonicSolutions LLC was contacted for further specifics regarding ultrasound technology. Following numerous conversations regarding the Ross Island lagoon site, SonicSolutions recommended the use of two solar pontoon floats, each with Quattro- DB units (the ultrasonic transducer). These Quattro- DB units have a 150- meter radial control range of green and diatom algae, and a 400- meter radial control range of blue- green (cyanobacteria) algae, as presented in Figure C.3 for the Ross Island site (Assael and Hutchinson, 2019). As the Quattro- DB transducer is the main working design feature of the ultrasonic system, additional design features include the anchor, pontoon with navigable light and bird deflectors, solar panels, battery box, and a buoy. These design features are also presented in the functional design tree shown in Figure C.4 of the Appendix.

5.2. Cost (Capital and O&M)

The total cost of the multiple solar pontoon float system was estimated by SonicSolutions at $28,340.00. This cost includes two 180- Watt Pontoons with Quattro- DB transducers and shipping (see Figure C.5 of the Appendix for the cost table given by SonicSolutions). Additionally, SonicSolutions offers a 3- month rental program that gives the option to buy the units outright or return them after the rental period. If the units are purchased following the renting period, the rental cost is applied to the total cost of the unit. The total cost of the rental option is $15,350.00 (see Figure C.5 for the cost table given by SonicSolutions). Regarding the cost of operations and management, SonicSolutions did not provide an exact cost, though monthly monitoring of the instruments are recommended and a 3- year full warranty is provided.

5.3. Habitat Loss

As the ultrasonic system is placed on an anchored pontoon within the lagoon, no shallow water habitat is expected to be loss with the use of the instrument (0 acres of habitat loss).

5.4. Effectiveness

As the objective of this project is to reduce the duration and frequency of seasonable HABs within Ross Island lagoon, analyzing the effectiveness of each alternative is critical. A benefit of using the Quattro- DB transducer is its ability to output 2000+ varying frequencies versus other transducers that may only output up to 20 frequencies (Assael and Hutchinson, 2019). The ability for more frequencies can allow for targeting a wider range of bacteria if necessary. When looking at the true effectiveness of ultrasonic methods for removing algae, both literature and case studies provided by SonicSolutions show reduction in blue- green algae. Wu et al. provides a helpful summary and review of ultrasonic conditions for algae removal (shown in Figure C.6 of the Appendix). Though Wu. et al. provides studies completed within only 400-1000 mL, results showed a 100% reduction in cyanobacteria and 15-61% reduction in Microcystis, depending on frequency. Figure C.7 of the Appendix presents results from a SonicSolutions case study performed by Paul V. Zimba, a professor at Texas A&M University Corpus Christi. This figure displays the results of Microcystis cell counts for an installation of a SonicSolutions product within a 2- acre pond. It is observed that by the end of the ultrasound experimentation, cell densities of Microcystis declined to levels below detection (<1 cell/mL). Though ultrasonic technology has the ability to be highly effective, due to uncertainty and need for further research, the expected effectiveness for this site is considered medium.

Additionally, SonicSolutions expects existing blue/green and/or filamentous algae to be eradicated in a period of 3 to 5 weeks. Though once the water is clear of existing algae, minor additional blooms may be observed as pre- existing algae spores on the bottom of the pond are being warmed by the new direct sunlight. These new minor blooms are expected to be eradicated within 2 weeks. When observing the literature of this topic, Wu et al. and Paerl et al. mention algae eradication between 2-6 months when using ultrasonic methods.

5.5. Flood Event Failure

The ultrasonic instrument has the ability to just be implemented seasonally (low flow season for algal bloom) or to be implemented all- year long. If the instrument was implemented all- year long, for both low and high flow season, the ability for the pontoon system to float up and down with water levels would result in a low likelihood of failure during flood events. Additionally, if the instrument was implemented only during the low flow season, the likelihood of failure during flood events would be even lower.

5.6. Aquatic Taxa Benefits

There is a variety of conflicting literature regarding the expected impacts of ultrasonic technology on aquatic species. Studies have shown some reduction on Daphnia using certain frequencies (Luring and Tolman, 2014), though some studies have also concluded that there is no negative effects on Daphnia (Oosterbaan, 2017). Studies have also shown no effect on fish, including steelhead and salmonids (Zimba and Grimm, 2008).

5.7. Unintended Impacts

Unintended impacts of the ultrasonic technology may include impacts towards diatoms (foundation of the food chain), Daphnia (zooplankton), and snails. As stated earlier, the Quattro-DB transducer does have the ability to kill green and diatom algae within 150- meters of the instrument; however, as seen in Figure C.3, fortunately, this radius only accounts for a small portion of the lagoon. Additionally, a study regarding ultrasonic use on algae found a significant effect on snails (Goodwiller and Chambers, 2012).

5.8. Failure Mode Analysis

Using the functional design tree (shown in Figure C.4), a PFMA was performed for this alternative. The PFMA analysis, shown in Figure C.8 of the Appendix, concluded that failure modes related to the ultrasonic technology are low, only ranging from 2-4 RPN values. Note, that each of the failure modes had similar severity rankings, with the only difference being within the ability to detect the specific failure. A few of the main failure modes include mechanical failure of the solar panel causing loss of power, mechanical failure of Quattro- DB transducer causing an inability to send ultrasonic waves, and the inability for the ultrasonic waves to effectively remove the HABs. Each of these failures result in an ineffective HAB removal method, leaving sustained blooms within the lagoon.

In comparison of the ultrasonic alternative to the hydraulic alternative failure mode analysis, failures are presented at a much lower risk. This is mostly due to the fact that the hydraulic solution is making the largest impact on the ecosystem, including being located on restored wetland habitat. Additionally, unlike the ultrasonic solution, the hydraulic solution has potential of affecting the CAD cells and impacting the operation of RISG which can lead to an economic loss. The failure modes of the ultrasound technology are mostly impacting the effectiveness of the product, and therefore though the removal of algae will be decreased, the impact towards habitat and RISG is very low.

A summary table of the hydraulic and non- hydraulic alternative analyses is presented in Appendix D.

6. No Action Alternative

If no action regarding algae removal methods is performed on the Ross Island lagoon, HAB conditions will continue to bloom seasonally. These continued seasonal blooms will leave this lagoon in impaired conditions year after year, leaving downstream water quality conditions questionable for recreational purposes if algae is swept out of the lagoon. Additionally, though the no action alternative is in respect to algal removal methods, action towards CAD cell protection is still necessary due to current scouring conditions.

7. Future Work and Data Gaps

Extended design and modeling analysis is highly recommended for the hydraulic alternative. Due to limitations and high complexity of the HEC- RAS 2D model, the effectiveness of this alternative was difficult to model and fully understand. The largest limitations of the HEC- RAS model include the fact that since it is only a 2-D model, only the flow of water across the lagoon surface is modeled. For a location like the Ross Island lagoon, with depths up to 130 feet, the 2D model is unable to model the mixing that is occurring beneath the surface, and therefore unable to fully understand the effectiveness of the hydraulic design. Data gaps and limitations were also present within GIS modeling for the hydraulic alternative, including not having a more recent terrain file, as well as not knowing the exact location of the CAD cells.

Regarding both of the alternatives, a different PFMA ranking system is recommended for this specific project. Though the USACE ranking template was a useful tool to get an overall idea of the associated risk for each failure, a different ranking tool more focused on the environment could have been more beneficial. The USACE rankings are mainly focused on impact on humans, which is critical, though not as prevalent for this project. Additionally, for either alternative, including the no action alternative, further inspection of the exact location of the CAD cells and current scouring conditions is critical.

8. Conclusion and Recommendations

In conclusion, three alternatives were analyzed with the goal of reducing HABs at Ross Island lagoon, including a hydraulic (SW conveyance), non- hydraulic (ultrasonic technology), and no action alternative. Each of these alternatives analyzed effectiveness, habitat disturbance, wildlife disturbance, protection of CAD cells, cost, maintenance, and likelihood of failure. Following the results of each these alternative analyses (shown in Appendix D), the non-hydraulic solution of ultrasonic technology is recommended as the most suitable and practicable solution in reducing the duration and frequency of HABs within the lagoon. In comparing the ultrasonic technology to the SW conveyance channel, the ultrasonic system is by far the more cost effective and less invasive solution. Additionally, as discussed previously, the PFMA results of the two alternatives concluded that the SW conveyance solution poses much higher risk compared to the ultrasonic alternative. The minimal literature on the effectiveness of ultrasonic technology used in practice is noted, though the rental- program provided by SonicSolutions could be a beneficial and cost-effective option to use as a trial.

9. References

Aquatic Control Engineering. Water Control Management: Tilting Weirs. https://www.aquaticcontrol.co.uk/products/tilting-weirs/.

Assael, D., Hutchinson, G., and SonicSolutions (2019, March). Applying Ultrasound Technology to Control Algae and Biofilm.

Bureau of Reclamation. (2001)vCanal lining demonstration project: Construction Cost Table.

Gordian. (2019) Building construction costs with RSMeans. 33rd edition.

Goodwiller, B. T. & Chambers, J. P. (2012) The Potential Use of Ultrasound to Control the Trematode *Bolbophorus confusus* by Eliminating the Ram's Horn Snail *Planorbella trivolvis* in Commercial Aquaculture Settings. *N. Am. J. Aquac.* 74, 485–488.

LG Sonic. (2017, November 28). How LG Sonic Ultrasound Technology Controls Algae. https://www.lgsonic.com/blogs/how-ultrasound-controls-algae/.

Lürling, M., Tolman, Y., Lürling, M. & Tolman, Y. (2014) Effects of Commercially Available Ultrasound on the Zooplankton Grazer Daphnia and Consequent Water Greening in Laboratory Experiments. Water 6, 3247–3263.

National Oceanic and Atmospheric Administration, U.S. Department of Commerce. (2009, November 16). Harmful Algal Blooms: Tiny Organisms with a Toxic Punch.

Oosterbaan, J. (2017) Memo: Field research regarding possible effects of ultrasonic sound on zooplankton.

Oregon Fences and Cost. ProMatcher Cost Report (2019) https://fences.promatcher.com/cost/oregon.aspx

Paerl, H. W. *et al.* (2016) Mitigating cyanobacterial harmful algal blooms in aquatic ecosystems impacted by climate change and anthropogenic nutrients. *Harmful Algae* 54, 213–222.

Portland BES (Bureau of Environmental Services, 2016). Characterization of Current and Historical Habitat and Biological Conditions in the Lower Willamette River through Portland.

Sangale, A., Valunjkar, S.. (May, 2015) Cost Effectiveness of Different Canal Lining Materials. International Journal of Engineering and Technical Research.

Spann, G., Larson, L. (2019) Unsteady, 2D HEC- RAS Culvert Tutorial. River Engineering, Spring 2019.

Wu, X., Joyce, E. M. & Mason, T. J. (2011) The effects of ultrasound on cyanobacteria. Harmful Algae 10, 738–743.

Zimba, P.V., Grimm, C.C. (2008) Ultrasound Tested in Channel Catfish Production Systems. Global Aquaculture Advocate.

Zimba, P. V. , and SonicSolutions (2013, May). How Ultrasonic Technology Kills and Controls Algae: Aquatic Weed Control Short Course.

10. Appendix A: Hydraulic Conditions in Lagoon

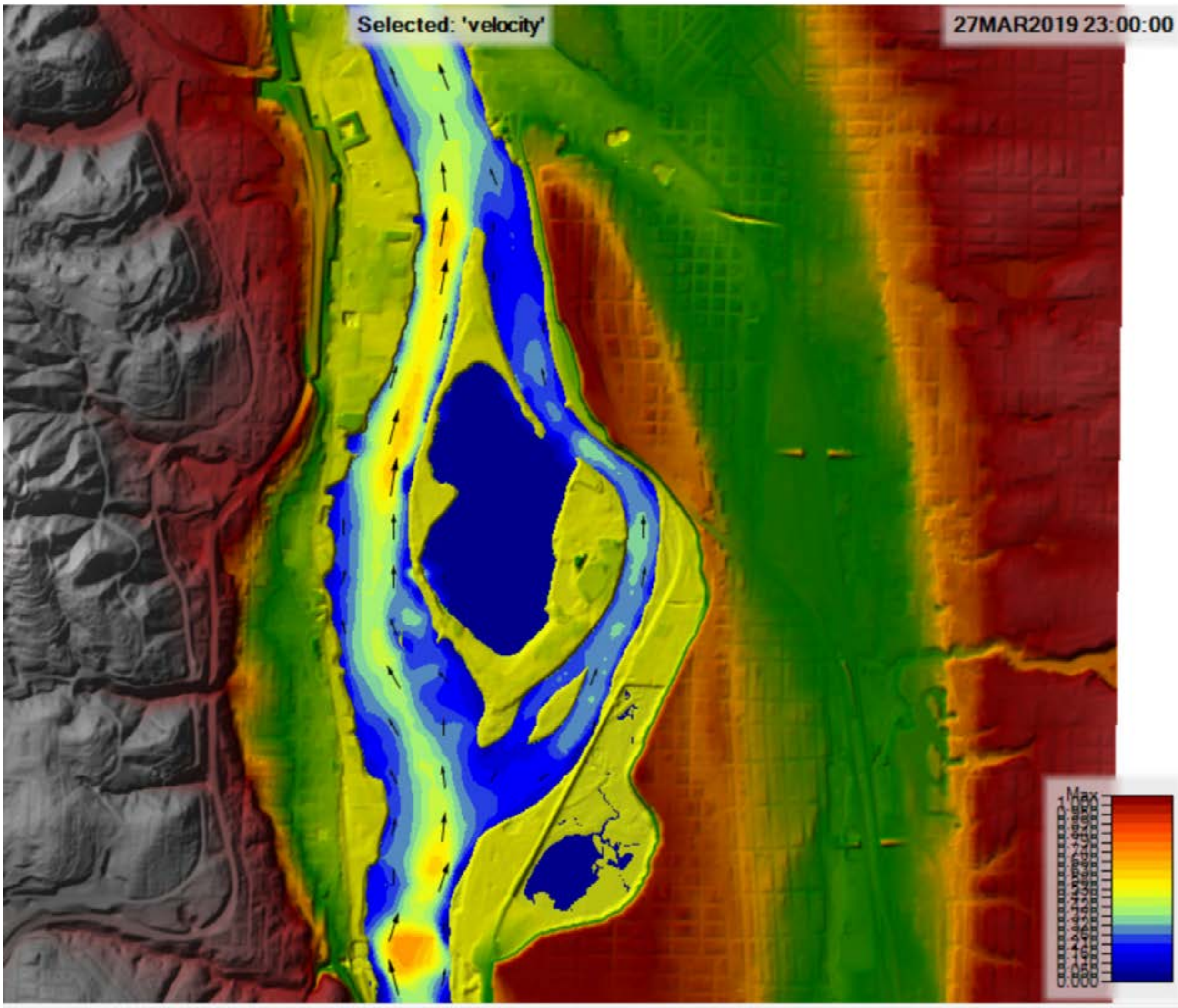

Figure A.1: 2D HEC-RAS modeled velocity results of the Ross Island lagoon.

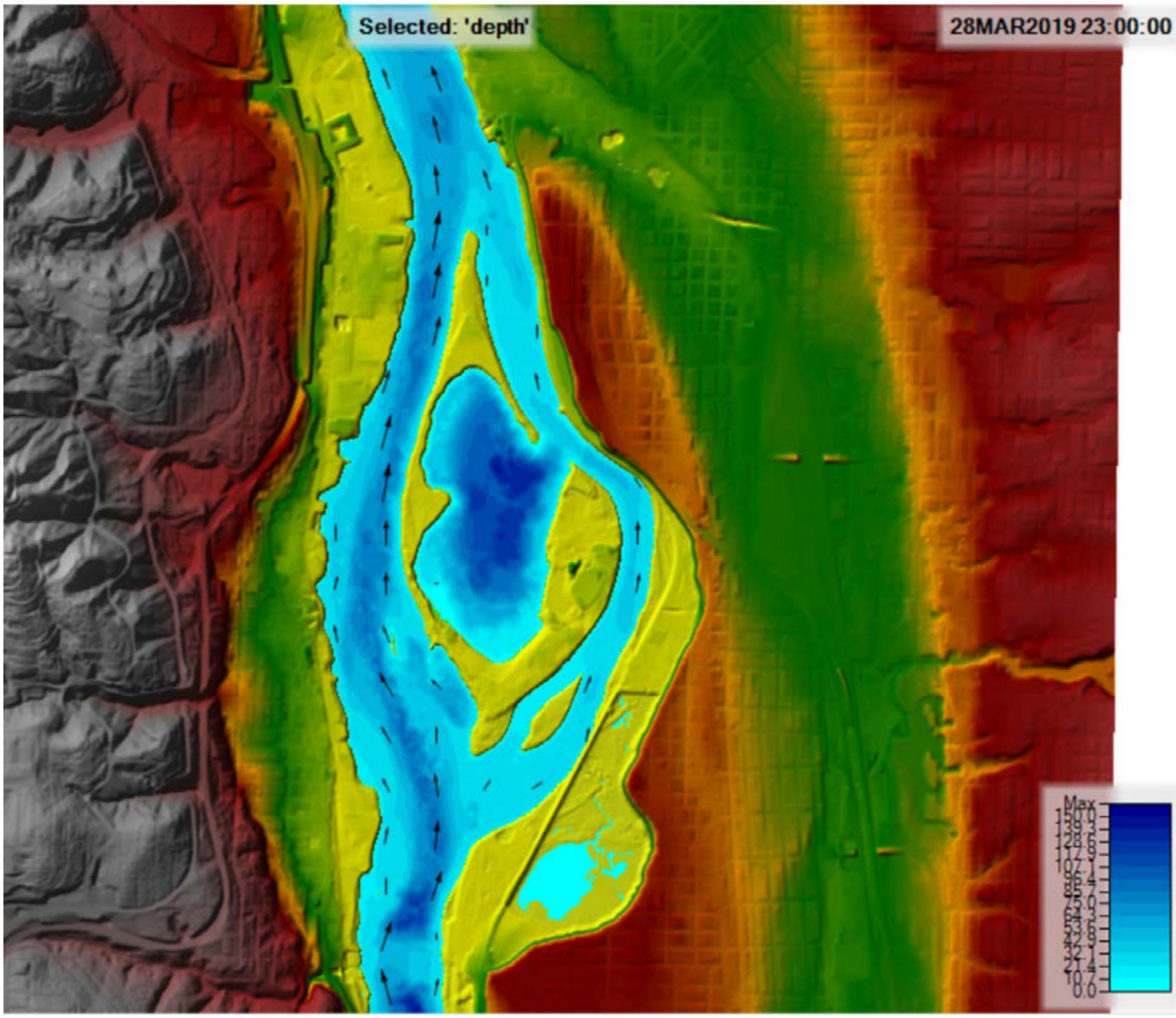

Figure A.2: 2D HEC-RAS modeled depth results of the Ross Island lagoon.

11. Appendix B: Hydraulic Alternative Analysis

Table B.1: Cost estimation of hydraulic alternative, including O&M and capital costs.

Component	Description	Unit	Price ($/unit)	Quantity	Bare Cost	Source
Equipment						
Hydraulic Excavator 2CY	80HP; Track mounted; Equipment only (no labor)	week	$3,095	2	$6,190	RSM, p.541
Dump Truck 2CY	Equipment only (no labor)	day	$541.80	3	$1,625.40	RSM, p.543
Concrete Mixer Truck	Delivery of concrete for canal, lining, and protection over CAD cells	week	$3,025	2	$6,050	RSM, p. 548
Dozer- 3C.Y. Capacity	Moving sediments into the new created habitat	week	$420	2	$840	RSM, p. 550
Labor/ Crews						
Heavy Equipment Operator	For excavator	Hour	$54.15	250	$13,537.50	RSM, p.541
Heavy Equipment Operator	For dump truck	Hour	$42.60	32	$1,363.20	RSM, p.543
Specialized Laborer	Placement and construction of tilitng weir gate; applying concrete	Hour	$52.35	180	$9,423.00	(Skwk in RSM); RSM, Back Page
Common Building Laborers	Placing canal liner; placing new habitat	Hour	$39.35	70	$2,754.50	(Clab in RSM); RSM, Back Page
Common Building Laborers	Tilting gate operator	Hour	$18	10	$180	Estimation
Mobilization						
Mobilization, large equipment	Transport and activation of excavator and dump trucks; up to 25 mi.; 20- ton capacity; Includes labor and equipment	Each	$602	3	$1,806	RSM p. 21
Demobilization	Transport and activation of excavator and dump trucks: up to 25 mi.; 20- ton capacity; Includes labor and equipment	Each	$602	3	$1,806	RSM p. 21
Materials						
Concrete	Liner and canal	94lb. bag	$13.40	8,666	$116,127.39	RSM, p. 53
Waterproofing	Waterproofing the concrete for better resistance to water and longer lasting cement	C.Y.	$22	226.85	$4,877	RSM, p. 53
Canal Lining- Polyfiber reinforced Shotcrete	Liner underneath the concrete to protect from sedimentation	square ft.	$0.87	22,050	$19,183.50	Outside source (Canal Lining demostration project)
Tilting/ Overshot Gate	25ft. wide canal gate	per foot width	$2,500	25	$62,500	U.S. Department of
Silt Fencing	Install prior to construction, maintain, and remove after construction (length along both sides of proposed canal)	LF	$1.40	800	$1,120.00	RSM, p. 241
Chain Link Fence	Safety fence for security purposes once canal is in place (length along both sides)	LF	$14.37	800	$11,496.00	Outside source (https://fences.promatcher.com/cost/oregon.aspx)
Dewatering System						
Dewater Construction Area	Includes pump, 20LF suction hose, 100 LF discharge hose	Day	$170.55	21	$3,581.55	RSM, p. 243
Maintenance						
Concrete Maintenance	Maintanance for the usual wear and tear that a concrete canal would be exposed	$/square ft/Year	$1.16	22,050	$25,578.00	Cost Effectiveness of Difference Canal Lining Materials (Sangale and Valunjkar, 2015)
City Cost Index (Portland, OR)	0.98					
O&M ($/year)	**$25,578.00**					
Bare Costs (with applied city cost index)	$259,172.09					
Contingency (15%)	$38,875.81					
O&P (25%)	$64,793.02					
Total Cost	**$388,418.93**					

Table B.2: Values from HEC-RAS used to calculate Richardson's number for mixing.

Location	u [ft/s]	g [ft/s^2]	h [ft]	Ri [-]
SW conveyance outlet	0.34	32.2	18.8	5236.678
Lagoon Outlet (existing)	0.24	32.2	57.75	32283.85
Lagoon Outlet (proposed)	0.22	32.2	57.75	38420.45

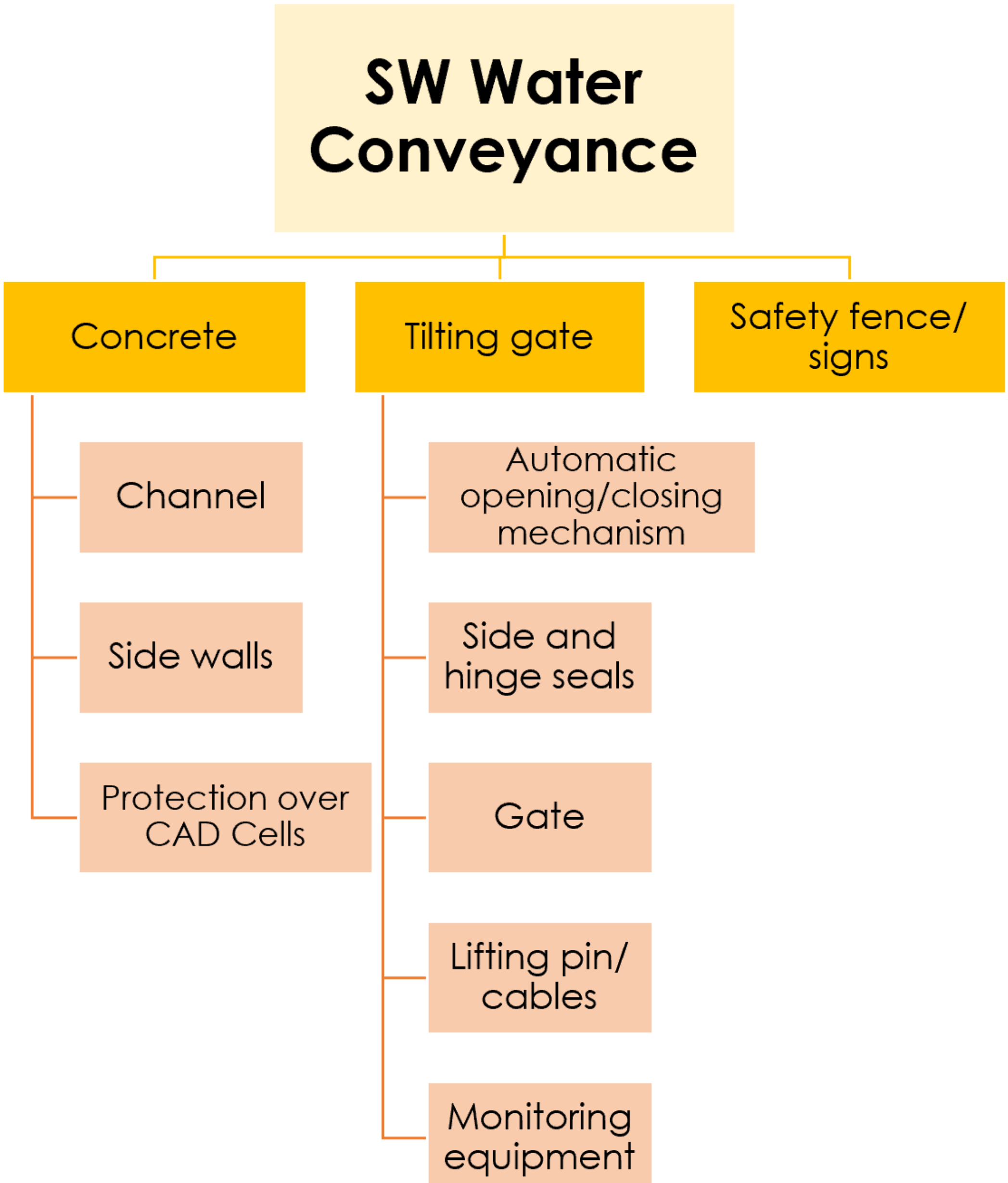

Figure B.1: Hydraulic alternative (southwest water conveyance) functional tree diagram, displaying design features.

Figure B.2: Map of proposed surface channel location in the SW portion of the lagoon; impacted shallow water habitat and location of replaced habitat is also shown.

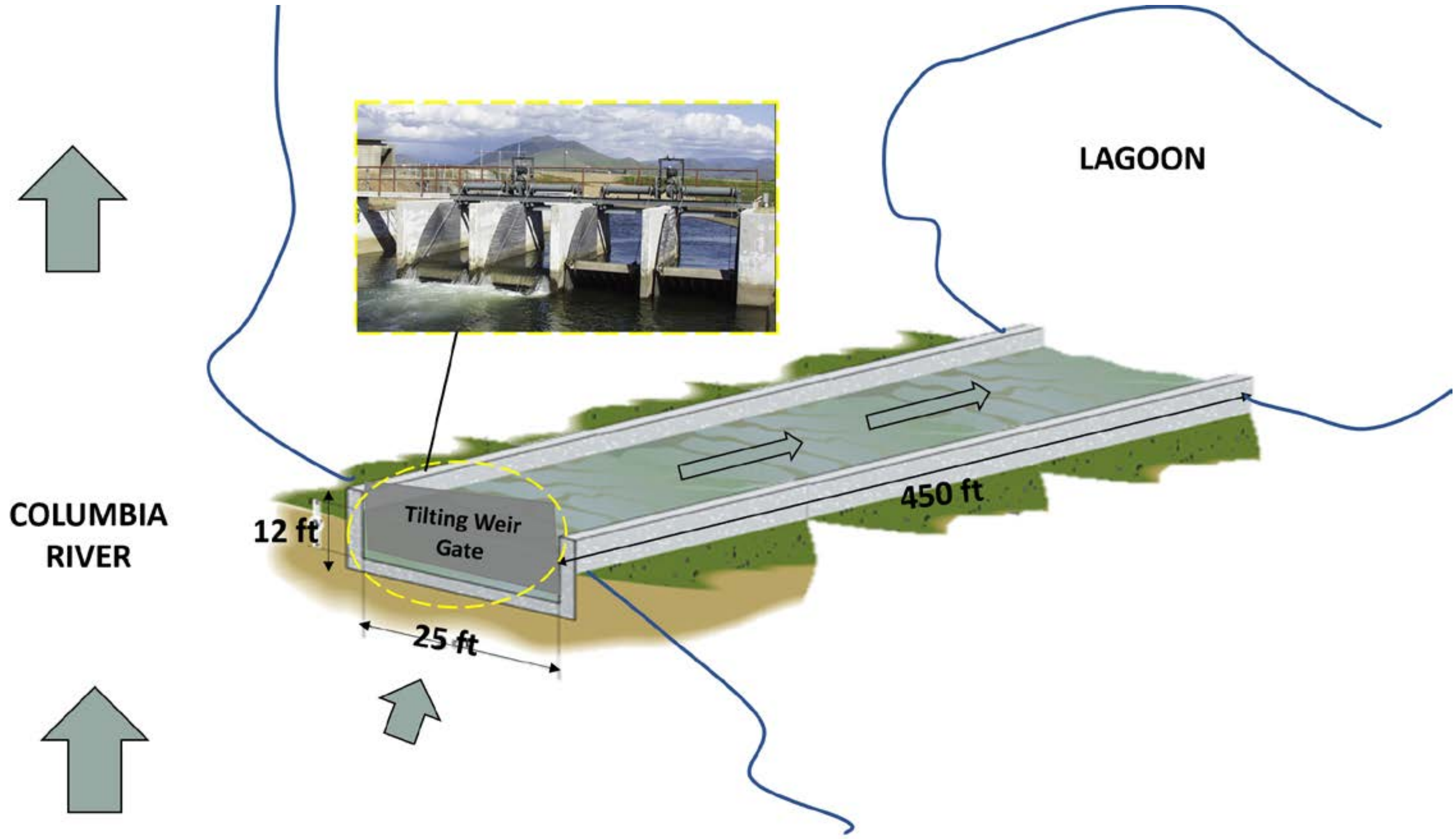

Figure B.3: Conceptual design of hydraulic alternative including a concrete channel within the SW portion of the lagoon, operated using a tilting weir gate at its entrance.

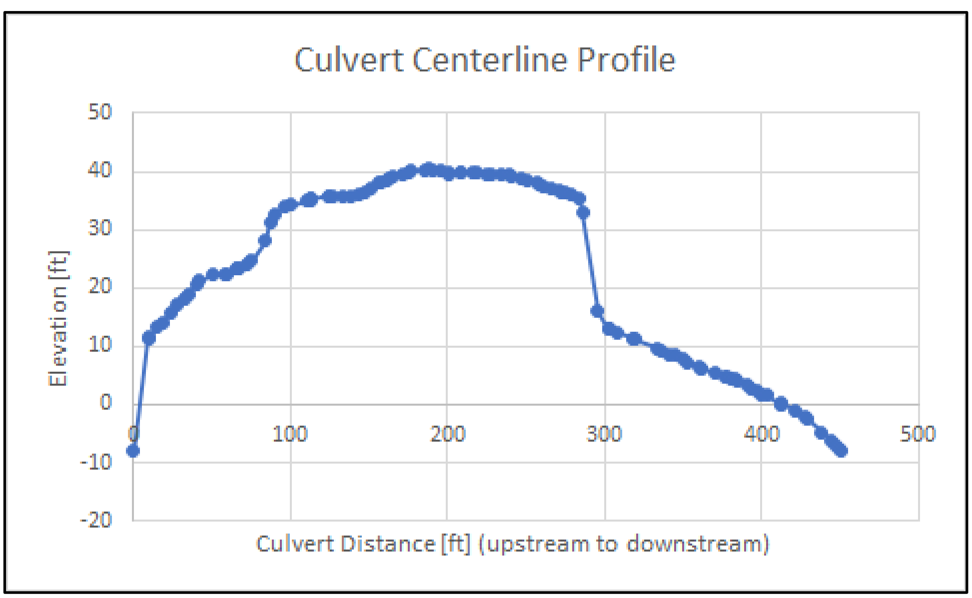

Figure B.4: Station elevation profile of the proposed channel centerline.

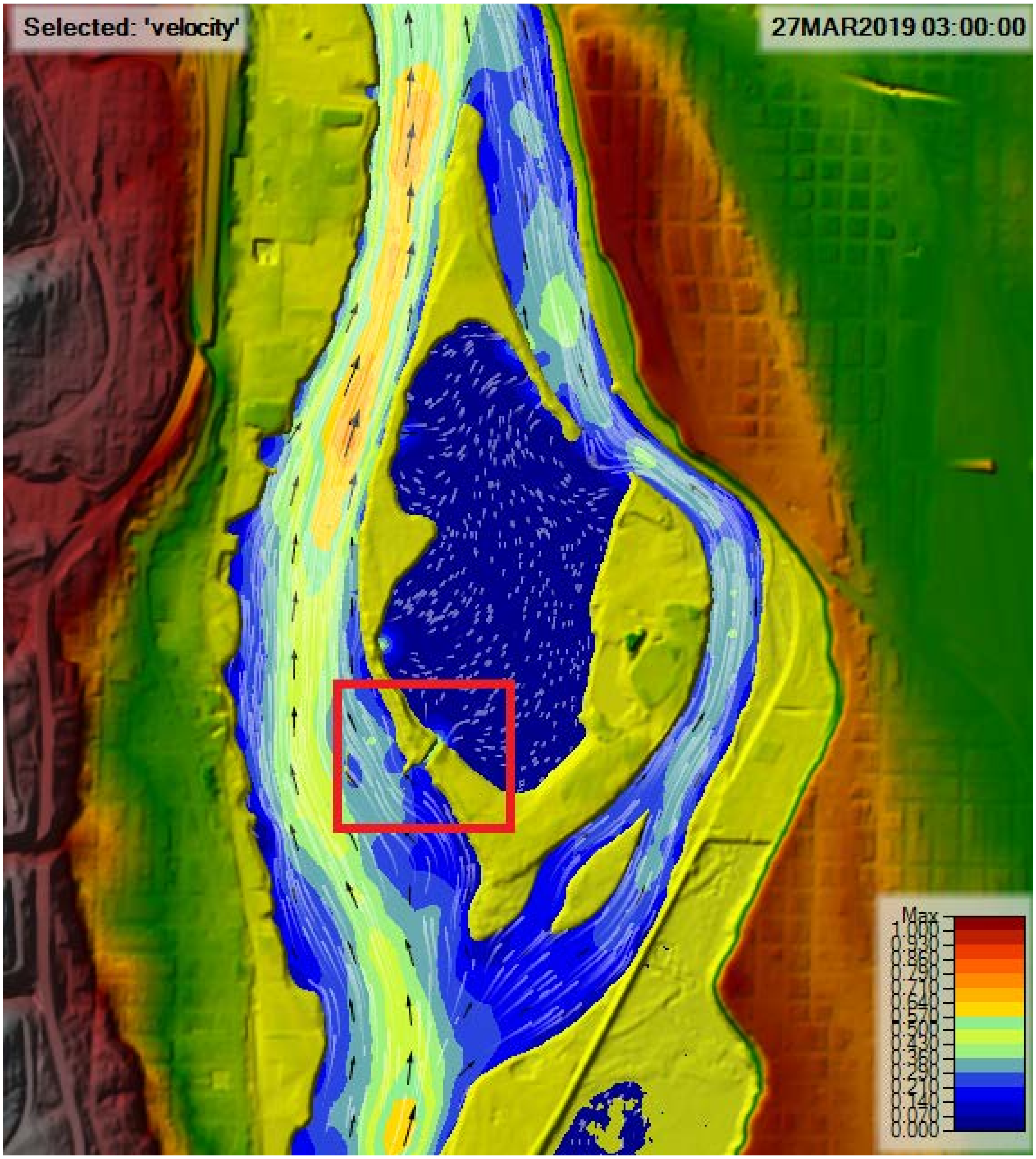

Figure B.5: Proposed condition Ross Island Lagoon Southwest conveyance location and velocity vector model results, full scale.

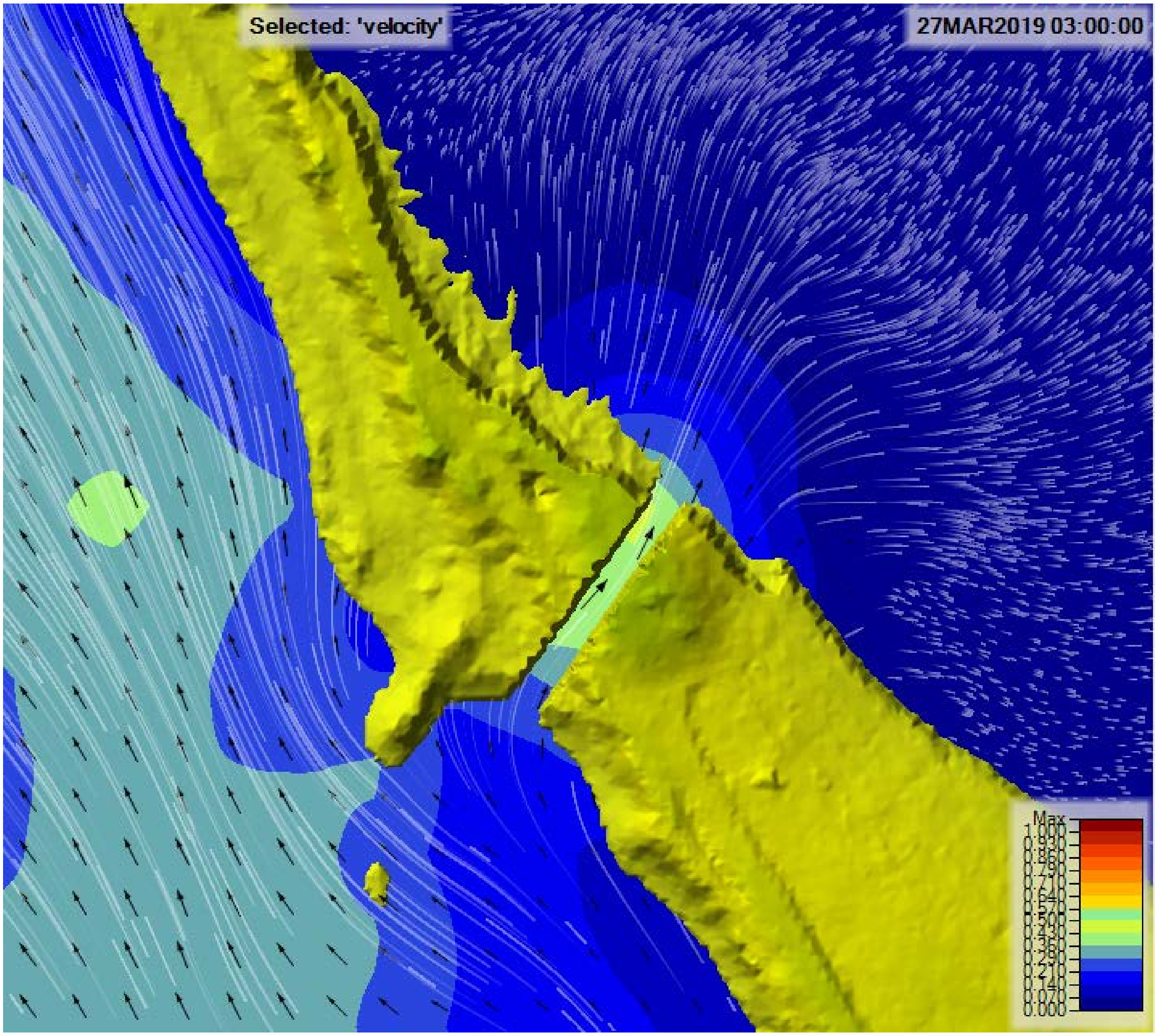

Figure B.6: Ross Island southwest conveyance velocity vector profile, zoomed in.

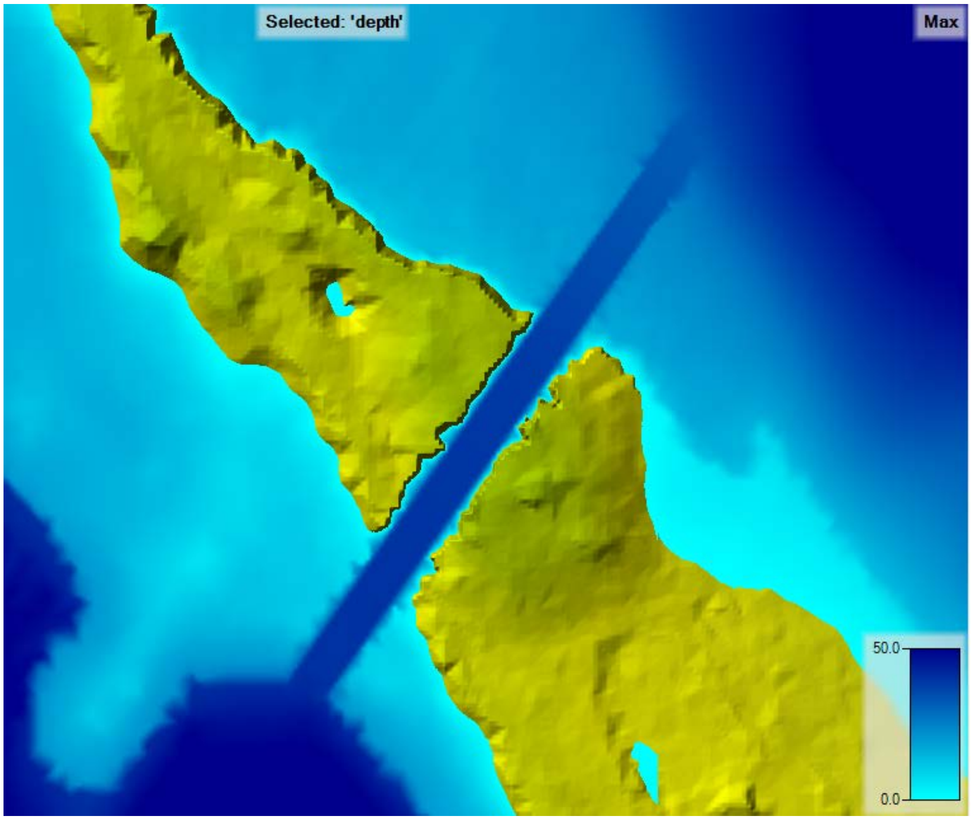

Figure B.7. Water depth for the April Flood event, the highest flow regime.

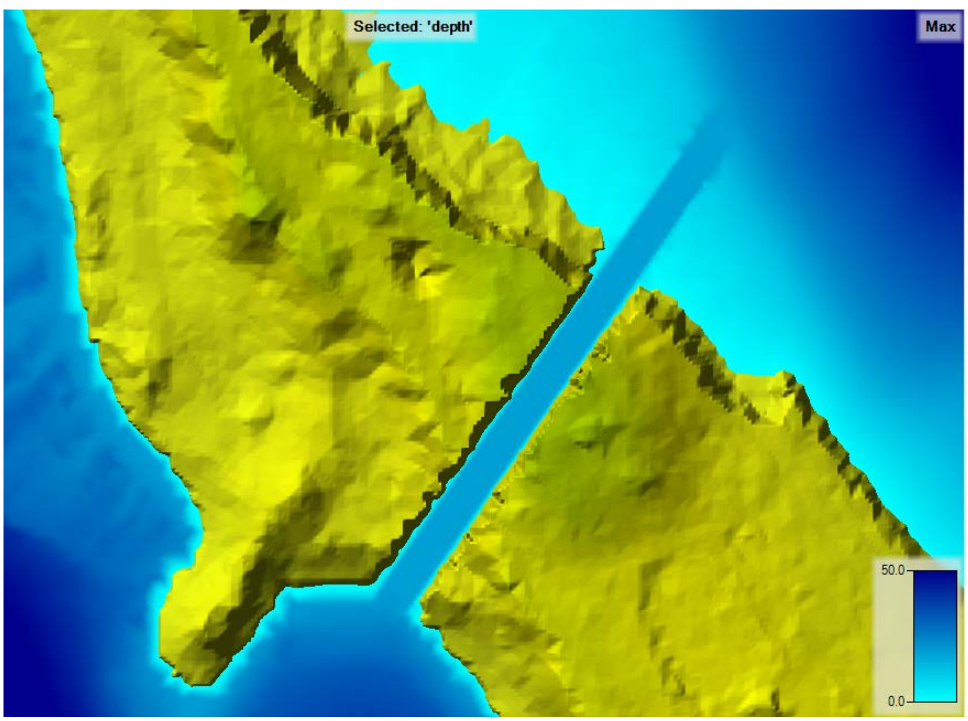

Figure B.8. Water depth for the August flow event, the lowest flow regime.

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?
1	Surface channel - concrete	Lining failure, cracking	Erosion of island (can led to exposure of CAD cells and loss of habitat); Loss of water to lagoon due to infiltration (decreased mixing, decreased effectiveness)	4	Inadequate design; Subsidence; Aging infrastructure	3	Design reviews; Regular monitoring; Maintenance when necessary	1	12	Seasonal monitoring (prior to usage in low flows)	N/A
1	Surface channel - tilting gate	Failure of mechanical connections (gate and lifting pins); Inadvertantly left open	Lagoon could capture river; loss of operations for RISG, navigation, habitat, etc.	5	Inadequate design; High flood event; Aging infrastructure; Operational misuse	3	Design reviews; Regular monitoring	1	15	Proper operator training	N/A
1	Surface channel - tilting gate	Failure of sealing (sides and hinges)	Erosion of island (can led to exposure of CAD cells and loss of habitat); Loss of water to lagoon due to infiltration (decreased mixing, decreased effectiveness);	4	Inadequate design; Subsidence; Aging infrastructure	3	Design reviews; Regular monitoring; Maintenance when necessary	1	12	Seasonal monitoring (prior to usage in low flows)	N/A
1	Surface channel	Debris/large wood blocking flow	Overflow of canal, gate; Loss of habitat; Damage to mechanical parts; Loss of water to lagoon (decreased mixing, decreased effectiveness);	3	High flow event	4	Regular monitoring; Removal of large debris	1	12	Predicting and increased monitoring for high flow events	N/A
1	Surface channel - tilting gate	Vandalism to gate mechanisms	Impact effectiveness of gate, decreasing effectiness of flow into lagoon	2	Disrespectful people	1	Regular monitoring; Signs around area; Safety fence	1	2	Seasonal monitoring (prior to usage in low flows)	N/A
1	Surface channel - tilting gate	Overtopping of gate	Lagoon could capture river; loss of operations for RISG, navigation, habitat, etc.	5	Extremely high flow events!!!!!!	1	Flood forevasting (detect only)	1	5	N/A	N/A
1	Surface channel - HAB effectiveness	Not provide enough mixing into lagoon to fully remove algae blooms, especially in areas not near canal entrance	Sustained harmful algae blooms in lagoon; Stratification	2	Not high enough of velocities moving through canal and into lagoon	4	Regular monitoring of algae	1	8	Increasing velocities into lagoon; Correct usage of opening gate within low flow season	N/A

Figure B.9: PFMA analysis for the SW conveyance, using provided spreadsheet and USACE ranking definitions.

12. Appendix C: Non- Hydraulic Alternative Analysis

Figure C.1: Photograph of solar- powered ultrasonic pontoon system, provided by SonicSolutions.

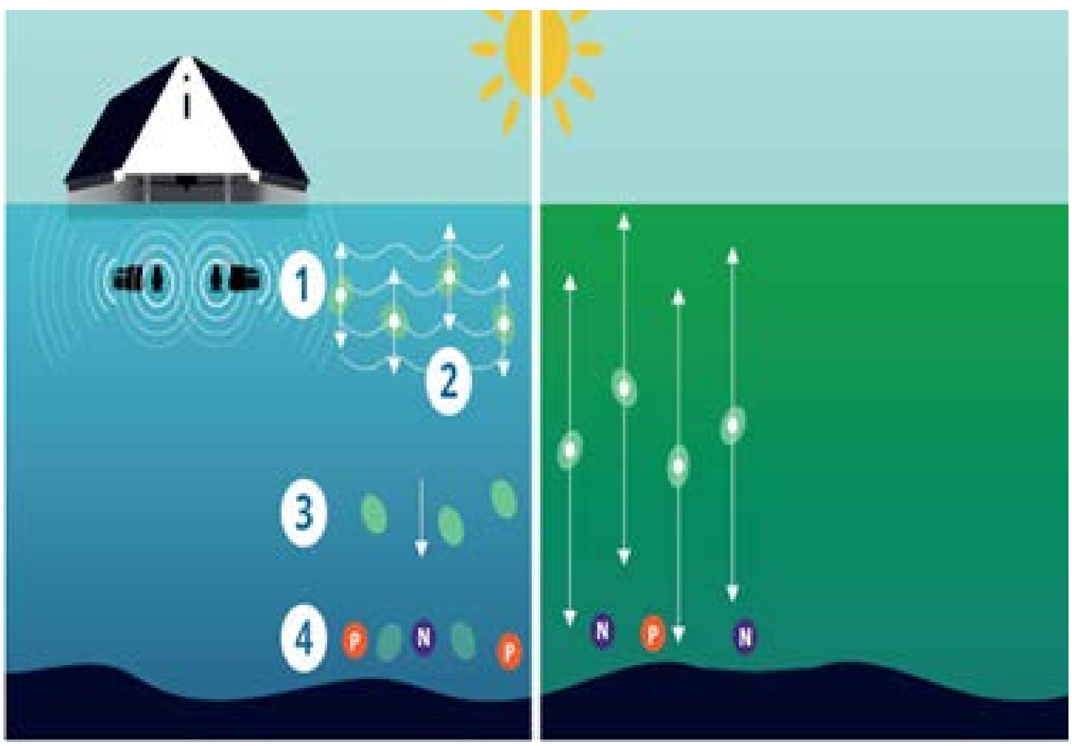

Figure C.2: Schematic of the algae removal method using ultrasonic technology, provided by LG Sonic.

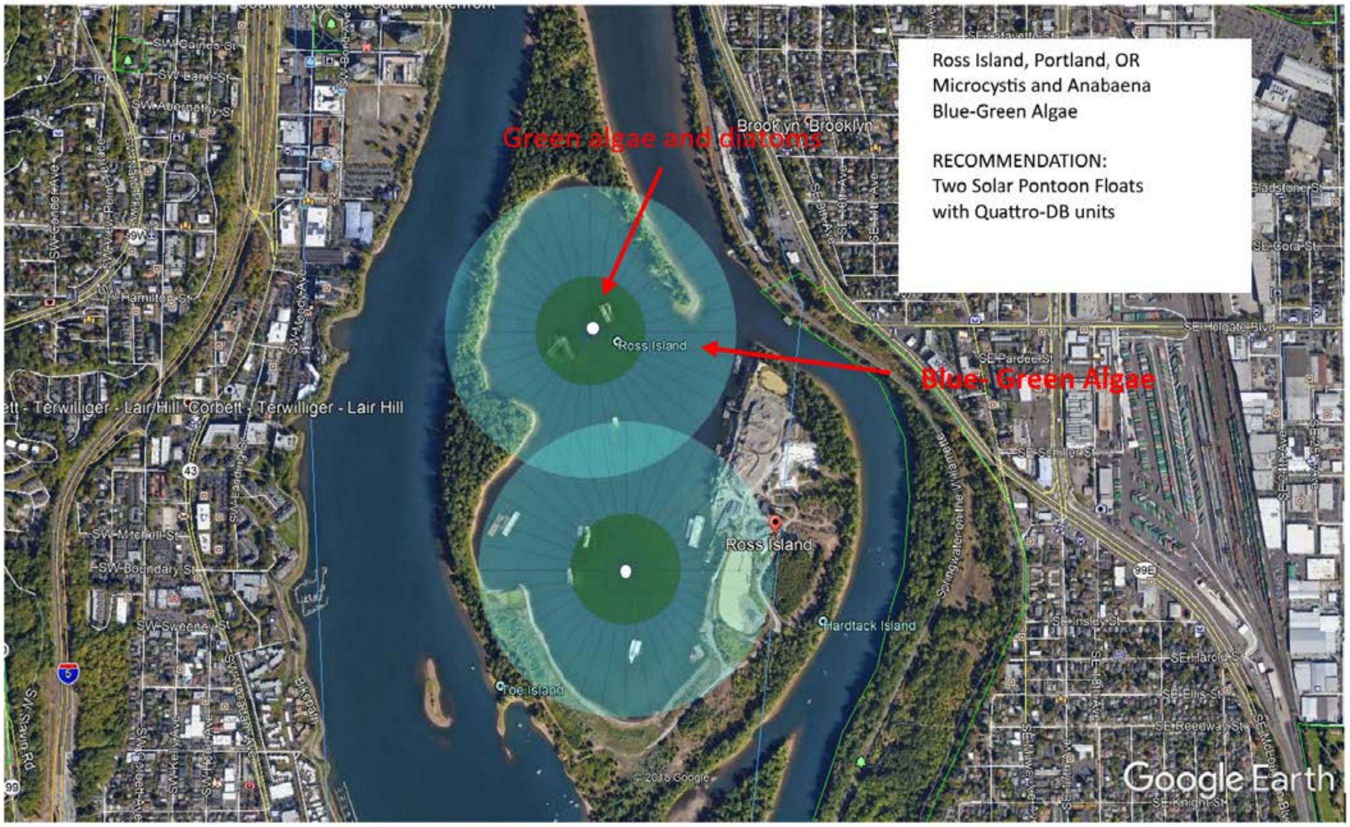

Figure C.3: Google Earth image of the coverage of using two solar pontoon floats with Quattro- DB units, provided by SonicSolutions. The coverage radius for green algae and diatoms are shown in green, and the coverage radius for blue- green algae is shown in blue.

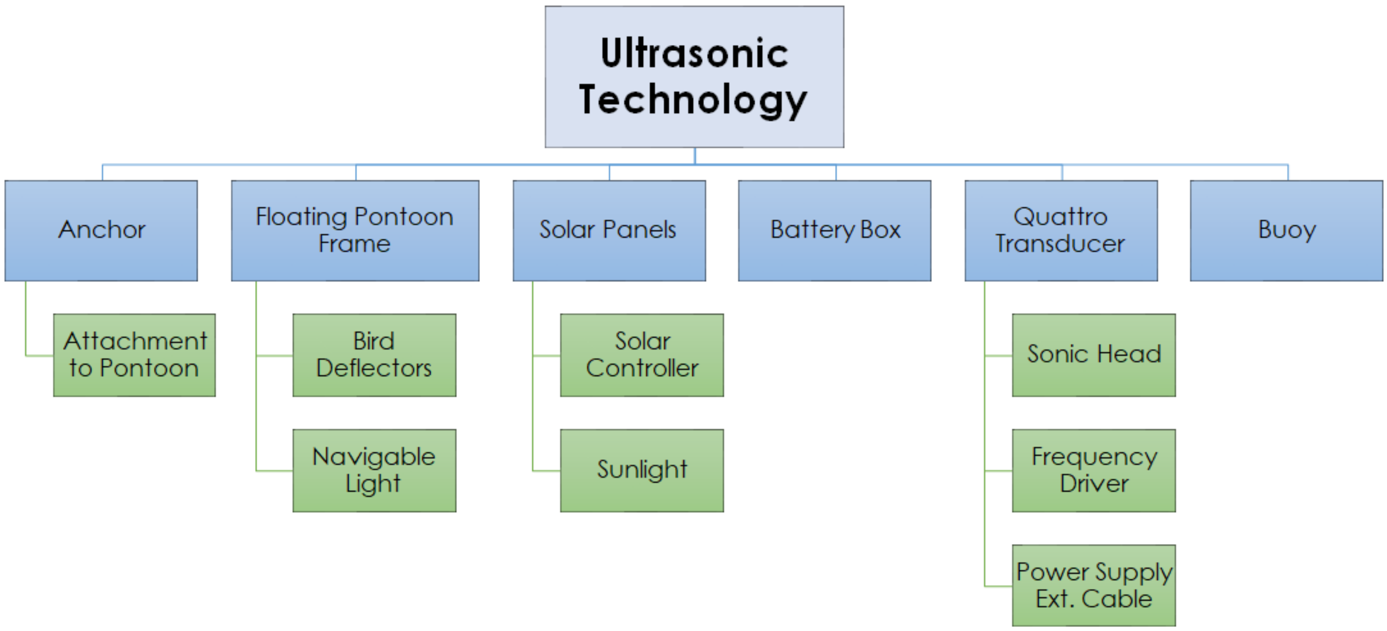

Figure C.4: Non hydraulic alternative (ultrasonic technology) functional tree diagram, displaying design features.

SonicSolutions
ALGAE CONTROL

238 Bridge St, Unit B
Northampton, MA 01060

Pricing

Ross Island - Oregon State University	BLUE-GREEN ALGAE RANGE			
Item	**PART #**	**Qty**	**MSRP 18**	**Subtotal**
180W Pontoon w Quattro (Factory Assy)	40S-24A060F180-00	2	$ 13,995.00	**$ 27,990.00**
Shipping Estimate				**$ 350.00**
Total			**Total**	**$ 28,340.00**

Optional Rental Program:

SonicSolutions offers a 3-month rental program (max 2 units). At the end of the 90 days, you can buy the units outright or return them. Should you decide to purchase the units, the money paid for the rental cost is applied to the total cost of the unit.

Ross Island - Oregon State University	BLUE-GREEN ALGAE RANGE		
Item	***Rental Price per unit***	***Qty***	***Total***
180W Pontoon w Quattro (Factory Assy)	*$7,500.00*	*2*	*$ 15,000.00*
Shipping Estimate	*TBD*		*$350*
Total		*Total Rental*	**$ 15,350.00**
		Balance Due at end of 90 Days	**$ 12,990.00**

Figure C.5: Cost estimates given by SonicSolutions for two Quattro- DB pontoon systems. Rental option costs are also shown.

Table 1
Review of ultrasonic conditions for algae removal.

Author (year)	Algal species	Ultrasonic frequency and intensity	Volume	Time (min)	Effectiveness
Simon (1974)	*Anabaera cylindrica*	Not reported; 1000 $W\,cm^{-3}$	100 µL	2	75% protein released
Tang et al. (2003)	*Spirulina plantensis*	1.7 MHz; 0.6 $W\,cm^{-3}$	Not reported	9	Inhibition of growth
Hao et al. (2004)	*Spirulina plantensis*	1.7 MHz; 0.07 $W\,cm^{-3}$ 20 kHz; 0.014 $W\,cm^{-3}$	800 mL	5	~50% reduction 33.33% reduction
Mahvi and Dehghani (2005)	Cyanobacteria	42 kHz; 0.07 $W\,cm^{-3}$	1000 mL	2.5	100% reduction
Zhang et al. (2006b)	*Microcystis aeruginosa*	20 kHz; 0.08 $W\,cm^{-3}$ 1320 kHz; 0.08 $W\,cm^{-3}$	1000 mL	10	14.29% reduction 55% reduction
Joyce et al. (2010)	*Microcystis aeruginosa*	40 kHz; 0.021 $W\,cm^{-3}$ 864 kHz; 0.049 $W\,cm^{-3}$	200 mL	30	Declumping effect 21.3% reduction
Pawalee et al. (2011)	Natural blooming algae	200 kHz; 0.015 $W\,cm^{-3}$	200 mL	0.5	94.9% reduction
Wu (2011)	*Microcystis aeruginosa*	40 kHz; 0.0466 $W\,cm^{-3}$ 864 kHz; 0.0929 $W\,cm^{-3}$	400 mL	30	4.31% reduction 61.11% reduction

Figure C.6: Summary of review of ultrasonic conditions for algae removal (Wu et al., 2011).

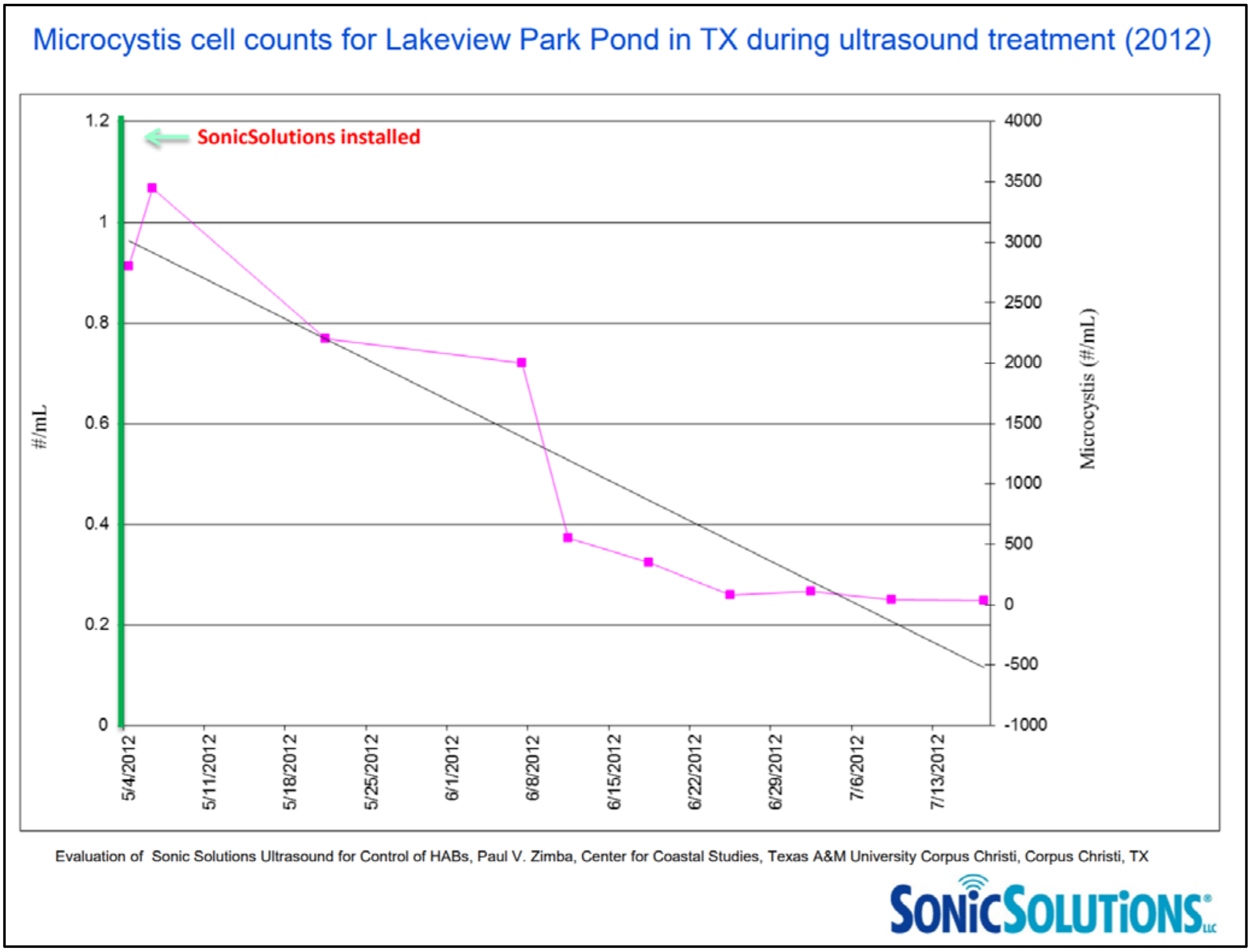

Figure C.7: Microcystis results for a SonicSolutions case study performed by Paul V. Simba of Texas A&M University Corpus Christi (Zimba, 2013).

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?
2	*Ultrasonic - Solar panel*	*Lack of sunlight; Mechanical issue of panel*	*No power supply to Quattro transducer or charging of battery; Ineffective algae removal*	*2*	*Prolonged overcast, smoky conditions; Inadquate design; Aging and weathering of panel*	*1*	*Design reviews; Regular monitoring*	*2*	*4*	*Seasonal monitoring (prior to usage in low flows)*	*N/A*
2	*Ultrasonic - Anchor*	*Anchor cabeling breaks/ comes unattached from pontoon frame*	*Pontoon is no longer anchored to bottom of lagoon, will float with flow of lagoon; Radius of ultrasonic waves will move and algae removal will be decreased in desired area*	*2*	*Inadquate design; Aging and weathering of cabeling; Extremely high winds*	*1*	*Design reviews; Regular monitoring*	*1*	*2*	*Regular monitoring*	*N/A*
2	*Ultrasonic - Navigable light*	*Light runs of out power supply/ breaks*	*Boats navigating through lagoon may not see pontoon frame and hit it, breaking ultrasonic mechanisms*	*2*	*Aging and weathering of panel (power supply) and light*	*1*	*Regular monitoring; Maintenance when necessary*	*1*	*2*	*Regular monitoring; Notify RISG of location of pontoons*	*N/A*
2	*Ultrasonic - Pontoon Frame*	*Frame breaks and falls apart*	*Unable to hold solar panel, battery, Quattro transducer*	*2*	*Boat runs into pontoon frame; Vandalism*	*1*	*Regular monitoring*	*1*	*2*	*Regular monitoring; Notify RISG of location of pontoons*	*N/A*
2	*Ultrasonic - Quattro transducer (main mechanism)*	*Mechanical failure*	*Inability to send ultrasonic waves; Ineffective algae removal*	*2*	*Inadquate design; Aging and weathering of mechanisms*	*1*	*Design reviews; Regular monitoring*	*2*	*4*	*Seasonal monitoring (prior to usage in low flows)*	
2	*Ultrasonic - HAB effectivness*	*Ultrasonic waves are ineffective and unable to fully remove harmful algae bloom, especially in areas far from source of ultrasonic waves*	*Sustained harmful algae blooms in lagoon*	*2*	*Inadquate design; Aging of mechanisms*	*2*	*Design reviews; Regular monitoring*	*1*	*4*	*Seasonal monitoring (prior to usage in low flows); Rent-to-buy option available for technology (can rent and test)*	*N/A*

Figure C.8: PFMA analysis for the ultrasonic technology, using provided spreadsheet and USACE ranking definitions.

13. Appendix D: Alternative Analysis Summary

Table D.1: Summary of each alternative analysis.

Evaluation criteria	1. SW Conveyance	2. Ultrasonic	3. No action
Capital cost ($)	$388,420.00	$28,340.00	$0.00
O&M ($, frequency)	$25,578.00/yr.	N/A, Monthly	$0.00, None
Loss and creation of shallow water habitats (acres)?	+0.16 (-0.08)	+0 (-0)	N/A
Expected effectiveness at controlling HAB (unknown, low, med, high)?	Low/Unknown	Medium	Low
Likelihood of failure during flood events (unknown, low, med, high)	Low	Low	N/A
Risk to CAD cells (USACE likelihood scale)	3	1	1
Likely benefit to widest range of aquatic taxa (Steelhead, chinook, lamprey, sturgeon, mussels)	Chinook, lamprey, coho salmon, steelhead, sturgeon	Chinook, lamprey, coho salmon, steelhead, sturgeon	None
List any unintended impacts (List species, infrastructure, RISG operations, etc.)	Shallow water species, CAD cells	Diatoms, Daphnia, Snails	Recreational use downstream