Research to Inform the Transition of Wastewater Sludge Lagoons to Freshwater Wetlands on Iona Island, BC

Prepared by:

Trisa Ngo
UBC Sustainability Scholar, 2021

Prepared for:

Lea Elliott
Senior Policy Analyst, Iona Island Program (Project Delivery),
Metro Vancouver

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Disclaimer

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Acknowledgements

University of British Columbia, Point Grey Campus (Vancouver, BC) – We [I] would like to begin by respectfully acknowledging that the land on which we gather is the territory of the xʷməθkʷəy̓əm (Musqueam) People.

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1. Executive Summary

This report includes case studies, lessons learned, and recommendations that will contribute to the body of research informing the restoration design of sludge lagoons to a freshwater wetland in the Iona Island Wastewater Treatment Plant. Expert interviews and case studies will provide a foundation for past lessons learned in wetland restoration to maximize the benefits of the wetland transition. Subsequently, the final recommendations will be based on lessons learned which encompass restoration design, implementation, maintenance, monitoring, and adaptive management.

The objectives of this project are three-fold:

1. Research and summarize case studies of comparable sludge lagoon to freshwater wetland restoration projects.
2. Complete a literature review to investigate Metro Vancouver identified research questions.
3. Derive recommendations from case studies and the literature review to inform the restoration design, implementation, maintenance, monitoring and adaptive management program that incorporate lessons learned from similar projects and support the habitat requirements of key species.

In total, five case-study interviews that encompassed tangible lessons learned were conducted from:

- **Port Rowan Wetlands, ON**
- **Grimsby Wetlands (Biggar Lagoon Wetlands), ON**
- **Niagara College, Niagara-on-the-Lake College, ON**
- **Niverville Wetland, MB**
- **Blakeburn Lagoons Park, BC**

In summary, five recommendations were derived from the literature review and case-study lessons learned:

- **Project Goals: Humans VS Environment**
- **Indigenous Groups, Public & Stakeholders: Practice Engagement**
- **Ecological: Let the Wildlife Decide**
- **Process & Operations: Practice Active and Adaptive Management**
- **Research Gaps: The Opportunity of Iona Island**

2. Introduction

2.1 Project Scope

Iona Island is the location of the Iona Island Wastewater Treatment Plant (IIWWTP) and Iona Beach Regional Park (IBRP). The existing IIWWTP uses four sludge lagoons to stabilize wastewater solids. The project definition report (IIWWTP Project Definition Report, Draft in 2021) was initiated in 2018 and with a goal to integrate the IIWWTP with the community and IBRP. Commissioned in 1963, the IIWWTP is a primary treatment plant currently serving 750,000 residents. In accordance with regulatory requirements, the new treatment plant will provide secondary treatment by approximately 2034. The function of the sludge lagoons will be replaced with technological solutions in the new IIWWTP which provides an opportunity to restore these areas into freshwater wetlands and enhance biodiversity and habitat values for birds and other wildlife. A conceptual design has been developed that recommends transitioning some of the sludge lagoon area to freshwater wetlands and using treated wastewater from the IIWWTP to recharge the wetlands. For the scope of this project, we focus on Ecological Restoration Project Area 06: the transition of southwest sludge lagoon to a freshwater wetland (Figure 1).

Figure 1 Southwest lagoon on Iona Island outlined in red (Google Earth, 2021).

To develop a robust detailed design, further research is needed. The current study will contribute to this work by surveying relevant literature, summarizing case studies, and conducting expert interviews to synthesize evidence-based research on the effect of sludge lagoons on bird health, the restoration of wastewater treatment plant sludge lagoons to freshwater wetland habitat, and the use of treated wastewater to recharge wetlands.

This report includes case studies, lessons learned, and recommendations that will contribute to the body of research informing the restoration design of sludge lagoons to freshwater wetland in the IIWWTP. Expert interviews and case studies will provide a foundation for past lessons learned in wetland restoration to maximize the benefits of the wetland transition. Subsequently, the final recommendations will be based on lessons learned which encompass restoration design, implementation, maintenance, monitoring, and adaptive management.

The objectives of this project are three-fold:

1. **Research and summarize case studies of comparable sludge lagoon to freshwater wetland restoration projects.** Here, expert interviews were conducted to solidify the focus of gathering evidence-based research.

2. **Complete a literature review to investigate Metro Vancouver identified research questions.** The following research questions seek to inform the development of the sludge lagoon transition design based on biological, physical, and chemical uncertainties:
    - How does bird use differ between sludge lagoons and freshwater wetlands? Here, we discuss bird foraging and other parameters that attract birds to sludge lagoons.
    - What are the effects of long-term sludge lagoon use on bird health?
    - What was the effect of transitioning sludge lagoons to freshwater wetlands on species diversity and composition?
    - Do biophysical parameters differ between sludge lagoons and freshwater ecosystems?
    - What are the habitat requirements and water quality parameters of similar Pacific coastal freshwater wetlands?

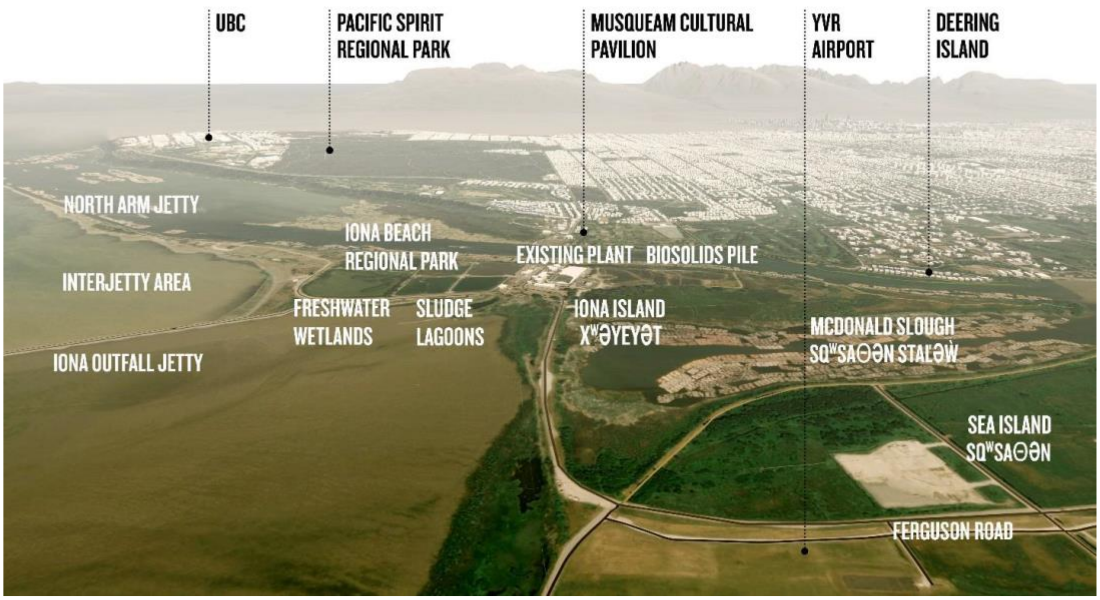
3. **Derive recommendations from case studies and the literature review** to inform the restoration design, implementation, maintenance, monitoring, and adaptive management program that incorporate lessons learned from similar projects and support the habitat requirements of key species.

2.2 Site Description

Bounded by the Fraser River Estuary, Sturgeon Banks, and the Salish Sea, Iona Island is located in Richmond, BC (Figure 2). The island is connected to Sea Island by a public road north of the airport within agricultural land. The site is characterized as a Maritime subzone of the Coastal

Douglas-fir biogeoclimatic zone (IIWWTP Project Definition Report, Draft in 2021). Specifically, the summers are warm and dry while the winters are mild and wet. Natural vegetation on Iona Island is dominated by shore pine, black cottonwood, red elderberry, dune grass, large-headed sedge, tall Oregon grape, and bryophytes. Historically, the ecosystem of Iona Island was likely a non-forested area with a mix of tidal marsh and wet meadow (IIWWTP Project Definition Report, Draft in 2021). As Iona Island is located in the Fraser River Estuary, the geology of the island is underlain by sediments and till with shallow areas containing mud and sand. Iona Island includes diverse terrestrial, marine intertidal and freshwater wetland habitats. The island contains areas of novel and rare coastal sand ecosystems, and other ecological communities at risk in BC. Many invasive plant species are present in the regional park including, Scotch broom and Himalayan blackberry. In terms of wildlife, Iona Island is a refuge for several birds, fish, mammals, reptiles, and amphibians (IIWWTP Project Definition Report, 2020).

Figure 2 Overview of Iona Island (IIWWTP Project Definition Report, 2020).



3. Literature Review

3.1 Bird and Wildlife Use of Wastewater Lagoons

Coastal wetlands are estimated to decline by 70% by 2080 with sea-level rise associated with climate change acting as a major contributor to the deterioration (Nicholls et al., 1999). One encroachment to coastal wetlands is human-made wastewater treatment wetlands. This type of treatment takes advantage of a wetland’s natural ability to treat wastewater through chemical, physical, biological natural processes used to remediate pollutants (Rittmann, 2004; Werker et al., 2002). Common configurations of passive semi-engineered wastewater treatment systems include wastewater stabilization ponds (WSPs), constructed wetlands (CWs), and a receiving environment. WSPs are open-water basins commonly referred to as sewage lagoons and are comprised of multiple arrays and numbers of lagoon cells (Daley et al., 2018; Murray & Hamilton, 2010). Both constructed wetlands and WSPs use natural processes to treat wastewater in a more controlled environment compared to naturally occurring wetlands used for wastewater treatment (Murray & Hamilton, 2010).

A major driver to the current restoration project is that of improving and conserving the diversity and abundance of bird and wildlife species in the IIWWTP sludge lagoons. A portion of the current research focuses on bird health and factors that influence bird abundance and diversity surrounding the usage of sludge lagoons. In this section we seek to understand the following questions:

- How does bird use differ between sludge lagoons and freshwater wetlands? Here, we discuss bird foraging and other parameters that attract birds to sludge lagoons.
- What are the effects of long-term sludge lagoon use on bird health?

The literature is limited in terms of wastewater treatment wetlands as habitat for waterfowl. Specifically, Murray & Hamilton (2010) suggest there are research gaps in the following areas in wastewater treatment wetlands related to birds: “Global distribution of wastewater treatment wetlands, …appropriate methods for deterring or excluding waterbirds where such action is warranted from either a bird health or human use perspective, means of mitigating disease outbreaks in waterbird populations frequenting wastewater treatment wetlands, the effect of wastewater contaminants and diseases on waterbirds, and the role of waterbirds in human disease transmission”. Additionally, food web interactions in WSPs are not well understood and little research has been conducted regarding how constructed wetlands influence biodiversity and ecosystem functioning (Hsu et al., 2011; Orlowski, 2013).

3.1.1 Foraging and Eco-toxicity

Despite the benefits that CWs bring to birds and wildlife, the nature of the wetland and of many bird species invites potential impacts to bird health as Hamilton (2007) described the microbial, chemical, and mechanical effects posed to birds. The gregarious nature of many bird species, meaning they are social creatures that flock or cluster together, creates ideal conditions for disease transmission especially in the case of pathogens and toxins (Murray & Hamilton, 2010). In terms of amphibian health, Ruiz et al. (2010) found that Bullfrog tadpoles from wastewater wetlands receiving direct inputs of treated wastewater showed a higher frequency of developmental abnormalities including “severe edema, scoliosis, and extreme calcinosis of soft tissues”. Park et al. (2009) examined the potential of biomagnification of endocrine disrupting chemicals (EDCs) within prey species such as birds and bats that consume aerial invertebrates in primary foraging grounds of wastewater treatment plants. The authors found that aerial invertebrates developing on WSPs absorbed chemicals that act as endocrine disruptors because concentrations were significantly higher in invertebrates found near WSPs compared to those located 2km away at non-wastewater treated sites.

Although treatment wetlands may pose a risk to species that forage within these areas, constructed wetlands and WSPs create favorable environments for waterfowl especially when nutrient levels are elevated. As a result, improved nutrient removal technologies create lower-quality foraging habitats for waterfowl (Murray & Hamilton, 2010). Murray et al. (2013) described factors that make wetlands suitable habitats for waterbirds as varied. Specifically, the authors stated vegetation was a crucial food to waterbirds and to their invertebrate prey. Similarly, Zimmerling & Ankney (2005) stated that WSPs provide valuable foraging sites for waterfowl due to their high insect biomass especially during the breeding season of many bird species in their study that examined incubation patterns of Red-winged Blackbirds at WSPs in Eastern Ontario. Further, Hussell & Quinney (1987), examined the abundance of food (insect biomass) at different sites within a treatment wetland. They found that insect biomass which tends to be elevated in WSPs is positively related to female Tree Swallows clutch sizes (number of eggs laid in a single brood).

3.1.2 Ecology Dynamics

Orlowski (2013) described the most abundant bird guilds on seven WSPs located in southwest Poland as waterbirds, shorebirds, passerines, and aerial feeders. Further, Murray & Hamilton (2010) identified wading birds (Ciconiiformes, Charadriiformes, and Gruiformes) as users of WSPs based on multiple accounts outlined in the study. Murray et al. (2013) describe "wetland size, connectivity, susceptibility to disturbance, accessibility to food within the wetland, and the presence of both emergent and adjacent vegetation" as commonly known factors that determine wetland usage by waterbirds. This study examined relationships between waterbirds and different biophysical parameters in Australian urban and wastewater treatment wetlands. Although the authors did not find significant differences in terms of abundance and density of birds between these two types of wetlands, significant differences were observed between species and feeding guilds. Physical wetland characteristics including increased surface area were correlated with waterbird abundance and density (which is expected if waterbirds distributed themselves in proportion to wetland size). Additionally, the diversity of habitats within wetlands including open areas such as mudflats and grasslands create favourable breeding and foraging environments for multiple bird species around the world (Orlowski, 2013). Pursuit Predators in Murray et al. (2013) preferred larger surface area wetlands thus increasing bird density for these predators while non-pursuing predators like duck species preferred smaller wetlands.

3.2 Restoration of Sludge Lagoons to Wetlands

Wildlife habitats are often by-products of constructed wetlands as the decline in natural wetlands has created critical habitat for wildlife, especially for waterfowl. CWs for wastewater treatment or public amenity has become a refuge for waterbirds (Orlowski, 2013; Zedler, 2000). However, it must be understood that CWs are not the functional equivalents of natural wetlands (Campbell et al., 2002; Murray et al., 2013). Although countries throughout the world are increasing the construction of artificial wetlands, knowledge on proper design and implementation of wetlands in terms of nutrient reduction and biodiversity conservation is scarce (Hansson et al., 2005).

In this section we seek to understand the following questions by looking at past examples of similar restoration projects and studies:

- What was the effect of transitioning sludge lagoons to freshwater wetlands on species diversity and composition?
- Do biophysical parameters differ between sludge lagoons and freshwater ecosystems?
- What are the habitat requirements and water quality parameters of similar Pacific coastal freshwater wetlands?

3.2.1 Species Richness and Abundance

Species richness (number of different species) and abundance (number of individuals per species) can be influenced by the design and siting of a CW. For example, Hsu et al. (2011) found that species richness was influenced by wetland area, cover of macrophytes (aquatic plants), and water quality. Further, the authors found that proper design and management of CWs can enhance biodiversity. Kelly et al. (2008) describes wetlands with connectivity designed like a mosaic with the ability to reduce disturbances and provide optimal habitats to increase the presence of waterbirds species. Murray et al. (2013) outlines potential disturbance variables as waterbird security (maximum distance a bird can retreat from a disturbance), urban encroachment, and human access. The functional area of CWs and bird species and richness show a positive relationship (Hsu et al., 2011). Additionally, bird richness is affected by adjacent and regional land use such as road density and connectiveness (Hsu et al., 2011). Whited et al. (2001) stresses the need for wetland conservation planning to shift from site to landscape scale to reduce fragmentation and increase opportunities for bird species.

The variability of a CW's design and composition can also influence species richness and abundance at the invertebrate community level. Hansson et al. (2005) examined 32 constructed wetlands located in southern Sweden and found that large wetland surface areas and high shoreline complexity is more likely to yield higher species richness in terms of macrophytes and invertebrates. Larger wetland surface areas were found to retain more nitrogen compared to smaller and deeper wetlands that were found to retain greater levels of phosphorus. As phosphorous is particle-bound, smaller and deeper wetlands increase particle sedimentation. However, high amounts of phosphorus can result in low species richness of benthic invertebrates (Hansson et al., 2005). McKinnon & Mitchell (1994) observed that although nutrients are essential in supporting species richness and abundance, wetlands that retain increased nutrients can cause eutrophication thereby reducing macrophyte and phytoplankton biomass, ultimately reducing bird abundance. Keddy & Fraser (2000) warns that high nutrient inflows to wetlands can result in low biodiversity of macrophytes. Hamilton et al. (2005) found that zooplankton was more abundant in later areas of the treatment process (areas further away from WSPs). Specifically, toxicity gradients, un-ionized sulphide, and low dissolved oxygen were likely determinants of the availability of phytoplankton and zooplankton (Kersten et al., 1991). According to Hansson et al. (2005), a minimum of 4 years was required to reach maximum richness of benthic invertebrate species.

3.2.2 Biophysical Parameters

Biophysical parameters and the intention of a wetland can alter the species richness and composition of a wetland. Satori et al. (2014) examined natural ponds and artificial ponds in CWs of Northern Italy to investigate the effects of water quality, morphology, and environmental characteristics on the macroinvertebrate level. The goal of the study was to realize to what extent can natural or artificial lagoons contribute to local biodiversity. The findings suggested the composition of macroinvertebrates was similar between natural and artificial lagoons both with the intention of creating new habitat in the park; however, the macroinvertebrates among natural and CWs created with the intention to treat wastewater were significantly different. The authors found that habitat heterogeneity (diversity or variety of habitat types) was a major factor influencing species richness. Water quality was also a major contributor affecting species composition structure of macroinvertebrates as water quality analysis showed gradients in different microhabitats amongst natural and artificial ponds. Specifically, different ponds and pools within natural and artificial ponds displayed division based on morphological diversity, nutrient concentrations, and phytoplankton blooms when analyzing chemical total oxygen demand (COD) and dissolved oxygen (DO) (Satori et al., 2014).

Kirby (2002) examined a case study of River Herbert Marsh in Nova Scotia designed for tertiary wastewater treatment (polishing level of wastewater treatment) following conventional treatment. The goals of the project included providing tertiary wastewater treatment, creating wildlife habitat, promoting public education about improving wastewater treatment, and documenting technical information and data regarding this technology. The next step involved creating two treatment facilities (a free water surface constructed wetland of 1.82 hectares and an un-landscaped marsh of 6.23 hectares) to compare treatment efficiencies. Considering biophysical parameters, the un-landscaped marsh was greater in area, water depth, detention time, and storage capacity. Overall, the un-landscaped marsh performed better than the constructed wetland, was less costly, and provided increased wildlife habitat (Kirby, 2002). However, the author notes that these findings are site-specific and may differ between environments. In general, research comparing biophysical parameters between sludge lagoons and freshwater ecosystems is sparse and often results as a by-product of studies investigating species diversity and abundance as demonstrated in Kirby (2002) and Satori et al. (2014).

3.2.3 Habitat and Water Quality Parameters

The National Research Council (1995) defines wetlands as inundated areas of land characterized by water indicators, substrate, and biota. The water table tends to be near the surface with land covered with water not exceeding two meters (Oakley et al., 1985). They are productive ecosystems proving ecosystem services to humans, plants, and various species (Environment and Climate Change Canada, 2016). Wetlands are sources, sinks, and transformers of materials especially in terms of nutrients such as nitrogen and phosphorous (US EPA, 2008). Temperate freshwater wetlands can vary throughout the globe in terms of geomorphic setting ranging from wetlands that are influenced by river channels to those that are isolated and driven by groundwater (Brinson & Malvárez, 2002). Oakley et al. (1985) included habitats such as marshes, swamps, bogs, seeps, wet meadows, and shallow ponds in their description of freshwater wetlands. Five major elements to describe and distinguish between freshwater wetland in the Pacific Northwest: Topography, vegetation, surface water, soil, and local climate (Oakley et al., 1985). The distribution of marshes and swamps is dictated by the elevation gradients and decreasing hydroperiod. Specifically, flood frequency, depth, and duration create distinct wetland habitat types. Soil organic matter can vary significantly depending on geographic location and the proximity of salinity source. Rainfall patterns are a major contributor to differences between the Atlantic and Pacific coasts. As the Atlantic coast experiences relatively regular rainfall throughout the year, the Pacific coast experiences strong rainfall variability that influences salinity and mixing levels (Leck et al., 2009). In terms of vegetation, freshwater wetlands are composed of floating or submergent aquatic vegetation in saturated or seasonally saturated soil conditions; however, in certain areas such as mudflats, vegetation may be lacking as fluctuations in water levels prevent hydrophyte vegetation growth (Oakley et al., 1985).

4. Case Studies

The main objective of conducting interviews with researchers, natural resource management, and wastewater professionals is to capture lessons learned from past restoration projects. These interviews and restoration projects are presented as case studies contributing to the body of research informing the restoration design of sludge lagoons to a freshwater wetland in the IIWWTP. Case studies like the IIWWTP sludge lagoon in different jurisdictions are summarized to encompass recommendations, restoration design, implementation, maintenance, monitoring, and adaptive management.

The case studies were selected based on a criterion that considers geographic environments, goals/objectives, water recharge techniques, ecology, and relevant stakeholders (Table 1). Currently, there are few cases in Canada that document a transition from a sludge lagoon to a freshwater wetland. As a result, a snowball sampling technique was used to recruit future case studies from existing cases and interviewees. A caveat to using the snowball sampling technique to recruit potential case studies includes introducing bias towards the interview selection thereby limiting the impartiality of the study.

Another limitation to the case-study sampling approach is to acknowledge the lack of interviewing multiple stakeholders and disciplines involved in delivering restoration projects. Stakeholder groups will not always hold the same viewpoints when describing project goals, objectives, challenges, and successes. Inherently, not all groups are involved in the same project deliverable nor hold the same viewpoints. Consequently, some interviewees were not able to answer all interview questions (Appendix A) due to this acknowledgement of multiple stakeholders and disciplines. Ultimately, more interviews are needed to provide a clear, unbiased account of each case study; however, the viewpoints of current interviewees should not be discounted. All interviews are considered valuable as they represent the perspective of an individual involved in the restoration of a wetland to some degree.

Table 1 Case study selection categories and criteria

Categories	**Criteria**
Geographic environment	• Location • Canadian context for comparing similar environments/processes and for permitting purposes • Environmental features and landscape types • Waterbodies (fresh water, saltwater, mixed environment types) • Baseline and background environment before the disturbance
Goals and objectives	• Main case-study goals and objectives • Focus of current study: restoring wastewater lagoons to wetlands as many cases exist that use constructed wetlands for treatment which is not within scope of the current study • Cost association (understanding rough cost estimates will support cost comparison in the planning process)
Processes	• Use of treated wastewater to recharge wetlands • State of the water quality before and after restoration • Maintenance and operations
Ecology	• Focal species in restoration (birds) • Ecological impacts related to diversity and abundance • Challenges & successes with species that encompass limitations and changes to make in the future
Indigenous groups, public, stakeholders	• All those involved in the restoration project and division of expertise for completing project deliverables by those involved • Land/facility owner and managing practices • Challenges & lessons learned for the in terms of stakeholder planning, operation, and maintenance • Challenges & lessons learned for the in terms of the public • Takeaways related to public experience

4.1 Port Rowan Wetlands, ON

Interviewee: Member of Bird Studies Canada

Located in the Long Point Region of Norfolk County in Southwestern Ontario, Port Rowan is home to 1,102 residents and the Port Rowan Wetlands (Statistics Canada, 2016). The initial treatment facility was created in 1971 to naturally treat and dispose of wastewater. Commissioning of a new mechanical treatment facility commenced in 2012 allowing the opportunity for the 60-acre area to be restored into a functioning wetland with a riparian buffer (Long Point Biosphere, 2021). Currently, the wetlands are approximately 9 hectares squared with a perimeter of 1.2 kilometers (Figure 3). Based on reports from the Simcoe Reformer (2013), the restoration project cost $1.2 million at a minimum.

Figure 3 Location of Port Rowan Wetlands, ON outlined in red (Google Earth, 2021).

This project was considered novel to the province due to its restoration goals and ability to bring together many local community partners and provincial groups. Specifically, the following groups were involved: Long Point Region Conservation Authority, Ministry of Natural Resources & Forestry, Long Point Biosphere Reserve, Nature Conservancy of Canada, Norfolk Land Stewardship Council, Ontario Power Generation (Forest Corridor Project), and Bird Studies Canada (Long Point Biosphere Reserve, 2021).

The wetlands feature a riparian buffer corridor leading to Lake Erie, vernal pools (ponds that retain water for some parts of the year and are important breeding habitat for amphibians), and native prairie grassland areas that help to improve the area's natural features (Long Point Biosphere Reserve, 2021). The Port Rowan wetlands is a valuable refuge for many wildlife species including birds, snakes, turtles, and various others. The wetlands were designed with community recreation and accessibility in mind. As a result, an interpretive walking trail follows the perimeter of the wetlands and numerous lookouts were created for wildlife observation (Amazing Places, 2016).

From the perspective of the member of Bird Studies Canada, the main goals of the restoration project in Port Rowan were two-fold: remove or filter agricultural/wastewater nutrients from the landscape to reduce eutrophication and to generally increase wetland habitat in Ontario. The interviewee stressed that "[wetlands] have been degraded probably at a faster rate than other ecosystem types" signifying that wetland depletion was a major concern not just in Ontario but throughout the world.

Lagoon in Port Rowan Wetlands, ON (Amazing Places, 2016).

In terms of the ecology of the wetlands, those tasked with designing the restoration approached the project with an "if you build it, they will come" mentality. The first steps in the restoration process were to remove soil from the bottom of the lagoons, create vernal pools, and start the planting of native species including trees, bushes, grasses, and flowers. The next steps of the project included removing the berm that separated the two treatment ponds and replacing it with an island structure. Additionally, variations in water depths were created through contouring of the ponds which encompassed the municipal drain. The municipal drain enters from one side of the wetlands allowing water to circulate and exit through the other end of the wetland (Long Point Biosphere, 2021). Subsequently, the wetlands are recharged with precipitation and stormwater runoff from the municipal drain.

During the beginning stages of the restoration, there was a boom in wildlife and vegetation growth. Now, the wetlands are "being used by wildlife but is just not being used by nearly as much wildlife as it could". The member of Birds Studies Canada explained that "on-going management remains a challenge…with respect to water levels and managing wetland vegetation" and this lack in active management could be creating barriers to wildlife utilizing the wetlands. The water level management is passively controlled and not actively managed; specifically, there exists a gate on the wetland's outflow to maintain a minimum level. When the wetland water level rises above the drain, the water naturally flows out. The member of Birds Studies Canada explained how water level management was crucial to wildlife when they stated that "it is invaluable to maintain the ability to control water levels, so to raise and lower them for migratory shorebirds". Due to this lack of active management, the current state of the wetlands is diminishing in terms of diversity and abundance of wildlife.

Lagoon in Port Rowan Wetlands, ON (Stuart Mackenzie, 2021).

4.2 Grimsby Wetlands (Biggar Lagoon Wetlands), ON

Interviewee: Member Hamilton Naturalists' Club

The Grimsby Wetlands are located in the town of Grimsby in southern Ontario on a 29-acre property. Currently, the Federal Department of National Defense (DND) owns the northern 9-acre land area of the wetlands while the Niagara Region owns the southern 20 acres (Figure 4).

Between 1950-2000, the former Biggar Lagoon Wetlands were used as wastewater treatment lagoons for Grimsby's west end; the population of Grimsby includes 27,314 residents (Statistics Canada, 2016). Following the decommissioning of the lagoons in 2001 and lengthy conversations with multiple federal, provincial, and regional stakeholder groups, the Niagara Region allowed the lagoons to remain as is rather than filling in and reverting the lagoons into their original farmland state. Additionally, the non-profit environmental organization, Hamilton Naturalists' Club (HNC), was granted permission by the Niagara Region to carry out restoration projects on their property. Since 2017, the HNC has been carrying out wildlife and habitat enhancement projects on the 20 acres of the property belonging to the Niagara Region.

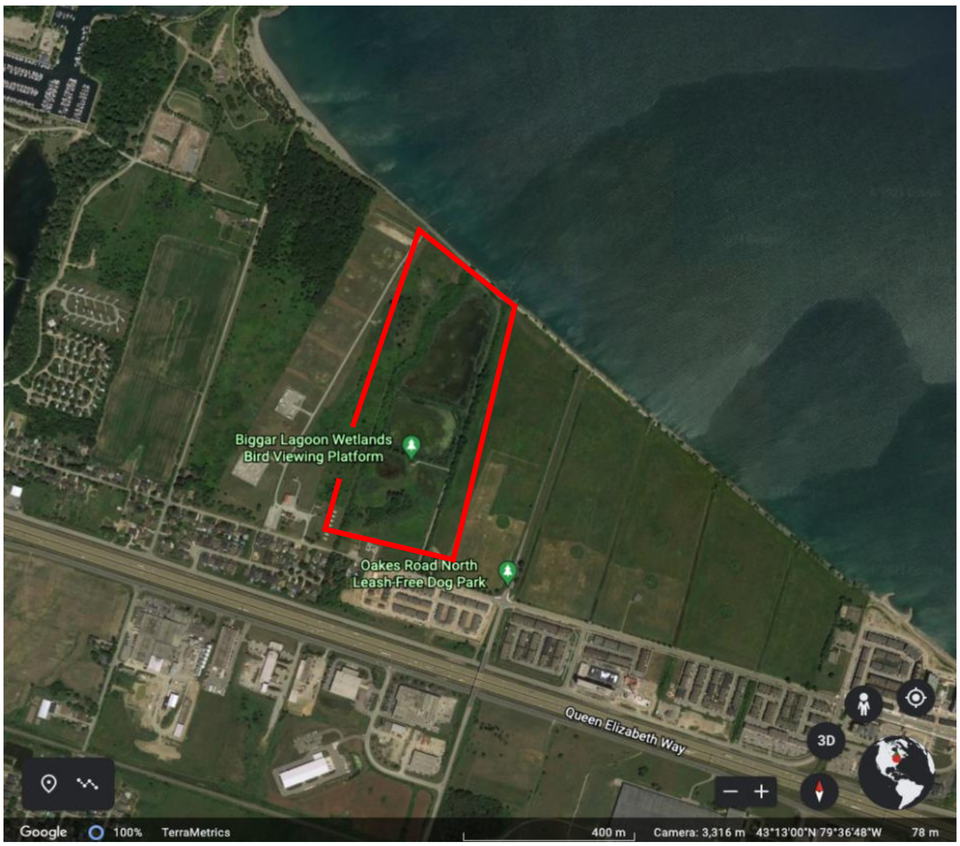


Figure 4 Location of Grimsby Wetlands (Biggar Lagoon Wetlands), ON outlined in red (Google Earth, 2021).

The Grimsby wetlands feature 12 acres of wetland recharged by precipitation and upland habitat, two lagoons approximately 1 acre in size, and another 6-acre lagoon that is adjacent to the 9-acre lagoon belonging to the DND property (Mackenzie, 2016). In 2015, a waterfront trail with a wildlife viewing tower was constructed by the Niagara Region. The HNC restored the Grimsby wetlands to include 2 smaller transient ponds. The motive behind this design was to create a diverse, suitable habitat for wildlife and to test which species would ultimately take advantage of the new habitat. This was evident when the HNC member stated: "you can design something that you think [wildlife] will like. But why don't you do it in three different ways and let the bird tell you which one works." During a dryer summer, the 6-acre lagoon became shallow due to increased evaporation exposing valuable mudflats to migratory waterbirds. When the wastewater treatment plant was operating, exposed mudflats and similar habitats were never available as wastewater was constantly being pumped into the lagoons resulting in high water levels in the lagoons (Mackenzie, 2016). Some notable wildlife enhancement projects completed by the HNC include the installation of floating platforms in the lagoons where waterbirds and turtles can sun, the installation of multiple bird nesting structures, and the construction of a gravel and sand pad for further waterbird nesting opportunities (Mackenzie, 2018; Mackenzie, 2019). Much of the restoration efforts and regular maintenance have been allocated to the removal of invasive species in the area including phragmites and wild parsnip. Removing invasive species has allowed suppressed native species to establish, in turn creating more opportunities for wildlife to reestablish.

The HNC member stressed the importance of involving the public when designing the restoration to garner support for habitat restoration as they specified "I want them to make a connection with the property."

Aerial view of Grimsby Wetlands (Biggar Lagoon Wetlands), ON (Bruce Mackenzie, 2021).

4.3 Niagara College, Niagara-on-the-Lake College, ON

Interviewee: Niagara College staff and faculty

Niagara college maintains a satellite campus and 15 acres restored wetland located in Niagara-on-the-Lake, ON (Figure 5). The wetland system is located at the base of the Niagara Escarpment, which is a designated United Nations Educational, Scientific, and Cultural

Organization (UNESCO) Biosphere Reserve encompassing many conservation and sustainability initiatives.

The two-cell constructed wetlands system was built by the Niagara Region to treat wastewater from a commercial building complex and an approximate horse track as there did not exist an extension of the municipal sewer system to this area (Niagara College, 2021). During the late 90s and early 2000s when the satellite campus was in construction, the municipal sewer line was extended, and the wastewater lagoons were no longer needed for treatment purposes. At this time, a faculty member in the Niagara College developing curriculum for the School of Environment led a series of negotiations that ultimately concluded with the college taking over ownership of the land for the price of $1. The caveat attached to the sale includes the agreement that the college would restore the lagoons through their ecosystem restoration postgraduate program. Since then, the land has transformed into a diverse ecosystem owing to the ongoing wetland restoration projects completed through academic delivery of the restoration postgraduate programs (Niagara College, 2021).

Figure 5 Location of the Niagara-on-the-Lake College Wetlands, ON outlined in red (Google Earth, 2021)

Niagara College staff and faculty described the main goals of the wetland restoration as utilizing the lagoons and wetlands as a method to deliver academic programming while having an accessible living laboratory for students to practice hands-on environmental restoration techniques. The wetland presented an opportunity for students to gain the experience of completing a wetland restoration project and monitoring for impacts on a year-to-year basis while incorporating adaptive management strategies.

In terms of operation and maintenance, the priority is to mitigate safety risks to the public through regular maintenance of walking trails within the wetland. Currently, wooden weir structures passively monitor and control the water levels in the wetland. Due to the risk of the wetlands permanently drying up, the weir structures have persisted since the original construction of the wastewater lagoon. Therefore, maintenance on the wooden weir structure has been crucial in maintaining water levels in the wetland although maintenance on the water levels themselves is a fairly passive process. The fate of the wetlands is unknown regarding the presence and role of the weir structures.

The wetlands are primarily recharged by precipitation and surface runoff which channels into the wetland ponds through a collection ditch. Subsequently, the water exits from the southernmost pond discharging into the adjacent watershed.

Students performing restoration projects at Niagara-on-the-Lake College, ON restored wetland (Niagara College, 2021).

From a design standpoint, Niagara staff and faculty described minimal design changes of the wetlands during the restoration process. Bank reinforcement of the ponds was completed to ensure safer and more accessible areas for students and the riparian zone was improved. Initially, planners identified variability in pond depth as beneficial for the intent of wetland drainage because the depth at the time, was consistent throughout the wastewater lagoons; however, due to concerns of potential ground contamination, the planners decided not to drastically alter the variability in depth to the wetlands. When dealing with invasive phragmites, the College found that controlling the water level by increasing the water to a certain level beyond precipitation can help manage the invasive species in the ponds. Native plant species were prioritized as reestablishing these species helped establish habitat for wildlife. The College also acknowledged times where floods and droughts have occurred. These changes to the ecosystem were natural and contributed to the diversity found within the wetland.

4.4 Niverville Wetland, MB

Interviewee: Consultants of Native Plants Solutions

Niverville is located approximately 42km south of Winnipeg, Manitoba. The former Niverville municipal wastewater treatment plant contained two lagoon cells (4.6-ha primary cell and an 8.8-ha secondary cell) that operated for 37 years between 1971–2008 serving a population of 2,500 when it ceased operation (Figure 6) (Jeke et al., 2016a). When it came time for the town to decommission the lagoons as they could no longer sustain the growing population of the lagoons cells, the province of Manitoba asserts the site of the former municipal lagoons must be decommissioned to establish new lagoons.

Figure 6 Former Niverville municipal wastewater treatment plant (left image) and current restored wetland layout (right image) (Jeke et al., 2016a).

In 2012, research was conducted by University of Manitoba researchers, in collaboration with Ducks Unlimited and Native Plant Solutions with the goal to examine the in-situ use of cattail in a wetland and terrestrial system to remove nutrients and metal contaminants from municipal biosolids in the decommissioned lagoon system using a technique called phytoremediation. This technique does not require the biosolids in the lagoons to be excavated; instead, it sequesters the biosolids in the lagoon while reducing potential contamination to surrounding environments that could occur if biosolids were spread on agricultural land similar to traditional methods of decommissioning (Jeke et al., 2016a). When the vegetation grown in biosolids is harvested and removed from site, the accumulated nutrients and contaminants sequestered are also removed. Multiple studies have been conducted related to phytoremediation in the Niverville Wetland that monitor for biosolid sediment, the water column, moisture effects, plant roots, nutrient availability, and pathogen levels (Jeke et al., 2015a; Jeke et al., 2015b; Jeke et al., 2016b; Jeke et al., 2017; Jeke, 2018; Jeke & Zvomuya, 2018a; Jeke & Zvomuya, 2018b; Jeke et al., 2019).

The design of the wetland includes a wetland cell, terrestrial system cell (dry pond), holding cell, wetland control (included for the purposes of the studies), and stormwater/precipitation influent pipe (Figure 6). The primary wetland cell (formerly Cell 1) was stripped and stockpiled in the lagoon, the cell was redesigned with benches to support wetland vegetation, cattails were planted in the benches. Part of the primary cell was isolated and left undisturbed during construction to serve as a control for the purposes of the study and a holding pond was created to store water for replenishing the wetland water with precipitation and water from stormwater ponds from the Town of Niverville. Wildlife species were not within the scope of the studies conducted in Niverville; however, the selection of seeding and growing native species was deliberate due to the low maintenance and cost aspects. Planting native species create more habitats and a refuge for wildlife as a result.

At the time, phytoremediation had not been tested to improve the quality of biosolids anywhere in Canada. Regulators in the region were hesitant to allow permits for the wetland to discharge until researchers and consultants could demonstrate that their treatments were effective. In the end, the researchers found that the phytoremediation was successful and contaminants that once above guidelines were found to have consistently declined below guidelines while nutrient loading potential had also reduced. As a result, regulators are now recommending phytoremediation to other towns in similar decommissioning stages.

The consultants noted that focusing on restoring a single wetland cell will provide detailed results regarding the wetland system of the single pond; however, as the project includes the restoration of multiple wetlands and ponds, it is important to understand how multiple interacting sites will be influenced by one another and how they will work in conjunction by one another. This was evident when the consultants stated, “it is great to look at one lagoon cell, but often we think about how those cells actually work in conjunction with one another when we are creating multiple sites”. The consultants recommended that maintaining water within the lagoon cells during the restoration will allow more restoration options. This was suggested because the Niverville secondary lagoon cell dried up prior to the restoration and cattails immediately established in the cell. Once established, cattails are difficult to manage. Ultimately, maintaining a level of water in the lagoon cell can reduce the establishment of such species which can interfere with restoration plans and designs.

4.5 Blakeburn Lagoons Park, BC

Interviewee: Consultant of ISL Engineering

Located in Port Coquitlam, BC, Blakeburn Lagoons Park is an 11-ha nature reserve and park opened to the public during spring 2018. Blakeburn Lagoons Park is bound by residential properties, a golf course, and farmlands (Figure 7). The site was a wastewater treatment plant until its decommissioning in 1978, leaving the site abandoned. Due to high levels of contaminants exceeding regulations for urban parks, high up-front capital was needed to reclaim the site owned by the city of Port Coquitlam, ultimately preventing the restoration until 2015 when federal and municipal funding ($2.85 million) became available (ISL Engineering and Land Services, 2020). This allowed the abandoned site to naturally restore and for contaminants to dilute for 37 years as “contamination levels have been mitigated…reducing drastically to the point of just small pockets leftover of higher contamination areas”. The consultant stated that often “nature takes care of itself” as evidence by the low levels of contaminants detected during the restoration. The consultant believed that nature’s ecosystem service of remediating contaminants and disasters is invaluable and is an event that occurs every day sometimes, benefitting the ecosystem.

Figure 7 Location of Blakeburn Lagoons Park, BC outlined in red (ISL Engineering, 2020).

The main goal of the restoration project was to convert the brownfield into a public amenity while reducing contaminant levels and prioritizing public safety, ecological restoration, and stormwater management (ISL Engineering and Land Services, 2020). Ultimately, the consultant stated the design of the restoration project was “geared around people and interaction with the water”.

Originally, the treatment plant contained two WSPs which were deepened, reshaped, and regraded to incorporate more ecological complexity for wildlife habitats. These improvements also helped in reducing water temperatures, reducing algae blooms, and improving water quality. The restoration process involved 50,000 m^3 of earthworks. Some areas in the wetland where remediation was required contained imported soil (3000 m^3) mixed with lagoon sludge and planted with phytoremediation plants. These areas were capped off to the public due to contamination concerns ensuring the rest of the park was accessible for public use (ISL Engineering and Land Services, 2020).

Many habitat elements were added to the park including “wetland habitat islands, gravel beaches, ephemeral pond (to help control bullfrog populations), tree snags, woody debris piles, bat boxes, and edible plants” (ISL Engineering and Land Services, 2020). Additionally, vegetative buffers and fencing were created to protect sensitive areas from public access. Hydrological enhancements included a new municipal stormwater inlet/outlet and wetland linkages allowing movement of water in the wetland (ISL Engineering and Land Services, 2020). The stormwater system was reconfigured to direct water to the wetland in order to help maintain water levels and support aquatic biofiltration/bioremediation processes. Incoming stormwater was pre-treated with a new hydrodynamic separator to remove contaminants and debris. Subsequently, a pre-treatment pond was the next line of defense with the main purpose of capturing suspended solids which were isolated from the wetland’s larger water bodies. Lastly, plantings were the final treatment for stormwater prior to entering the wetlands for polishing.

When asked about the main considerations while designing and planning the restoration project, the consultant listed four major concerns: redirecting stormwater to recharge the wetlands from the surrounding neighbourhood; ensuring the hydraulic grade line did not rise to the point of causing flooding hazards to the surrounding neighbourhood; mitigating concerns of the first flush (first considerable, sudden rainfall following the dry summer months that mobilizes contaminants into the environment); and providing an environment for wildlife to establish itself while being cognizant of establishing an integrated environment. The consultant specified their meaning of integrated environment in Blakeburn Park by describing it as the provision of multiple, varied types of ecosystems within the wetland. It is important to recognize the wetland is manufactured; therefore, allowing multiple, different ecosystems for nature to select from gives “nature its opportunity to establish itself and find its equilibrium”. This was a common theme throughout the restoration process made evident when the consultant said, “our ethos became let nature do its thing” and “nature will come by, and nature will decide what would actually work or not work”.

In terms of maintenance and operation procedures, the City of Port Coquitlam supports the park by maintaining the edges of trails and pathways. While discussing active management initiatives that should be implemented, the consultant noted that thinning out the vegetation is important in allowing space for larger vegetation such as trees to establish and to increase diversity of ecological habitats for wildlife. During the restoration process, a heavy planting schedule was implemented for phytoremediation processes and to drive out invasive species. Specifically, over 100,000 native shrubs and groundcover plants, 1,300 native trees, and two hectares of native grasses were planted to create six biotopes including "wet and dry meadow, forest, brush, emergent, and aquatic habitats" (ISL Engineering and Land Services, 2020).

In terms of stakeholder involvement, the consultant stated, "you have to know what your vision is, and hold that vision knowing you can [improve the current state of the environment]." The consultant acknowledged that some stakeholder groups may hold conflicting interests that can become problematic when they said, "you are not going to satisfy all of the public". Although some stakeholders may not agree, the true aim is to get the stakeholder to understand the goals and vision of the project. Currently, the park is a refuge to countless bird and wildlife species and is a well sought-after park for families and wildlife enthusiasts.

Lookout at Blakeburn Lagoons Park, BC (ISL Engineering and Land Services, 2020).

5. Lessons Learned

Port Rowan Wetlands, ON:

- Wetland management is crucial: once the wetlands have been established, the job is not finished. Active management needs to be an on going priority to ensure the intended stakeholder results and the wetlands reach their full potential of acting as a wildlife refuge.
- Ensure there is a long-term management plan following the initial restoration

Grimsby Wetland (Biggar Lagoon Wetlands), ON:

- It is important to have the support of the community and have the community involved in the project.
- Removal of invasive species was the pinnacle of the restoration efforts in this case. The majority of the limited funding for this project has been allocated to dealing with invasive which has proven to be very beneficial for other successional species.

Niagara College, Niagara-on-the-Lake College, ON:

- Provide educational opportunities for the community to alleviate any concerns regarding the area. Do not assume everyone will be supportive of the restoration initiative. Maintain an appropriate level of community outreach and educate the public about the values of the restoration.
- One of the greatest regrets from this project was not having good records and communication of the project so having good records of ongoing activities is important.
- Collaborating early on with Indigenous groups, the public, and stakeholder groups while prioritizing community engagement was a regret that the designers of the project wished had happened.

Niverville Wetland, MB:

- The main lessons learned from this project were to do research and understand the underlying science and processes of the restoration.
- Envision the bigger picture and understand the cumulative impacts that this project can have.
- Be patient because we are going to be here for the long haul.

Blakeburn Lagoons Park, BC:

- Integrated project delivery is a newer way to deliver projects where the owner, the consultant, and the contractor are on the same team at the beginning. In doing so, the design and the restoration process will be derived from a team with similar goals and interests while bringing different experiences together to achieve common goals. This allows innovative and creative ways of achieving commonly shared goals.
- Understand regulatory requirements during the design phase as regulatory requirements will drive and limit the design at each phase of the restoration.

- Make clear the purpose of the park to guide stakeholder involvement, ecological enhancements, and restoration design. If the park is mainly intended as an amenity for humans as opposed to enhancing the environment for wildlife habitat, the design and planning of the park may differ drastically.

6. Recommendations

6.1 Project Goals: Humans VS Environment

Many requirements are available for constructed wetlands with the purpose of wastewater treatment; however, in the case of Iona Island, the premise of the project is to construct a wetland for wildlife habitat and enhance biodiversity. It is important to understand the project goals and focus on the intentions of the restoration. Ask the question: Is the wetland *mainly* intended for human use or for the environment? Depending on the answer, the design of the wetland may drastically change. For example, if the wetland's main purpose is to serve as a public amenity, more walking paths will be created; however, increased walking paths create more habitat fragmentation and intensifies human and predator proximately to wildlife habitat. Based on the literature, variability in biophysical parameters from the planning stage can influence species richness and diversity at multiple trophic levels. Overall, understanding the balance between human and ecological needs will effectively alter the project design and implementation.

6.2 Indigenous Groups, Public, Stakeholders: Engagement

Based on lessons learned from past restoration projects, it is essential that Indigenous groups, the public, and stakeholders support the restoration. To garner support, all parties of concern must be involved throughout the early phases of the project. Provide opportunities for outreach, when possible, to alleviate public concerns and to justify project goals. As mentioned by multiple case studies, not everyone will be on board with certain project actions and processes. In this case, explaining the fundamental goals and vision of the restoration will be key to ensure continued public support. The vision and project goals should be generated from knowledge sharing of Indigenous groups, the public, and stakeholders. This restoration project provides an excellent opportunity to work with Indigenous knowledge holders and implement traditional ecological knowledge.

6.3 Ecological: Let the Wildlife Decide

Based on all case studies, no specific wildlife species were chosen to occupy a certain restored space. The main philosophy of most case studies was to allow the wildlife to decide which spaces they desire to use. Although one may argue that selecting specific species to model an environment can be beneficial especially if the goal was to encourage the growth of a species-at-risk, we must try to expand the ecological scope to encourage the integration of the entire ecosystem. All species that contribute to an ecosystem should be considered when designing ecological restorations. We recognize that some species (umbrella and keystone species) can encompass others; therefore, designing features to enhance them and other species is common.

The literature emphasized the success in biodiversity enhancement with increased wetland surface area and ecosystem complexity. Creating multiple biotopes within the project site inherently increases wetland surface area and encourages complexity and variability within the ecosystem. Overall, all case studies that proceeded with an attitude that emphasized nature as the decision-maker was rewarded with increased species richness and/or abundance.

6.4 Process & Operations: Practice Active and Adaptive Management

Most case studies did not include an active or adaptive management plan which created impedances to achieving increased biodiversity within restoration projects. In fact, passive system infrastructure was the main mechanism of management. Most cases believed a long-term management plan was needed to maintain/increase biodiversity and the functioning of the restored wetland. A long-term plan not only protects wetlands from threats but also ensures ecological sustainability goals. Some cases that used a passive management system were not completely satisfied with the performance or state of biodiversity in the wetlands. For that reason, active and adaptive management needs to be implemented and environmental monitoring is warranted to create baselines for the changing future climate while addressing limitations occurring in the present. Additionally, incorporating active and adaptive management into the restoration design allows for project goals and visions to be attained.

6.5 Research Gaps: The Opportunity of Iona Island

Restoration of wastewater wetlands is a new area of work; as a result, best practices, studies, and procedures of implementing such a restoration are scarce. The literature review demonstrated multiple gaps in knowledge that will be actively addressed throughout the current restoration project. Many times, restorations projects like some presented in this report proceed with scarce funding, few resources, and unclear expectations. The Iona Island restoration project provides a novel opportunity for Metro Vancouver to restore and improve a disturbed site for a balance of human and wildlife usage. Few cases with similar socio-economic and environmental variables exist as precedent to the Iona Island project; therefore, managing the wetlands should be experimental and flexible where we try to recognize and fill knowledge gaps.

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Appendix A: Interview Questions

1. Background

- Can you give a brief project description of the site?
  - Where is the case located?
  - What did the baseline/background environment look like before the disturbance?
  - What is the size of the wastewater treatment facility and of the restoration area?
  - What are the environmental features and landscape types?
  - Saltwater/freshwater/mixed
- What would you say were the main goals of the project?

2. Processes/design

- Can you talk more about the operation and maintenance of the wetlands?
- What were the main considerations that you had to consider in the design planning phase of the project?
- Are the wetlands using treated wastewater to recharge wetland?
- What is the current state of the water quality in the wetland following restoration?
- Was there any potential for lag-time effects during the construction/restoration process?
- What would be a ballpark estimate of the up-front capital cost of the project? What is the estimated cost for operation management of the project?
- Were there any challenges during development? Planning stages? Operation and maintenance issues?
- Were there any notable lessons learned that you would like to share?

3. Ecology

- What were the main species that the case focused on? Birds? Invasive species?
- Can you tell me more about the diversity and abundance of species before and after the restoration?
- Were there any challenges/success with species? What would you do next time?
- Were there any notable lessons learned that you would like to share?

4. Indigenous groups, Public, Stakeholders

- Who were some of the parties involved and how did they contribute to the project?
- Who owns the land and how are they managing it?
- Were there any challenges and lessons learned in terms of working/consulting the public?
- Were there any main takeaways related to public experience?

5. Other

- Can you share any relevant documents, summaries, reports, or plans with us?
- Are there any photos of the project that you are willing to share? The photos would be used in my report and presentation and credit will be given to the photos.
- Would you like to talk about anything else that I might have missed, or do you have any other information to pass along?