City of Richmond

Report to Committee

To:	General Purposes Committee	**Date:**	April 13, 2021
From:	Todd Gross Director, Parks Services	**File:**	06-2345-20- TNOV4/Vol 01
Re:	**Proposed Tidally Influenced Terra Nova Slough Update**		

Staff Recommendation

That, as described in the report titled "Proposed Tidally Influenced Terra Nova Slough Update" dated April 13, 2021, from the Director, Parks Services, Option 1 (Floodbox with Self-Regulating Tide Gate) be endorsed for the purposes of design, costing and evaluation of habitat compensation benefit and be submitted for consideration in the 2022 budget process.

Todd Gross
Director, Park Services
(604-247-4942)

Att. 2

REPORT CONCURRENCE		
ROUTED TO:	**CONCURRENCE**	**CONCURRENCE OF GENERAL MANAGER**
Engineering	☑	
Sustainability & District Energy	☑	
Finance	☑	
REVIEWED BY STAFF REPORT / AGENDA REVIEW SUBCOMMITTEE	**INITIALS:**	**APPROVED BY CAO**

Staff Report

Origin

At the Parks, Recreation and Cultural Services Committee meeting on May 28, 2019, staff received the following referral:

> *(1) That Option 2: Create a Tidally Influenced Terra Nova Slough, as outlined in the staff report titled "Proposed Tidally Influenced Terra Nova Slough Update" dated April 5, 2019 for the Director, Parks Services, be endorsed; and*
>
> *(2) That staff be directed to explore (i) design options for the tidally influenced Terra Nova slough, including the original plan, and (ii) additional funding sources.*

Staff presented information regarding the functional requirements which would see the existing freshwater pond habitat converted into a tidally influenced habitat supporting migrating Fraser River salmonids. In the ensuing discussion, staff advised Committee that any water control structure in the dike would need to meet the seismic and flood protection equivalent of a standard pump station.

The purpose of this report is to update Council, provide technical information to evaluate options and seek Council's direction on a preferred design option for consideration in a future capital budget process.

Background

In 2004, the Terra Nova Rural Park Plan called for development of a functional estuary slough with an outlet to the Middle Arm of the Fraser River to support salmonids within the park and potentially offset future impacts to fish habitat from City projects including diking. The first phase of the project was implemented in 2007 with the construction of the slough channel.

The second phase entailed engineering design and costing for a flood control gate and connecting pipe to link the slough to the Fraser River. Conceptual cost estimates to breach the dike and install an outlet structure were assessed in 2009; at that time, cost estimates exceeded the City's budget, and the project was put on hold. The slough has been functioning as a freshwater pond since 2007.

A technical review of the project, including assessing possible offsetting credits, was conducted in 2018 and options were presented to Committee in May, 2019. In response to the referral stemming from that meeting, staff commissioned a technical study by Kerr Wood Leidal (KWL) Engineering (Attachment 1: Terra Nova Slough Environmental and Engineering Design - Final Report (March, 2021), which included evaluating possible project options that may accrue offsetting credits for the City under federal authorization.

Analysis

The overall Slough project can be summarized as a conversion of the existing approximately 7,000 m^2 of freshwater aquatic and riparian habitat (the pond) into an estuarine marsh habitat (a tidally influenced slough). It would involve:

- Construction of a culvert connecting the pond to the Fraser River;
- Installation of a seismically resilient tide gate to regulate the flow of water;
- Creation of a channel from the mouth of the tide gate to the Fraser River;
- Upgrades to the dike and a portion of River Road;
- Crown land lease from the Province; and
- Modifications to the existing pond to convert it to a functional tidally influenced slough.

The City retained a consultant team to look at various design options as well as funding sources which are outlined in the KWL report. The scope of the study was to:

1. Re-evaluate the options to connect the slough to the Fraser River;
2. Identify key environmental, engineering, park, costing and permitting considerations for a tidal connection;
3. Identify conceptual options which maintain dike integrity and flood protection for the City;
4. Evaluate concept options based on a number of feasibility criteria; and
5. Recommend a preferred option and suggest next steps towards implementation.

This proposed project would impact portions of the existing park and freshwater pond. There are a number benefits as well as challenges with this project. These impacts were also part of the study's scope.

The focus of this report is to respond to the council referral and provide options for the slough to be connected to the Fraser River. An enhanced slough would diversify the habitat in Terra Nova Park, provide park visitors interpretative and public education opportunities and address the present challenges of the existing fresh water body. It will not necessarily provide the best habitat enhancement nor compensation opportunity when compared against other potential projects in the City.

This staff report was informed by and written with input from the KWL report.

Proposed Terra Nova Tidal Slough

The original 2007 design proposes a single entry and exit point between the Fraser River and the existing pond. The proposed tide gate structure would regulate the slough's water level, changing with the natural tide cycle. The tide gate structure would be designed to protect the slough during king tide and storm surge events and would be designed to the same engineering standards as the City's pump stations. If a tide gate structure is not used, a secondary dike would need to be constructed around the slough and connected to the existing City dike to isolate the slough from its surrounding context.

The purpose of the tidally influenced slough is to provide habitat for juvenile salmonids and other fish species that utilize estuarine habitats. In particular, the KWL report identifies the Chum Salmon as the most likely (of the Salmonid species) to use the tidally connected slough

due to the duration it spends in estuarine habitats as compared to the other major salmonids. Salmonid species would not use this habitat for spawning purposes nor would Sturgeon access the proposed system.

Environmental and Regulatory Setting

Terra Nova Rural Park functions as a hub in the City's Ecological Network. The slough has been functioning as a freshwater pond since 2007 and assists in maintaining wildlife movement along the West Dike and Fraser River Estuary. The level of salinity, nutrients and sediments suspended in the water, and biodiversity of the plants growing in the riparian zone all contribute to making the estuary a unique environment which supports juvenile salmon as they transition from the freshwater environment to the salt water stage in their life cycle. A slough connected to the Fraser River would become a part of this ecosystem.

The Federal Government: the Department of Fisheries and Oceans Canada (DFO), pursuant to the federal *Fisheries Act*. DFO assesses most activities occurring in or near water to determine risks to fish and fish habitat. Federal *Airport Zoning Regulations* restrict development such as natural vegetation growth and building heights near airports to ensure clear flight paths. The Province of BC: Protection of BC's freshwater resources are regulated by the Province under the *Water Sustainability Act*. Various elements of flood infrastructure, including the upgrade of the City's diking system is subject to requirements of the provincial *Dike Maintenance Act* and the *Water Sustainability Act*.

Fish Habitat Banking and Enhancements

Fish habitat banking was established federally by DFO as a tool for fish habitat compensation. Legislated under the *Fisheries Act*, project proponents can acquire credit, in the form of area, by creating or improving fish habitat that can be banked to offset future impacts on different projects. DFO approval is required before a habitat banking project can proceed. There is no habitat offsetting program that is currently available with the Province.

There have been various habitat offsetting and/or enhancement projects in the Lower Fraser River which Council has been previously updated, including:

- Port of Vancouver: The Port actively pursues potential projects to offset their land development activities including the Fraser River Estuary Enhancement Project and the proposed Finn Slough Enhancement Project, intended to offset the Robert's Bank Terminal 2 Project (subject to approval by the Federal Government).
- Fraser River South Jetty and Sturgeon Banks: The Raincoast Conservation Foundation has been working on increasing fish passage along the Fraser's South Jetty and Council endorsed an application in 2020 from the South Coast Conservation Land Management Program, which proposed three habitat enhancement projects in the Lower Fraser, including one on Sturgeon Bank.
- Iona Island Wastewater Treatment Plant: Staff also been involved in the engagement process for this Metro Vancouver-led proposed upgrade project. Metro Vancouver is currently proposing a comprehensive habitat enhancement plan as part of the upgrades to will maintain and enhance the biodiversity of the island.

- Other: A forthcoming staff report on this matter is coming for Council's consideration in 2021 related to offsetting requirements for future upgrades.

Flood Protection

The Council endorsed 2019 *Richmond Flood Protection Strategy* identifies the perimeter dike system as the primary flood protection system to protect the community against climate change induced sea level rise and seasonal flooding. Dike Master Plan Phases 1, 2, 3, and 5 have been endorsed and Dike Master Plan Phase 4, focusing on the North Dike, is under consideration.

Flood protection maintenance works and upgrades, include raising dikes approximately 1 metre in height, are required and impact the City's Ecological Network. Dike improvements require an expanded footprint when constructed and dike design and construction best management practices no longer allow for channelized watercourses or ditches adjacent to dikes. The proposed dike footprint in each planning phase has been conceptually designed to avoid high-value fish habitat along the Fraser River. Where it cannot be avoided, a loss of existing riparian and aquatic habitat on the land-side is projected and must be offset under provincial and federal regulations.

As detailed in the City's Flood Protection Management Strategy, Richmond is situated approximately 1.0 m above sea level and flood protection is integral to protecting the health, safety, and economic viability of the City. Richmond is protected from flooding by infrastructure that includes 49 km of dikes. The City's Flood Protection Management Strategy and Dike Master Plans are the guiding framework for continual upgrades and improvements to address climate change induced sea level rise.

Flood protection integrity, and alignment with the City's Dike Master Plans and Flood Protection Management Strategy, are critical components that all options proposed in this report were evaluated against. All proposed options and associated structures were required to maintain or enhance the current flood protection system and be built to be seismically resilient. Associated structures have the ability to be designed to the same engineering standard as existing City drainage pump stations and all proposed options support future upgrading of the existing dike to 4.7 m geodetic in the near term with the ability to be raised to 5.5 m geodetic in the future.

Further details on flood protection have been included with each option evaluation identified later on in this report.

Options for Consideration

The result of the study was the creation of seven options which were examined and evaluated in detail. The options are grouped into the following three categories:

1. Connect the slough to the Fraser River:
    - Option 1: Floodbox with Self-Regulating Tide Gate (Recommended)
    - Option 2: Open Culvert and Ring Dike
    - Option 3: Tide Gate and Flood Berm

2. Intertidal connection elsewhere in Terra Nova Park:

- Option 4: Alternate Intertidal Marsh Slough in the Northeast corner of Terra Nova Rural Park
- Option 5: Connect and Enhance Existing Wetlands in Terra Nova Nature Area

3. Alternate options for Slough:
   - Option 6: Convert to Ephemeral Marsh
   - Option 7: Fill Slough

For a summary of all seven options, please see Attachment 2 (Terra Nova Slough Evaluation of Concept Options).

The seven options were evaluated using the following feasibility criteria:

1. Cost: What is the approximate capital cost for design and implementation of the option? What is the per unit area cost in terms of the habitat created?
2. Flood Risk: What is the potential impact on flood risk to the Park and broader City?
3. Habitat and Ecological Value: What is the habitat type to be created and relative value of the habitat being connected to?
4. Park User Experience: How will the park visitor experience be affected? What opportunities might exist to enhance the visitor experience as a result of the option?
5. Operations and Maintenance: What are the operations and maintenance (O&M) requirements created by implementation of the option?
6. Fish Passability: What is the qualitative rating of fish passage into the slough or other habitat created that will be provided by the option?
7. Other Considerations: Permitting requirements, regulatory approvals process, and climate change resilience.

The following is a brief evaluation of the options proposed for Council's consideration. For additional information, please refer to Attachment 1 and specifically to *Table 1: Terra Nova Slough Engineering and Environmental Design – Evaluation of Concept Options* on page 27 of the KWL Report.

Existing Slough Conversion Options

The following three options look at converting the existing slough from its present form as a self-sustaining and hydrologically isolated freshwater pond to a tidally influenced, brackish channel connected to the Middle Arm of the Fraser River with water levels regulated with a tide-gate structure and integrated with existing City flood protection infrastructure.

Option 1: Floodbox with Self-Regulating Tide Gate (RECOMMENDED)
Estimated total cost: $2.5M + $250K for slough enhancements plus operating budget impact (OBI) (to be determined)

Brief Description: The staff recommendation for this option is subject to the City obtaining habitat offsetting credits in a defined agreement with DFO. Additional discussion and assessment is required to define these terms and staff will seek Council endorsement as appropriate. Creation of a culvert under River Road terminating in a self-regulating tide gate on the river-side. This is

essentially an update to the original 2007 design which was updated in 2018. The slough would be hydraulically connected to the River while the tide gate would limit flow in and out of the system at high tide (design elevation) to protect the City. Based on current sea levels, this would result in the tide gate being open approximately 72% of the time. Based on current climate change science, sea level is expected to rise by 1 m by 2100. In the 2100 scenario, the tide gates will reduce to being open 34% of the time. This is due to an increased probability that the river water levels will be above the design elevation of the slough.

The slough would be connected to the river via the existing ditch running along the south side of River Road. Two gates would be installed to completely isolate the water in the slough system from the area's drainage system. A culvert would be installed under the existing dike and River Road, with a self-regulating, seismically resilient tide gate installed at the end. The slough system is then connected to the Middle Arm of the Fraser River via a newly created channel. This new channel will be graded to permit the required volume of inflow and outflow from the River and slough system and will extend out to the main channel of the Middle Arm. The challenge with a culvert is that juvenile salmonids are generally reluctant to enter dark tunnels. See Figure 1 below for more information on the proposed slough system configuration.

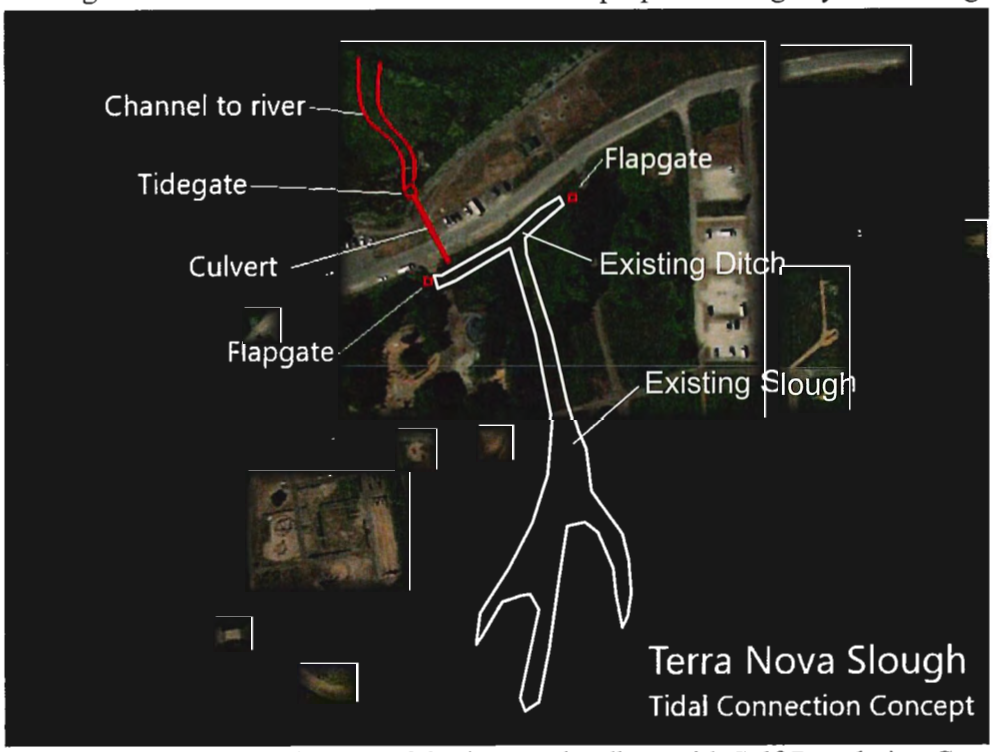

Figure 1: Conceptual Diagram of Option 1: Floodbox with Self-Regulating Gate.

The process to convert the existing slough from a freshwater pond habitat to a tidally influenced, saltwater riparian fish habitat will involve the following slough enhancements. (The following steps would also apply to Options 2 and 3):

1. Sludge Removal: The bottom of the existing slough has a significant volume of semi-decomposed organic sludge. This will need to be removed as part of the construction process. The slough would be drained, sludge dredged and potentially composted for re-use in Terra Nova Park.

2. Slough Regrading: Once the sludge is removed, the bottom of the slough will need to be re-graded to permit positive water flow north towards the river. This will ensure regular flushing of the slough and reduce the possibility of fish stranded at low tide. Fraser River silts would be used to fill in any low points and create tidal benches at optimum tidal elevations for low marsh vegetation. Habitat benches would be created using vertically placed untreated wood planks embedded into the bottom of the slough. Importation of silts would be over the existing 50 cm rock blanket presently lining the bottom of the slough and would mimic the types of sediments found in naturally occurring estuarine habitats.

3. Riparian and Intertidal Planting: Intertidal vegetation will need to be planted from native plant nursery stock. Dense planting will be necessary to limit invasive species establishment. Plantings would include additional native trees (outside of the dike footprint) and shrubs to provide shade and nutrients for the slough system.

Table 1: Option 1 Concept Evaluation

Evaluation Criteria	Evaluation Summary
Cost	$2.5M + $250K for slough enhancements plus OBI (to be determined).
Flood Risk	Very low; river debris may clog the gate preventing closure, risk can be mitigated through regular maintenance, automated sensors, a stop log structure and gates with fish screens along the existing ditch that can assist with park drainage if required. Tide gate structure will be seismically resilient and built to 4.7 m geodetic.
Habitat Value	New habitat for Fraser River fish species, including juvenile salmonids.
Park User Experience	Similar to existing although a change of aesthetics due to tidal variation.
Operations and Maintenance (O&M)	Increase over present (minimal). Regular monitoring and debris clearing per pump station maintenance practices. Tide gate maintenance will be required. Ongoing maintenance of the slough for invasive species.
Fish Passability	Moderate; decreasing with time due to sea level rise.
Regulator and Other Considerations	Slough would become subject to regulation of the federal *Fisheries Act* when connected to the Fraser River.

Option 2: Open Culvert and Ring Dike
Estimated total cost: $5M + $250K for slough enhancements plus OBI (to be determined)

Brief Description: This option sees the slough extended to the Fraser River with an open channel except for the portion running under River Road via a bridge structure. A standard dike would be built around the slough. This would further isolate the slough, increase the design elevation and create increased opportunities for fish passage throughout tide cycle. The standard dike would be built to provincial and City standards and be built to 4.7 m geodetic and have a base of approximately 20 m width. This would significantly impact existing features in the park, including the removal of very mature trees, existing paths and portions of the Terra Nova Adventure Play Environment (playground). The final routing of the standard dike would need to consider mitigating the impacts on these existing park features. The above referenced estimated

cost does not include expenses related to modifications to the surrounding Terra Nova Park area as specific impacts have not yet been determined.

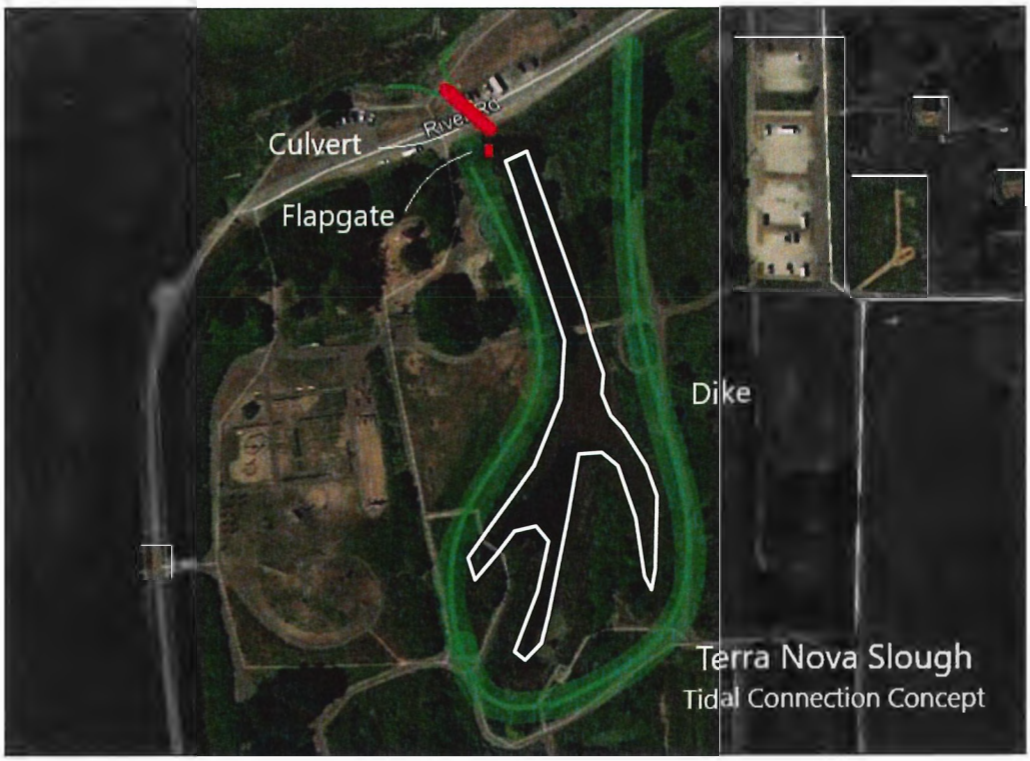

Figure 2: Conceptual Diagram of Option 2: Open Culvert and Ring Dike

Table 2: Option 2 Concept Evaluation

Evaluation Criteria	**Evaluation Summary**
Cost	$5M + $250K for slough enhancements plus OBI (to be determined).
Flood Risk	Very low; standard dike would isolate the slough from the rest of Lulu Island, providing the same level of flood protection for the City that currently exists. New standard dike would be built to 4.7 m geodetic with the ability to be raised to 5.5 m in the future.
Habitat Value	New habitat for juvenile salmonids. Significant negative impacts to upland vegetation, including mature trees.
Park User Experience	Significant impact to existing paths, trees and playground. New standard dike will provide the opportunity for a new path system and interface with new slough.
Operations and Maintenance (O&M)	Increased over present (minimal). No tide gates to maintain. Mowing of new standard dike and regular inspection required.
Fish Passability	Excellent; open to fish passage throughout the tide cycle.
Regulator and Other Considerations:	Slough would be subject to regulation of the federal *Fisheries Act*, provincial *Water Sustainability Act* and provincial *Dike Maintenance Act* would apply to new standard dike.

Option 3: Tide Gate and Flood Berm
Estimated total cost: $4.5M + $250K for slough enhancements plus OBI (to be determined)

Brief Description: This option is a hybrid of Options 1 and 2; the addition of a flood berm around the slough to increase the design elevation and extend the period of time the flood gate can remain open during a given tide cycle adding sea level rise resilience. The addition of the flood berm, in the 2100 sea level rise scenario, would increase the amount of time the flood gate is open from 34% in Option 1 to 58% in Option 3. The flood berm would not be constructed to the same flood protection standard as the standard dike outlined in Option 2 as it is only serving as a additional flood protection measure to the tide gate. Thus the flood berm would be built to 2 m geodetic (as opposed to 4.7 m geodetic for the standard dike) and considerably narrower at the base therefore the impact to the park is reduced in comparison to Option 2. The flood berm could be constructed after the tide gate is installed and the slough is connected to the Fraser River as it serves as an additional flood protection measure in response to sea level rise. The characteristics are otherwise the same as those outlined in Option 1.

Table 3: Option 3 Concept Evaluation

Evaluation Criteria	Evaluation Summary
Cost	$4.5M + $250K for slough enhancements plus OBI (to be determined).
Flood Risk	Very low; the area within the flood berm could flood should the tide gate fail. Risk can be mitigated through regular maintenance, automated sensors, a stop log structure and gates along the existing ditch. Tide gate structure will be seismically resilient and built to 4.7 m geodetic. Flood berm will be built to 2 m geodetic and can be constructed when sea level rise is realized. It will functionally act as flood protection for the park, but the existing dike alignment along River Road would remain as the City's standard dike and primary source of flood protection. This would allow for greater flexibility for the structure and landscaped form of the flood berm.
Habitat Value	New habitat for juvenile salmonids. Significant negative impacts to upland vegetation, including mature trees through the construction of the flood berm. Impact can be mitigated through careful site design and flood berm placement.
Park User Experience	Significant impact to existing paths, trees and playground. Flood berm to be integrated with existing park as new feature.
Operations and Maintenance (O&M)	Increased over present (minimal) with regular tide gate maintenance.
Fish Passability	Moderate; similar to Option 1 with an increase in the amount of time the flood gate is open to 58% in 2100 with sea level rise.
Regulator and Other Considerations	Slough would be subject to regulation of the federal *Fisheries Act*, the provincial *Water Sustainability Act* and Crown land tenure for required connecting channel.

Alternative Options within Terra Nova

City Staff also considered two other options which might have larger impacts and potential habitat and ecological benefits due to their large size over the existing slough. This would involve two separate areas of existing 'old field' habitat in the Terra Nova Park area.

Option 4: Alternative Intertidal Marsh Slough in the Northeast Corner of Terra Nova
Estimated total cost: Unknown at this time (based on size and complexity of final configuration)

Brief Description: To mitigate the impacts on existing park features such as the Terra Nova Adventure Play Environment, existing mature trees, heritage structures and existing park infrastructure (parking lot, trails, etc.) this concept sees a new slough system created in the northeast area of the site. This area, formerly cultivated farm fields, is currently managed as old field and seasonal wetland habitat and hosts open field, a few mature trees and shrubs along the perimeter. An opening and channel under River Road would be regulated by a tide gate (similar to Option 1), however, a more extensive slough system could be created in the open field areas near River Road and to the south near the fields currently managed by the Richmond Sharing Farm (see Figure 3 below). Though the existing slough would not be included as part of this intertidal system, the area available in this proposed quadrant of the park could allow for a very extensive and complex system with potentially more ecological benefits than the existing system (depending on the scale of the final project). The system could include benefits to terrestrial and avian species as well as Fraser River fish species. See Figure 2 below for additional information.

Figure 3: Option 4: Conceptual Diagram of the Alternative Intertidal Marsh Slough in the Northeast Corner of Terra Nova

Table 4: Option 4 Concept Evaluation

Evaluation Criteria	Evaluation Summary
Cost	Undetermined at this time.
Flood Risk	Very low; tide gate regulated system built to similar specifications as Option 1 and Option 3.
Habitat Value	New habitat for juvenile salmonids potentially more extensive than the existing slough (depending on scale), minimized impact to mature trees and old field habitat and seasonal wetland converted to intertidal marsh and slough system.
Park User Experience	Significant impact to existing paths, trees and playground. Flood Berm to be integrated with existing Park as new feature. Overall design allows for integration with Park to be fully optimized.
Operations and Maintenance (O&M)	Increased over present (minimal) with regular tide gate maintenance and maintenance of a potentially larger and more complex slough system.
Fish Passability	Moderate; similar to Option 3.
Regulator and Other Considerations	Slough would be subject to regulation of the federal *Fisheries Act*, provincial *Water Sustainability Act* and Crown land tenure for connecting channel required.

Option 5: Connect and Enhance Existing Wetlands in Terra Nova Natural Area
Estimated total cost: Estimated at $10M (based on size and complexity of final configuration) plus OBI (to be determined)

Brief Description: Similar to Option 4, this option sees the creation of a tidally influenced marsh and slough system independent of the existing slough. As per Figure 4, the proposed system is only shown occupying the area south of Westminster Highway in the Terra Nova Natural Area. The area is currently occupied by a large freshwater pond, some forested areas and segments of old field habitat. Barn Owls frequent the area and are supported by rearing boxes erected by City staff. The proposal is to create a complex marsh and slough system connected by up to three oversized culverts in the existing perimeter dike. In turn, because there would be no tide gates installed in the dike openings, a new inland dike would be constructed to isolate this tidally influenced system and would be integrated with the existing dike system. A complex system of sloughs, marshes, riparian habitat and open grass areas lined with hedgerows could be created in this area.

Figure 4: Option 5 - Connect and Enhance Existing Wetlands in Terra Nova Nature Area

The openings in the existing perimeter dike would be connected by new channels extending west into the Grauer Lands. With documented occurrences of juvenile salmonid species already using the Grauer Lands as rearing habitat, this new intertidal complex seeks to leverage this existing natural system in the Fraser River estuary. Some old field habitat and Barn Owl enhancement projects would be displaced by the creation of this proposed system and the existing Terra Nova Slough would remain in its current state.

This conceptual design presents an opportunity to offset future habitat impacts that are expected as part of Richmond's future dike upgrades. A staff report from Engineering and Public Works related to the City's future habitat offsetting requirements is forthcoming for Council's consideration. If this concept was to be considered, a significant planning and regulatory processes would be required to best optimize the benefits to both the environment and the City, including Council endorsement through future reports on the matter.

Table 5: Option 5 Concept Evaluation

Evaluation Criteria	Evaluation Summary
Cost	Estimated at $10M (could vary greatly based on size and complexity of final configuration).
Flood Risk	Very low; a new inland dike would be constructed to isolate this tidally influenced system and would be integrated with the existing dike system.

Habitat Value	New high-quality habitat connected to the Grauer Lands system. Existing pond would be removed. Impact to mature trees and old field habitat which would be converted to intertidal marsh and slough system.
Park User Experience	This area can only be accessed via a perimeter trail; no access within this area exists. A new inland dike could offer park visitors an opportunity to interact with this new Park feature.
Operations and Maintenance (O&M)	Increased over present (minimal) with regular maintenance of a potentially larger and more complex slough system and inland dike.
Fish Passability	Excellent; up to three open culverts provides many opportunities.
Regulator and Other Considerations	Habitat banking advantages to offset other City projects (dike upgrades) as well as sea level rise resiliency advantages. Would involve approvals from various Federal and Provincial authorities.

Alternative Options for the Existing Slough

The following two options would be considered if the decision is made not to proceed with converting the existing slough to a tidally influenced fish habitat connected to the Fraser River. While maintaining the existing slough in its present form (that is, as a hydrologically isolated, fresh water pond) is possible, the following two options present other potential directions for consideration. Should a status quo approach be taken with the existing slough, prudent habitat management efforts would be recommended such as invasive species removal and dredging the partially decomposed material along the bottom. Each option will also be subject to environmental permitting requirements and Option 7 would require that the City offset the loss of freshwater habitat with replacement works to meet provincial requirements.

Option 6: Conversion to Ephemeral Marsh
Estimated total cost: Approximately $500K plus OBI (to be determined)

Brief Description: This option would see the existing slough, which presently functions as an underperforming freshwater pond system, partially filled in to create a seasonal wetland. This would involve the de-watering of the present pond, partial removal of the partially decomposed organic material on the bottom of the pond and importation of mineral-based soils to be mixed in with the remaining organic material. The former slough area would be re-graded to create a shallow depression which would hold surface water during the wetter seasons of the year and substantially dry out in the summer months. The benefits of this system include the curtailment (and potential elimination) of the invasive, non-native American -Bullfrog which currently inhabits the existing slough. Furthermore, invasive plants presently in the slough would also be eliminated. The existing beaver population would also be displaced. There are no indications that there are significant populations of fish in the current slough system.

Option 7: Fill-in the Slough
Estimated total cost: Approximately $750K plus OBI (to be determined)

Brief Description: This option would see the conversion of the slough back to terrestrial habitat with the filling of the existing freshwater pond habitat. Existing riparian habitat would be removed, new mineral soil as fill would be imported and the site graded to create a flat area which could be integrated with the existing park context. Fill could be secured through

development sites seeking soil deposit sites thus creating an opportunity for the City to offset costs through soil deposit fees. Once the site is graded and filling completed, old field habitat and hedgerows could be integrated with the existing habitat south of the slough as an option to consider. Other park programming opportunities could be explored by staff and presented back to Council.

External Funding Opportunities and Partnerships

The following potential external funding sources have been identified for the City in the consultant's report (Attachment 1). These organizations and funds could be used to assist with the implementation of the preferred option:

- Environmental Damages Fund (EDF): The Environmental Damages Fund (EDF) is a specified purpose account administered by Environment and Climate Change Canada (ECCC) to direct funds received from fines, court orders and voluntary payments to priority projects that will benefit Canada's natural environment.

There are also environmental organizations working on salmon restoration projects related to tidal marshes and flood or river management infrastructure. It may be possible to partner with one of the following organizations to share resources and project costs or pursue funding opportunities jointly:

- The Resilient Waters project (which is part of the MakeWay.org platform);
- Raincoast Conservation Foundation's Lower Fraser River Salmon Conservation Program; and
- Ducks Unlimited Canada (The City previously worked with Ducks Unlimited on projects in the Grauer Lands).

Not all projects would qualify for habitat banking depending on the funding agency; this would need to be considered as part a project *pro forma* process.

If a slough connection is pursued by the City as a pure enhancement measure and funding is sought through grants such as the EDF, an application to a competitive process will be required. It is unlikely that any grant amount would exceed $1 Million.

Financial Impact

Subject to Council's direction, staff will proceed with a capital project submission, corresponding OBI and external funding applications to be considered in the 2022 budget process.

Conclusion

Further analysis of the original tidally influenced slough design took into account measures required to maintain the City's flood protection standards. This includes allowing for the impacts of climate change induced sea level rise and ensuring that the proposed tidal gate has the ability to be seismically resilient similar to existing drainage pump stations throughout the City.

Staff recommend Option 1: Floodbox with Self-Regulating Tide Gate which responds to Council's direction to convert the existing pond into a tidally influenced slough connected to the Middle Arm of the Fraser River with water levels regulated by tide gate structure. This structure would be constructed to City engineering standards equivalent to the City's pump station infrastructure network. This option would need to be considered in coordination with all other potential City-initiated projects requiring habitat compensation including the need to offset future fish habitat impacts from flood improvement works.

Should Option 1 be endorsed, staff will continue to explore grant funding opportunities, habitat banking opportunities and partnerships with potential funding partners who are interested in supporting similar projects supporting salmonid species in the Fraser River.

Alexander Kurnicki
Research Planner 2
(604-276-4099)

Att. 1: Terra Nova Slough Environmental and Engineering Design - Final Report (March 2021)
2: Table: Terra Nova Slough Evaluation of Concept Options

Attachment 1

Richmond

Terra Nova Slough Environmental and Engineering Design

FINAL REPORT

KERR WOOD LEIDAL
consulting engineers

March 2021
KWL File No. 651.153-300

Contents

Figures

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Executive Summary

This report summarizes the results of work to identify, develop, and evaluate options to convert the current freshwater slough in Terra Nova Rural Park to a tidal, fish-accessible slough connected to the Middle Arm of the Fraser River. The primary objectives of this report are to:

1. Re-assess the feasibility of converting Terra Nova Slough (the Slough) to a tidally-influenced system connected to the Fraser River.
2. Identify key environmental, engineering, park, costing, and permitting related considerations for connecting the Slough to the Fraser River.
3. Identify conceptual options to connect the Slough to the Fraser while maintaining dike integrity and flood protection.
4. Evaluate concept options based on a number of feasibility criteria, including but not limited to:
   a. Costs, including one-time capital costs and ongoing operations & maintenance costs;
   b. Regulatory aspects and requirements; and
   c. Impacts to the existing park.
5. Recommend preferred options and next steps towards implementation.

The following options were examined and evaluated:

- Connect the Slough to the Fraser River:
  - **Option 1** – Floodbox with Self-Regulating Tide Gate
  - **Option 2** – Open Culvert and Ring Dike
  - **Option 3** – Tide Gate and Flood Berm
- Intertidal connection elsewhere in Terra Nova Area:
  - **Option 4** – Alternate Intertidal Marsh Slough in the Northeast Corner of Terra Nova Rural Park
  - **Option 5** – Connect and Enhance Existing Wetlands in Terra Nova Nature Area
- Alternate options for the Slough
  - **Option 6** – Convert to Ephemeral Marsh
  - **Option 7** – Fill Slough

The seven options were evaluated using the following criteria:

- **Cost:** What is the approximate capital cost for design and implementation of the option? What is the per unit area cost in terms of the habitat created?
- **Flood Risk:** What is the potential impact to flooding risk to the Park and broader City of the option?
- **Habitat / Ecological Value:** What is the habitat type to be created and relative value of the habitat connected/created?
- **Park User Experience:** How will the experience of visitors to the Park be affected? What opportunities might exist to enhance the visitor experience as a result of the option?
- **Operations and Maintenance:** What are the operations and maintenance requirements that will be created by implementation of the option?

- **Fish Passability:** What is the qualitative rating of fish passage into the Slough or other habitat created that will be provided by the option?
- **Other Considerations:** Are there other considerations that should be included as part of the evaluation (e.g., regulatory approvals, climate change resilience, etc.)?

On June 23, 2020, KWL and City of Richmond staff convened to discuss preliminary findings by KWL and review options for Terra Nova Slough. Three connection options for the Slough were presented (Options 1–3) along with a fourth offsite option for Terra Nova Nature Area (Option 5). (Options 4, 6 and 7 were developed after the workshop.) Each option was reviewed and discussed based on the above screening criteria, in addition to each project's consistency with Council direction. City staff identified their preferences and requested development of additional options. Staff feedback informed the evaluation and this report.

Based on the results of the screening criteria, evaluation process, and additional feedback from City staff, KWL recommends **near-term implementation of Option 1** (Floodbox with Self-regulating Tide Gate), and **long-term implementation of the flood berm in Option 3** (Tide Gate and Flood Berm) for adaptation to climate change. Looking just beyond the Terra Nova Sough and in terms of **optimal tidal fish habitat**, however, **Option 5** (Connect and Enhance Existing Wetlands in Terra Nova Nature Area) is preferred among all project options. Option 5 offers a large area of habitat, low unit cost, habitat banking potential, alignment with existing park uses, and received strong City staff support.

1. Introduction

This report summarizes the results of work to identify, develop, and evaluate options to convert the current freshwater slough in Terra Nova Rural Park to a tidal, fish-accessible slough connected to the Middle Arm of the Fraser River. The City of Richmond (the City) retained Kerr Wood Leidal Associates Ltd. (KWL) to complete the assessment and provide information and recommendations to help inform City planning and decision-making regarding this potential environmental enhancement project. The report follows previous phases of work by KWL which involved design and construction of the existing Terra Nova Slough (known herein as 'Terra Nova Slough' or 'the Slough') in 2007, development of a preliminary outlet structure design in 2009, and a review of the previously developed design in 2018.

1.1 Project Objectives

The following objectives were identified for this project prior to initiation:

- Re-assess the feasibility of converting Terra Nova Slough to a tidally-influenced system connected to the Fraser River.
- Identify key environmental, engineering, park, costing, and permitting related considerations for connecting the Slough to the Fraser River.
- Identify conceptual options to connect the Slough to the Fraser, including pump station options for safe fish passage; while maintaining dike integrity and flood protection.
- Conduct a workshop to review and discuss various options with City staff.
- Evaluate concept options based on a number of feasibility criteria, including but not limited to:
  - Costs, including one-time capital costs and ongoing operations & maintenance costs;
  - Regulatory aspects and requirements; and
  - Impacts to the existing park.
- Recommend preferred options and next steps towards implementation.
- Explore funding partnerships/sources from senior levels of government & not-for-profit organizations.
- Provide the results of the assessment in a summary report.

1.2 Flood Protection Requirements

Flood protection is a critical criterion against which all options for the Slough tidal connection or salmonid habitat enhancement are assessed. Changes to existing infrastructure, recommendations for new infrastructure, and any required operations and maintenance activities considered within this report shall maintain or enhance the current City flood protection.

1.3 Project Team

The following key KWL team members provided input into the project:

- Patrick Lilley, M.Sc., R.P.Bio., BC-CESCL - Senior Biologist and Project Manager
- Colin Kristiansen, P.Eng. - Senior Civil Engineer and Technical Reviewer
- Alan Jonsson, B.A.Sc. - Ichthyo-Fluvial Specialist
- Craig Sutherland, P.Eng. - Senior Engineer and Tide Gate Specialist
- Daniel Brown, R.P.Bio. - Project Biologist
- Sonya Oetterich, M.Sc., B.I.T. - Junior Biologist

In addition, the following City staff also provided important input to the project and/or participated in the July 23 options review workshop:

- Alex Kurnicki, BCSLA, CSLA– Research Planner, Parks Planning, Design & Construction (City Project Lead)
- Chad Paulin, M.Sc., P.Ag. – Environment Manager, Engineering & Public Works
- Corrine Haer, P.Eng. – Project Manager, Engineering Planning
- Chris Chan, EIT, PMP – Project Manager, Engineering Planning
- Pratima Milaire, P.Eng., PMP – Project Manager, Engineering Design & Construction
- AJ Morris – Project Manager, Engineering Design & Construction
- Miriam Pishka – BCSLA, CSLA - Park Planner, Parks Planning, Design and Construction
- Matthew Discusso, B.Sc. – Environmental Coordinator, Engineering & Public Works
- Jason Chan – Manager, Parks Planning, Design & Construction

2. Project Background and Context

2.1 Project History

The Terra Nova Rural Park Plan, developed in 2004, includes development of a functional estuary slough with an outlet to the Middle Arm of the Fraser River to support salmonids. The first phase of the project was implemented in 2007 with the construction of the Slough channel.

The second phase entailed engineering design and costing for a flood control gate and connecting pipe to link the Slough to the Fraser River. Costs to connect the Slough to the river through the dike and install an outlet structure were assessed in 2009. At that time, cost estimates exceeded the City's expectations and budget, and the project was put on hold. The Slough has been functioning as a freshwater pond since 2007.

Since the Slough was constructed, Terra Nova Rural Park has been developed and site improvements around in the vicinity of the pond include paths, viewpoints with seating, natural plantings, signage, and a floating bridge.

In 2018, KWL was retained to conduct a review of the existing connection design. The scope of the review included:

- A technical review of the design drawings to connect the Slough to the estuary;
- Reviewing the ecological value and function of the existing freshwater pond compared to the potential value and function of a tidally-influenced slough;
- Updating the risk assessment for placing an opening in the dike at this location in the context of the City's Dike Master Plan; and
- Developing an updated project cost estimate.

In May 2019, City staff were directed by Council to further explore design options that would connect Terra Nova Slough to the Fraser River and identify provincial and federal funding and partnership opportunities with regional stakeholders.

In May 2020, KWL was once again retained by the City. The content of this report constitutes the results of the scope of work outlined in Section 1.1.

2.2 Site Context and Existing Conditions

Terra Nova Rural Park (the Park) is a unique heritage destination that offers a range of immersive ecological, recreational, and agricultural experiences. The vision for the Park is to preserve its unique rural character while catering to diverse user groups and appropriately balancing competing uses. Site vegetation includes remnant woodlots, orchards, hedgerows, and windbreaks from early settlers, as well as mature grasslands (a.k.a. old field habitat) and forest and shrub environments. Active agricultural areas in the Park include community gardens, demonstration gardens, and the Sharing Farm fields. The Park also contains wetland environments other than the Slough.

The Slough is located in the northwest area of the Park along with trails, an extensive adventure playground, landscape mound and a picnic area to the west; trails, public art, and forest and shrub vegetation to the south and east, and; a perimeter drainage ditch, dike, River Road, parking area and the Middle Arm of the Fraser River to the north. The Slough includes boardwalks, viewing platforms, furnishings, and a floating bridge.

The Slough, built in 2007, is predominantly surrounded by a fringe of shrubs adjacent to mowed fields and walking paths. Riparian trees are limited with most occurring at the northern end of the Slough. Cattail (*Typha latifolia*) growth is dense and monotypic along the marsh bench that forms much of the Slough perimeter. Perennial aquatic plants of unknown species were observed rooted in shallow zones.

Most of the Slough is subject to full sun exposure, with warm water temperatures in summer. In addition, nutrient loading from the surrounding agricultural lands and low dissolved oxygen limit the habitat quality in the Slough. Key challenges include invasive aquatic plant encroachment over large areas of the Slough surface and beavers, which have colonized the Slough and removed unprotected riparian trees.

2.3 Estuaries and Ecological Value of Estuarine Habitats

Connection of Terra Nova Slough to the Fraser River and tidal action is intended to benefit Pacific salmon and restore some of the former ecological function of this part of Richmond. To achieve this, an understanding of the biophysical nature of estuaries and their linkage to salmon is important.

Estuaries are widely regarded as some of the most biologically productive landscapes on earth. Seasonally varied river flows meet twice daily changing tidal flows to create ever-changing variations in water level, salinity, and currents. Tidal level variations, in particular, are critical to the organization of vegetation and biophysical conditions that characterize estuaries. As water levels move up and down, intertidal areas experience alternating periods of flooding and drainage. This has a profound effect on sediment oxygen levels, which in turn affects processes such as iron reduction and oxidation, biological production of hydrogen sulfide, and accumulation of organic carbon. The duration of inundation, and conversely drainage, is largely a function of elevation relative to tides. Inundation effects can be seen in the distinct vegetation communities that segregate by elevation in estuaries.

Salinity is very influential on the character of estuaries. Freshwater inflows from rivers and terrestrial groundwater affect the zonation of plants and animals within and beyond estuaries. Although mixing of the waters to create brackish conditions is typical, saline and fresh waters may segregate by density, with lighter fresh water remaining in a layer on top. This is common when river flows are high.

Much of the biological activity within an estuary occurs at the microscopic level (Figure 1). Bacteria, single-celled organisms, algae, and multicellular plankton thrive due to the high levels of fine organic particulates and dissolved nutrients. Rivers with large watersheds can transport immense quantities of organic matter to the ocean. The uptake and processing of nutrients and organic matter provide the base of a highly productive food chain. In some cases, the single-celled organisms and their byproducts are consumed directly by higher-order vertebrates. Diatoms and their biofilm have been discovered to be an essential food source for migrant shorebirds.

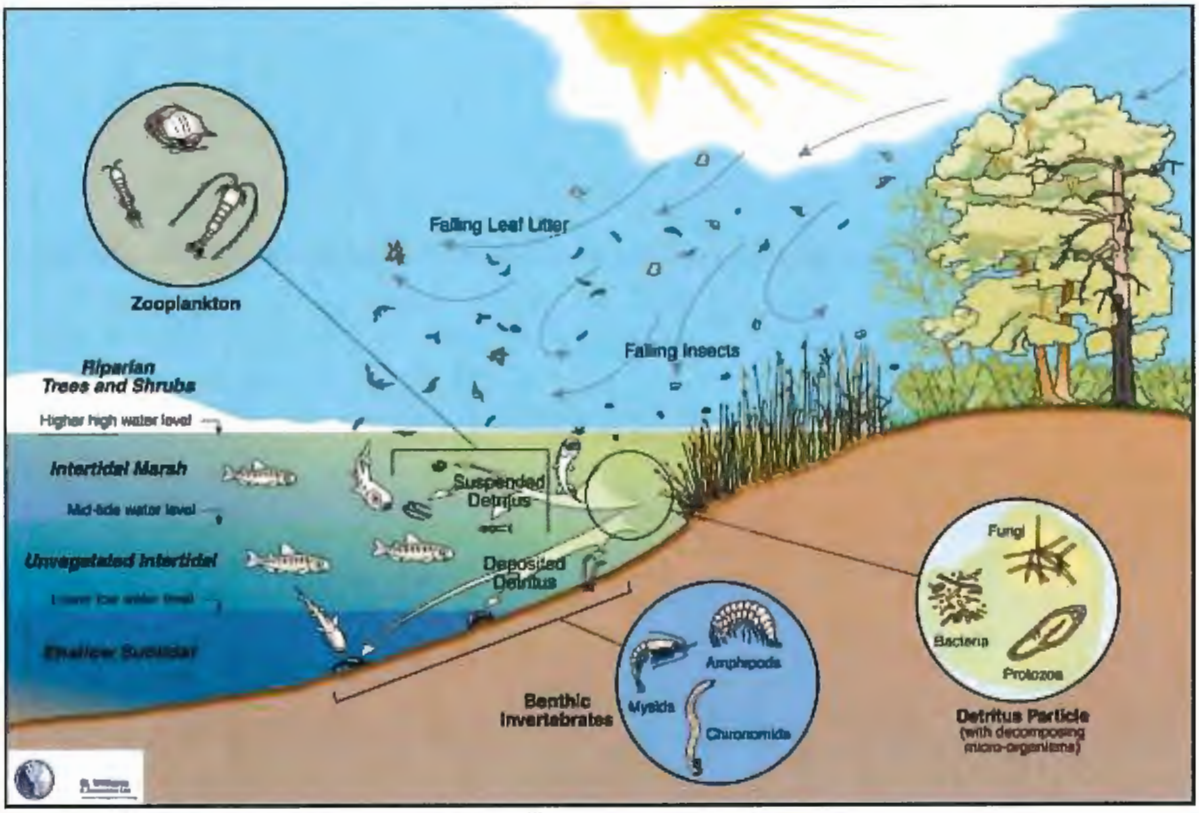

Figure 1: Schematic of Energy Flows in an Estuary
(Figure courtesy of Gary Williams, G.L. Williams and Associates Ltd.)

Tidal Channels

Connected channels and blind channels (sloughs) are a ubiquitous landscape feature in estuaries. They can range in size from less than a metre to several kilometres wide. Their formation and persistence are a product of tidal flows scouring on both tidal ebb and flow. Channels are dynamic and will grow or shrink as sediment, vegetation, and biological conditions change.

Tidal channels are immensely important to the plants and animals that are found in estuaries. For plants, channels provide vital drainage, improving oxygenation and decreasing toxic hydrogen sulfide levels. Plants living on the edge of channels are frequently healthier than those located some distance away. Improved plant health, in turn, can create stronger root systems reinforcing the channel slopes and binding otherwise unstable fine-grained silts and clays.

For animals, particularly fish, channels are both travel routes and prey concentrators. Drainage from an area of estuarine marsh, and all of the detritus and invertebrate drift contained within it, will be concentrated in the channel during certain periods of the tidal cycle. Fish will position themselves in the channel and feed on the abundant prey being carried past.

Tidal Channels and Salmon

Pacific salmon are present in West Coast estuaries twice in their lives: as juveniles on their way to the sea and as adults returning to spawn upriver. Their time as adults in estuaries is typically insignificant and rarely away from the main channel that is the migratory corridor. However, time in the estuaries for juveniles may last months (for some species) and utilize many diverse habitats within estuaries.

Estuarine residence serves two vital functions for juvenile salmonids: it allows time for physiologic changes required to transition from fresh to saline water environments and it provides a high prey/low predator environment for growth. Juvenile salmon are highly vulnerable to predation upon entering the open ocean and bigger body size is correlated with higher survival.

The importance of estuaries to Pacific salmon varies with species due to their diverse life histories and strategies. Those that have had a year or more of rearing time in fresh water, such as Coho salmon (*Oncorhynchus kisutch*) and Sockeye salmon (*Oncorhynchus nerka*), will spend minimal time in estuaries. Pink (*Oncorhynchus gorbuscha*) and Chum salmon (*Oncorhynchus keta*), that have weeks in freshwater but are abundant and school for safety, will also spend minimal time in estuaries. However, "ocean type" Chinook (*Oncorhynchus tshawytscha*), that spend only 90 days in freshwater, rely on estuaries for growth and may be resident there for months. At present, many threatened and endangered salmon Conservation Units are ocean type Chinook. Estuarine habitat loss may be a contributing factor to some Chinook stock declines.

Juvenile salmon are typically present in the estuary between March and August, with low numbers of Coho, cutthroat trout (*Oncorhynchus clarkii*) and char (*Salvelinus spp.*) present year-round. Other types of fish, such as starry flounder (*Platichthys stellatus*), eulachon (*Thaleichthys pacificus*), herring (*Clupea pallasii*), stickleback (*Gasterosteidae spp.*), sculpin (*Cottoidea spp.*), and native cyprinids utilize the estuary as well. Recent work by the Raincoast Conservation Foundation recorded 19 species of fish utilizing Fraser River estuary marshes (D. Scott, pers. comm.).

Chum, with their gregarious schooling behavior, are the most likely and numerous salmonids to utilize a connected Terra Nova Slough. They can often be observed in schools throughout March and April along Fraser River and marine shorelines.

It is important to note that the reversing flow and fine-grained sediments that characterize estuaries do not provide conditions suitable for salmonid spawning. The conditions lack the porous gravel and steady flow of water required for egg burial, incubation, and survival.

Tidal Channels within the City of Richmond

Prior to agricultural development and diking, many tidal channels penetrated deep into the islands that comprise present-day Richmond. As shown in the map below based on Royal Engineers vegetation surveys (1858–1877), a channel was present in the vicinity of the Park. The channel was approximately 1 km in length and would have provided tidal flooding and drainage to a vast area. Many, if not most, of these channels were either filled or incorporated into linear dug drainage networks.

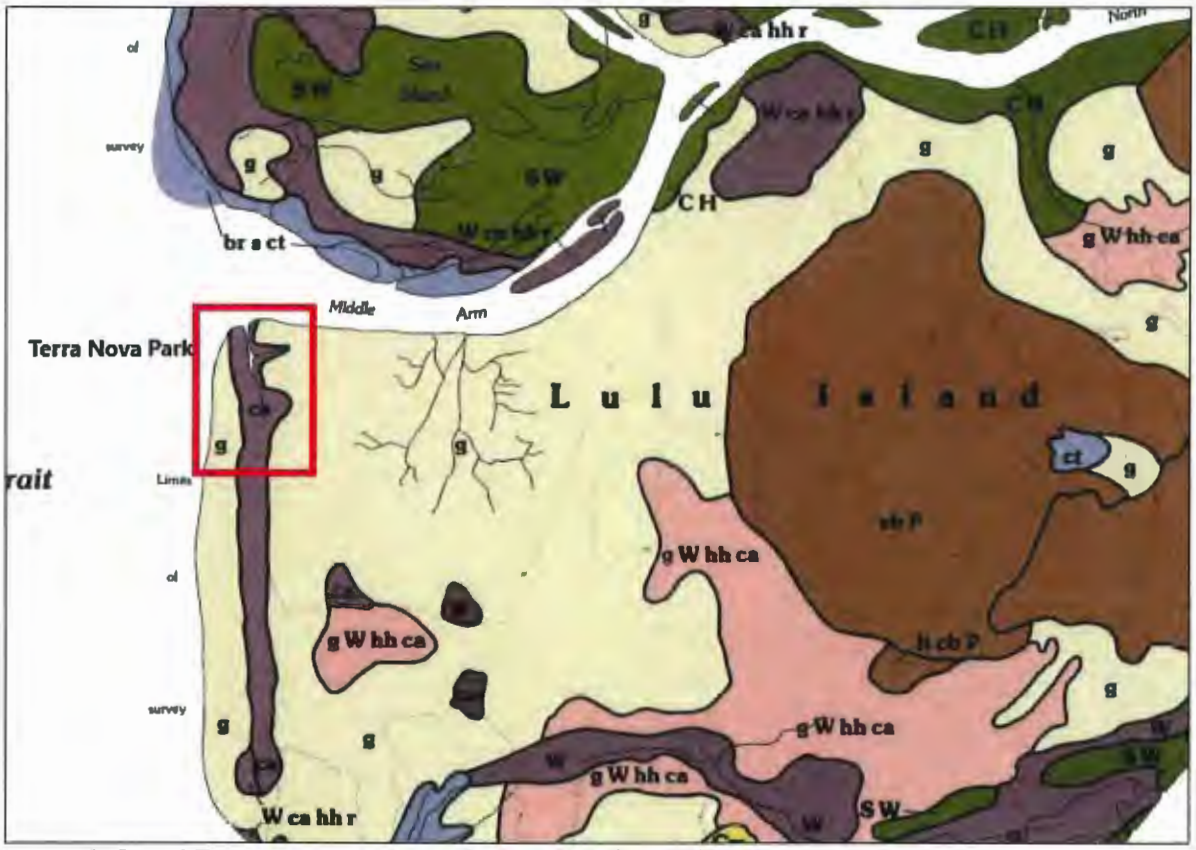

Figure 2: Royal Engineers Vegetation Survey Map (1858–1877)
(Source: North, Decker, and Teversham 1979)

3. Key Considerations

Evaluating the feasibility of converting the existing freshwater system of Terra Nova Slough to a brackish tidally-influenced system connected to the Fraser River requires examination of four primary factors used to gauge feasibility:

1. Biophysical considerations;
2. Park use and park user experience;
3. Park management;
4. Engineering requirements;
5. Capital and operating cost; and
6. Permitting requirements.

3.1 Biophysical Considerations

For the Slough to function as a tidal slough and provide quality habitat for juvenile salmon, the following factors must be considered:

- hydraulic connectivity;
- fish passage;
- water quality;
- type and extent of vegetation; and
- morphology.

Hydraulic Connectivity

The hydraulic connection between the Slough and North Arm is foundational to all other considerations. Water must flow in and out of the Slough with minimal restriction to maintain the rate and timing of tidal fluctuations. A connection with limited cross-sectional area would impair the rate of water exchange, create high flow velocities through the connection, and potentially act as a partial barrier to fish passage. In an extreme case of restricted tidal exchange, the Slough would neither completely fill nor empty creating an artificially damped tidal range. If tidal inflows are restricted substantially below the natural high tide, this may also create a tide cycle with an artificially long high slack period that can alter plant communities. An extended high slack period would not cause harm to juvenile salmonids. However, salmonids trapped in a low slack period, as may be caused by ponded water, may be subject to high water temperatures, lower dissolved oxygen, and predation. For fish passage and slough biological function, a restored slough should drain completely during low tides.

Fish Passage

The configuration of the hydraulic connection also defines fish passage potential into the Slough. Juvenile salmonids are often wary of entering areas where predator ambush may occur. This often results in them staying in shallow water along margin edges, adjacent to vegetation that can provide cover and away from shadows and darkness. In most cases, juvenile entry into sloughs is volitional – the fish will not enter unless they are sufficiently motivated. A long, dark culvert, especially one below the water surface, may be sufficient to deter solitary or risk-averse schools of salmonids. Mitigative measures for such culverts have not been developed.

Water Quality

Water quality, suitable for salmonids, will be maintained by daily tidal flushing. Ideally, flushing and water exchange within the Slough would be sufficient that water quality parameters would be virtually identical to the North Arm. Water quality may be problematic if the Slough cannot fully drain or is prevented from emptying at all. Without enough water exchange, solar heating and biological oxygen demand from plant decomposition could result in water conditions that are impaired compared with the North Arm and possibly even beyond the temperature and dissolved oxygen thresholds for salmonids.

Vegetation

Vegetation within and around the Slough will affect its fish habitat productivity. Many aquatic and terrestrial invertebrates, that are prey for salmon, live on plants for all or a portion of their life cycle. In the case of terrestrial vegetation (such as trees and shrubs), growing conditions in the Park are not limiting. However, emergent marsh species have specific substrate and elevation requirements. Vegetation will not grow below -0.5 m geodetic elevation (where soils are continuously inundated) and many species require a well-drained, mineral-based soil. Vegetated marsh areas also typically have very little slope to them. In contrast to this, the Slough has a coarse rock substrate topped with accumulated organic muck. This rock was placed to counteract the instability of the side slopes caused by groundwater emergence from the saturated soils beneath the Park.

Morphology

It is important to note that, morphologically, Terra Nova Slough does not mimic a natural tidal channel. Even with full tidal connection, it cannot achieve salmon habitat productivity seen in natural channels. The constructed Slough was designed with an emphasis on volume and depth, rather than edge and vegetated intertidal area. As previously described, natural tidal channels are created and maintained by the local area they drain. The contributing drainage area to the channel is analogous to a "watershed". The size of the watershed for a tidal channel determines the volume of nutrients, detritus, and invertebrates that will drain through that channel on each tidal cycle. A natural channel with the cross-sectional area of Terra Nova Slough would typically drain up to 10 ha of intertidal flats. However, due to the Slough design and limitations on the height of tidal inundation within the Park, the contributing "watershed" for Terra Nova Slough is limited to the Slough itself, an area of about 0.6 ha. This is a very simplified comparison but suggests that even under ideal conditions, the Slough may only achieve a fraction of the fish habitat productivity that a natural channel of similar cross section.

For habitat comparison purposes, Terra Nova Slough is more analogous to 650 m of Fraser River shoreline wrapped back on itself. Vegetated shoreline is valuable for juvenile salmonids and does contribute to fish habitat. However, the aspirations for salmon habitat value at Terra Nova Slough should be tempered by this observation. Achieving optimal fish habitat productivity within Terra Nova Slough would require a substantial expansion (up to 10 ha) of the intertidal marsh area around the Slough.

3.2 Impacts to Existing Park Features and User Experience

Terra Nova Park provides a diverse range of experiences to park users. As described by the City of Richmond, the Park offers "*immersive natural experiences, walks among farms and gardens, and gorgeous views of the Salish Sea*" as well as a "*network of trails, unique adventure playground, and many tranquil rest areas*"[1]. Specific mention is made of proximity to Sturgeon Bank and abundant migratory birds.

Modification of the Slough by habitat enhancement works and tidal connection will change the physical characteristics and aesthetic qualities. If the Slough is connected, Slough water will vary in level and turbidity and marsh vegetation will diversify. Slough variation may evoke different responses from park users, depending upon their values and preferences. If the Slough is to be used as a habitat banking location and/or become fish habitat, permanent delineation of the vegetated perimeter of the Slough may be required to minimize public access and potential disturbance of the riparian vegetation.

Slough modification options involving berming or diking around the perimeter of the Slough would have significant impacts to existing park features and user experiences. For example, berming or diking would result in obstructed sightlines across the Slough and park, require realignment of existing trails and boardwalks, removal of vegetation and trees, and potential replacement of play equipment. Based on restrictions that are in place to protect dikes from structural damage, should a dike be added around the perimeter of the Slough, trees would not be permitted within the dike crest and planting would be limited to grass and small shrubs.

Public consultation and education before, during, and after any Slough modification is highly recommended. If the Slough is tidally connected and becomes salmon habitat, educational signage explaining the ecological function of the Slough and tidal marshlands would be a beneficial addition to the Park.

3.3 Park Operations and Maintenance Impacts

The proposed change from a static, freshwater body to a brackish, tidally-influenced slough will have a myriad of effects on this part of the Park. Existing public access to the Slough and City Park Services management practices will need to be adjusted should the Terra Nova Slough be connected to the Fraser River. Conversion to a tidally-influenced slough should be accompanied by fish habitat enhancement measures such as dense riparian planting, dredging of the existing pond, and removal of non-native plant species.

Once completed, public access to the Slough area will need to be limited to key points in order to protect habitat. Existing public access points to the Slough and new/alternative opportunities for visitors to experience enhanced habitat areas, require further exploration. Additional study will be required on the effects of a change in water elevations and quality in the Slough on the surrounding landscape, including mature trees, existing biota in the pond and heritage structures. Although the Slough connection will be engineered to limit flood heights and allow complete drainage, resident beavers may build dams that interfere with these objectives and will need to be managed.

Existing operations and maintenance practices will need to be modified following the construction of the Slough. The flood protection infrastructure will need to be maintained per current City practices on similar structures. This includes the removal of debris and regular maintenance of mechanical components. Maintenance of the enhanced landscape and riparian habitat area around the Slough may

[1] City of Richmond. 2020. Terra Nova Rural Park. URL https://www.richmond.ca/parks/parks/SigParks/parkinfo/park.aspx?ID=80.

include care of riparian vegetation, additional mowing, on-going invasive plant management, and management of public access to restored riparian areas.

Regular dredging or maintenance in the Slough is not anticipated. Due to the tidal connection, sediment accretion and erosion in the Slough will be self-regulating. The flow will likely scour a channel through the substrate that carries most of the flow, like a tidal channel. There may be slow deposition of sediment in some areas of the Slough, but not enough to impact function or warrant maintenance.

3.4 Engineering Requirements

The following engineering requirements have been identified for the project:

- Connection of Terra Nova Slough to the Fraser River must adhere to all standards and practices for flood protection, seismic stability, and public safety within the Province of British Columbia.
- City Engineering staff has stipulated that any connection must not reduce the level of flood protection to Lulu Island, i.e., the project design must meet the same standards that apply to other flood control infrastructure and drainage projects within the City, including level of service and seismic stability.
- The connection must be able to accommodate future flood protection upgrades in the area. The current Dike Master Plan for the area (Lulu Island Dike Master Plan Phase 2) requires that the dike be upgraded to a +4.7 m geodetic minimum dike crest height with an allowance for future upgrades to +5.5 m geodetic. Current dike crest elevations within the Park vary from +3.2 to 3.3 m geodetic with the land within the dike at +1.0 m geodetic.
- If a lower standard for flood protection for a portion of the Park were to be deemed acceptable by Richmond City Council, the rest of the City would still need to be protected to the above standard. This could potentially be achieved through construction of a secondary dike to isolate the Park as a separate flood cell.

3.5 Summary of Key Considerations

Connection of the existing Terra Nova Slough to the Fraser River presents a number of potential challenges. The following key considerations have been identified:

- The current Slough morphology does not mimic a natural tidal channel and significant interventions would be required to prepare it for tidal connection and increase in value as salmonid habitat.
- The appearance of the Slough should be a key consideration as this will impact the park user experience. This includes impacts to existing park features such as trails, boardwalks, furnishings, sightlines, trees, and potentially playground equipment in the Terra Nova Adventure Play Environment.
- Parks Operations resources and impacts should be considered in terms of the extent of habitat enhancement measures that can be feasibly maintained after implementation
- Ongoing flood protection of the Park and the integrity of the Lulu Island perimeter dike system is essential and limits the type of slough connection options that can be considered.

4. Salmon Habitat Enhancement Options

Several options for modification of Terra Nova Slough have been developed. Broadly, three enhancement options were explored:

1. **Connect the existing Terra Nova Slough to the Fraser River**, allowing fish access and tidal cycling;
2. Undertake an **alternative salmon habitat enhancement project** in the Terra Nova Area; and/or
3. **Do not connect the Slough** but modify its freshwater function.

4.1 Connect Existing Slough to the Fraser River

General Slough Habitat Enhancements

Regardless of the tidal connection method chosen, the Slough requires remediation and upgrades to ensure functional fish habitat. Several measures are required:

- **Sludge Removal:** The Slough is currently a nutrient-rich freshwater body with large amounts of semi-decomposed organic sludge. Although currently settled, the sludge will be suspended when the Slough is subjected to tidal action. Upon suspension, the sludge will create a substantial biological oxygen demand and turbidity, both of which are detrimental to aquatic habitat and particularly salmonids. Removal of the sludge will require draining of the pond and suction dredging. After dewatering, the organic sludge may be beneficially reused as a soil amendment or composted.
- **Slough Regrading:** Following dredging and while the water level is held low, portions the Slough should be filled with Fraser River silts to eliminate low sumps and allow full drainage of the pond from south to north. This will eliminate potential for fish stranding and improve drainage and oxygenation of sediments. Based on the pond bathymetry of the original design, fill depths may be up to 1.5 m in the lowest parts of the Slough. Additional sediments should be placed to create benches (or terraces) at optimal tidal elevations for low marsh vegetation. The benches may be placed on top of the 50 cm thick rock blanket that presently lines the Slough. Benches will require some form of initial structural reinforcement as the edges will be near vertical. Staked coniferous planks would be suitable, providing support until root structures have fully established and provide structural support.
- **Riparian and Intertidal Planting:** Intertidal vegetation may naturally colonize the Slough through floating seeds. However, planting of wild gathered or nursery-grown stock will accelerate marsh establishment and deter invasive species establishment. Additional planting of trees and shrubs around the Slough perimeter would also be beneficial to provide shade, nutrients, and filtrating of overland flow.

A cross-section of the enhanced Slough is shown in Figure 3.

The recommended actions will be challenging due to factors such as dewatering, sludge handling, and limitations associated with working in and about a public park. It is estimated that these enhancement works, which include dewatering, dredging, sludge treatment/remediation, terracing, lining, edging, and riparian planting, will require a budget of approximately $250,000.

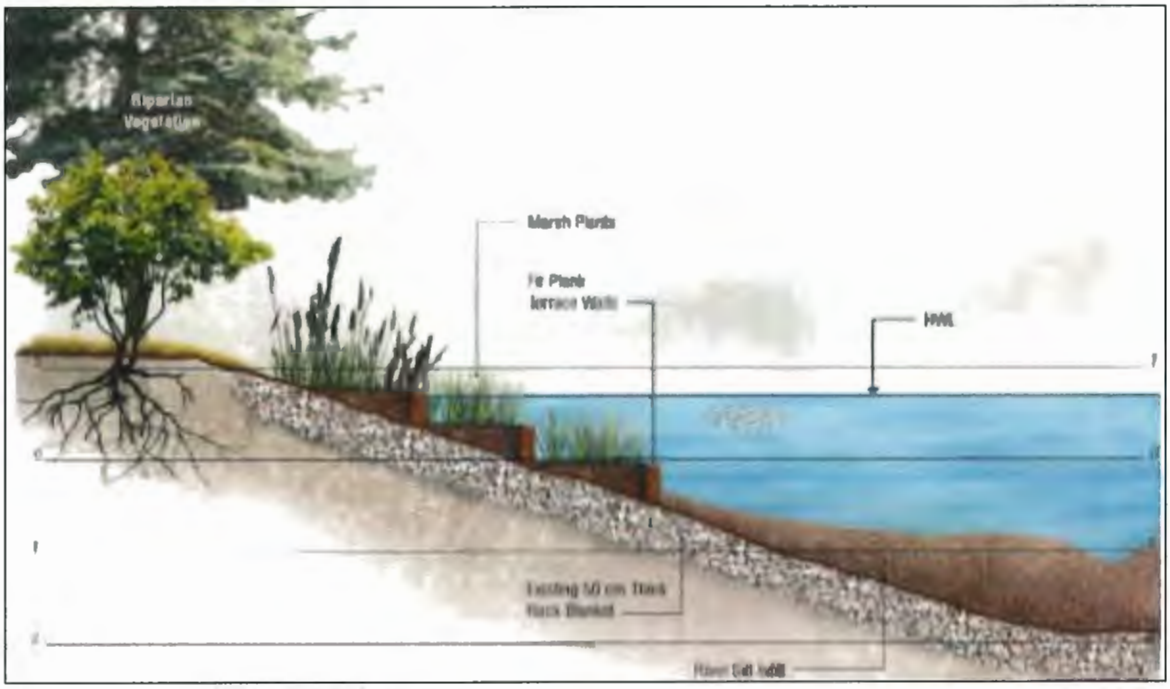

Figure 3: Cross-section of Enhanced Slough

Option 1 – Floodbox with Self-regulating Tide Gate

Design – Option 1 consists of a culvert under River Road terminating in a self-regulating tide gate (Figure 4). This is the original connection option that was designed in 2007 and reviewed in 2018. The floodbox would hydraulically connect the Slough to the North Arm while the gate would limit inflow during high tides. This would be achieved by utilizing a float switch or power controls that keep the gate open at low and mid tides and close the gate at tidal elevations approximately +0.75 m geodetic and above to protect the Park from flooding. As the tide falls, the gate would again open at +0.75 m geodetic and allow the Slough to drain. This would give the Slough a depth range of approximately 1.75 m. Based on hourly recorded and predicted tide levels from Point Atkinson between 1914-2020, the tide gate would be closed 28% of the time under current conditions. Assuming a 1 m sea level rise (SLR) from current tide levels, the tide gate would be closed 66% of the time in the year 2100 (Figure 5).

The connection from the Slough to the floodbox would utilize a portion of the River Road ditch, necessitating hydraulic isolation of this segment from the regional drainage system. Flap gates would be required to prevent tidal inflows from travelling east up the ditch to the No. 1 Road North Drainage Pump Station. A channel through the existing low marsh would be cut to connect the tide gate invert to the North Arm channel.

The risk of flooding from runoff if the tide gate fails to the "closed" position is small. Currently, the drainage from the Slough area flows east to the No. 1 Road pump station. This would be restricted by a flap gate that could be opened up to drain the park if needed. If not, the park would get flooded, not any homes.

Biophysical Requirements / Fish Passability – Fish access into the culvert may be limited at tidal heights above +0.5 m geodetic since that is the elevation of the top of the culvert. As previously discussed, a fully submerged pipe may be perceived by juvenile salmonids as an area with high predation risk. The maximum water elevation limitation creates an artificially extended "high slack" period. This extended inundation may affect the health of marsh plants in the Slough at low elevations. The lower elevational limit for marsh inside the Slough may be higher than in the estuary. However, the exact effects of longer duration high slack periods are uncertain.

Figure 4: Option 1 – Floodbox with Self-Regulating Tide Gate

Maintenance/Operational Considerations – All infrastructure would be built to current flood and seismic standards and require regular inspection and maintenance. Floodboxes can be vulnerable to jamming with floating debris such as logs. Grillage or a floating boom could be used to keep debris from entering the gate and floodbox. However, ongoing monitoring and maintenance will be required. Automated sensors to detect jammed gates and/or water level is advisable. The design of the debris barrier must address whether it could act as an unintentional deterrent to juvenile salmonid passage.

The addition of a tide gate into the dike structure is comparable to adding a new pump station. It includes a pipe and automatically closing gate within a seismically stabilized structure. The pipe and gate will operate similarly to flap gates that exist in many of the City's 41 drainage pump stations. These existing flap gates let internal drainage water flow out through them by gravity during low tides, and close automatically due to hydraulic back pressure during tides above the height of the gate. The only difference with a tide gate is that it can be set to close at a higher tide than the elevation of the gate.

Both systems can be jammed open and require inspection and maintenance to keep them working correctly. Both should be backed up by a slide gate or stop log structure that permit hard closures for maintenance or as a backup.

The automatic closure mechanisms are more complex on a tide gate than a flap gate, but they are not as complex as pump stations. They may be unfamiliar to City Operations Staff at first, but won't take long to gain familiarity.

Impacts to Existing Park –The connection of the Slough to the Fraser would subtly change the Park user experience, principally through the visual change in Slough water level and vegetation. Paths, bridges and viewscapes would not be affected.

Permitting – A significant regulatory and management change would occur with the connection. The Slough and fringing riparian areas would become subject to regulation of the federal *Fisheries Act* and provincial *Water Sustainability Act* as a result of reconnecting the Slough to the river. Activities such as bridge repairs, path construction, and tree management would require notification or possibly review by Provincial and Federal government agencies. The existing Slough is subject to the Provincial *Water Sustainability Act* as it is connected to the groundwater network.

Cost Estimate – Based on the 2018 review of this proposal, the current estimate for implementation of this connection is $2.5 million.

Additional Considerations – Future sea level rise would decrease the open time for the flap gate as tidal elevations rise. This would gradually increase the duration of the artificial "high slack", decreasing fish access periods and potentially affecting Slough marsh plants. Uncertainty regarding the rate of sea level rise prevents prediction of when these effects may occur.

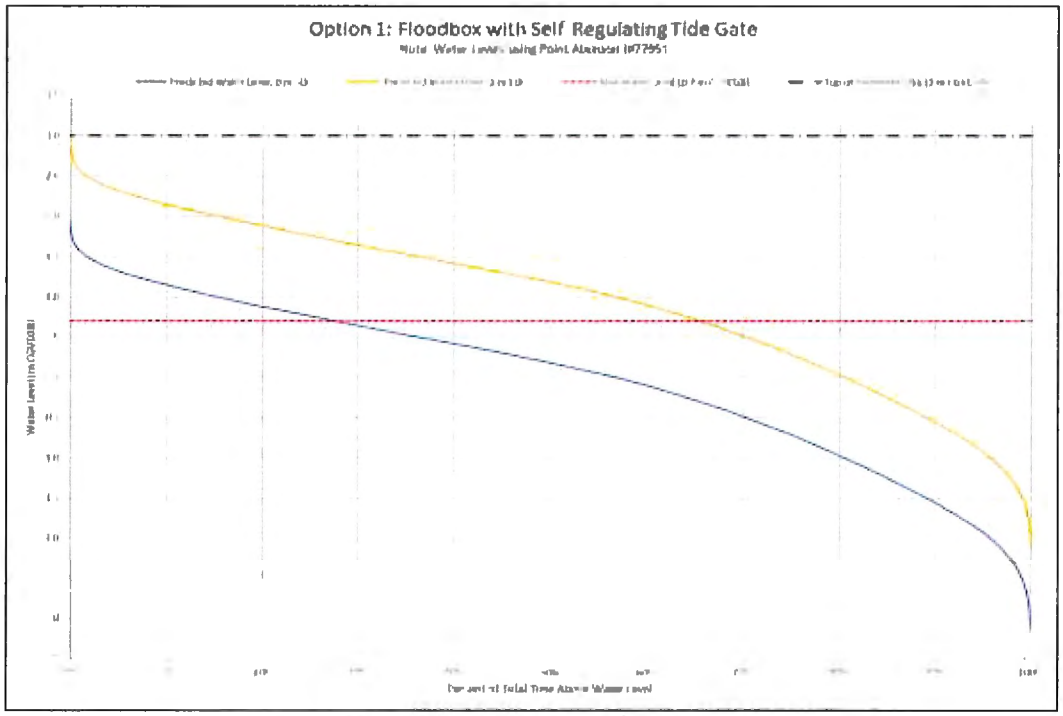

Figure 5: Option 1 – Tide Level Analysis and Gate Utilization

Option 2 – Open Culvert and Ring Dike

Design – A legal standard dike would be built to encircle the Slough and an open culvert or bridge would connect the Slough to the North Arm (Figure 6). This would allow an increased vertical tidal cycle within the Slough as the level could exceed the +1.0 m geodetic ground elevation of the Park without flooding the larger region. As with Option 1, the Slough would be required to be hydraulically isolated from adjacent drainage infrastructure and pumps by disconnection of this segment of the River Road ditch from drainage systems to the east.

Biophysical Requirements / Fish Passability – Fish access would be greatly enhanced through the longer duration connection, especially at high tide, and the ability to maintain a bridged open channel or oversized culvert connection. Establishment of riparian trees or shrubs adjacent to the Slough would be negated by requirements for low mowed grass on the dike and within 15 m of the dike toe.

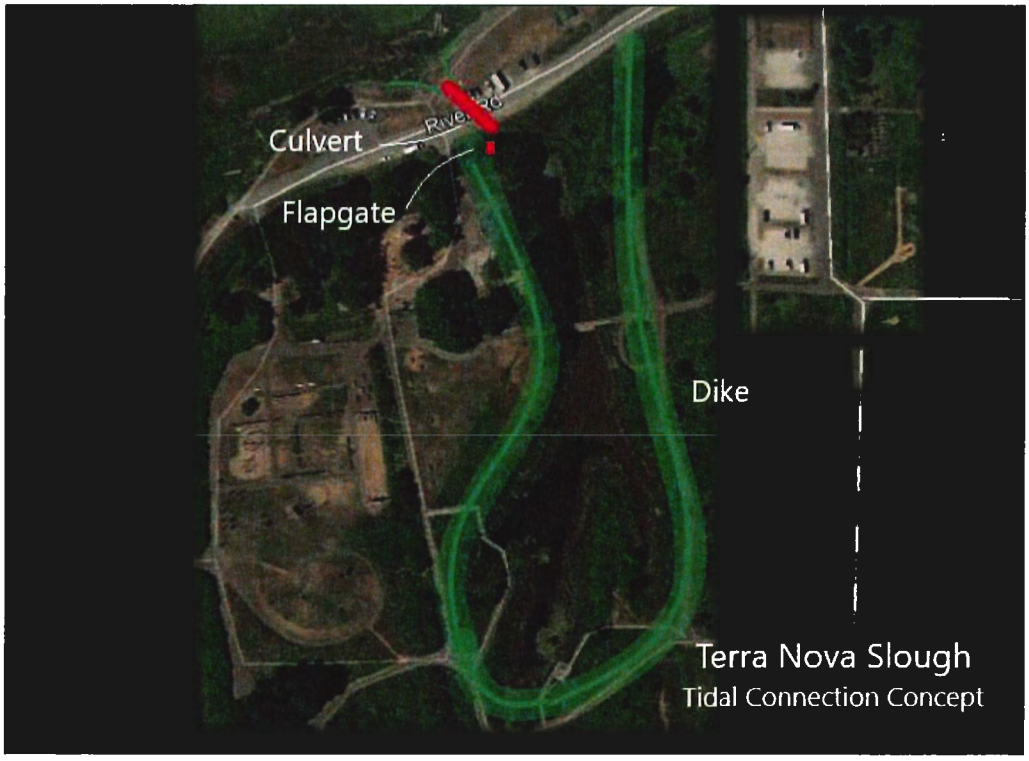

Figure 6: Option 2 – Open Culvert and Ring Dike

Maintenance/Operational Considerations – A legal standard dike would be approximately 20 m wide toe to toe and 3 m tall. The side slopes and crest would need to be maintained with mowed grass with no tolerance for trees or shrub growth that could compromise the integrity of the dike and limit inspection access during high water events. Furthermore, unless set back 15 m from the Slough wetted edge, there would be no room for trees for riparian benefits. Alternative alignments for the dike away from the Slough are possible; however, any part of the Park between the Slough and dike would be subject to flooding at tides that exceed +1 m geodetic.

Impacts to Existing Park – Dike construction would substantially change the landscape and appearance of the Park. Play structures located in the Terra Nova Adventure Play Environment and heritage trees located to the west of the Slough would be in conflict with a perimeter dike alignment. Dike avoidance of the area would place the trees and structures inside the flood zone, but a dike could not be placed between the Slough and playground without significant tree loss. Parks may consider placing replacement playground equipment and other assets on fill to avoid regular inundation, which would result in additional costs.

Permitting – A significant regulatory and management change would occur with the connection. The Slough and fringing riparian areas would become subject to regulation of the federal *Fisheries Act* and provincial *Water Sustainability Act* as a result of reconnecting the Slough to the river. Activities such as bridge repairs, path construction, and tree management would require notification or possibly review by Provincial or Federal government agencies. Additional permits and limitations would be imposed by the provincial *Dike Maintenance Act*.

Cost Estimate – The current estimate for implementation of this connection is $4.75 million, including the cost of the ring dike. This does not include the potential relocation or raising of the adventure playground or other assets.

Additional Considerations – Future requirements for dike crest raising will increase the width of the dike by several metres, thus the dike should be sufficiently setback from the slough to accommodate the dike raising to 5.5 m in the future.

Option 3 – Tide Gate and Flood Berm

Design – This option is a hybrid that adds a flood protection berm to Option 1 in order to increase culvert connection time and add sea level rise resilience. The berm could be constructed concurrent with, or sometime after, the connection of the Slough (Figure 7). The primary purpose of the berm would be to extend the open period for the tide gate to tidal levels above +1.0 m geodetic. However, it would be required to close at a lower level than Option 2 as the berm would be lower than the standard dike proposed for Option 2.

The maximum design water level of the berm would be +1.4 m geodetic. This allows for 0.6 m of freeboard, as the crest of the berm would be +2.0 m geodetic. Based on hourly recorded and predicted tide levels from Point Atkinson between 1914–2020, the water level in the Slough would reach the design elevation and be closed 4% of the time under current conditions. Assuming 1 m SLR from current tide levels, the water level in the Slough would reach the design elevation and be closed 42% of the time in the year 2100 (Figure 8). In both cases, this is less time that the gate is closed than for Option 1.

An inundation analysis was undertaken to assess the flooding risk to the Park and surrounding land if the berm were to breach. The analysis assumes the Slough is filled to the maximum design elevation (+1.4 m geodetic) at the time of the breach; the current ground elevation surrounding the Slough is +1.0 m geodetic. The inundation analysis used GIS to project extent of inundation of the volume of water between +1.0 m and +1.4 m geodetic[2] contained in the berm at the time of the breach (Figure 9).

Although the berm would functionally act as flood protection, it would not be the primary protection and thus would not be a legal dike subject to the provincial *Dike Maintenance Act*. This would allow much greater flexibility in its structure and landscaped form. There would be no impediments to trees or

[2] Please note that the tidal level and gate utilization analysis provided in Figure 8 was conducted using CGVD28, whereas the inundation analysis provided in Figure 9 was conducted in CGVD2013.

shrubs growing on it, allowing unimpeded riparian enhancement or landscape features. Side slopes could be varied and could even incorporate steep walls to create sunny alcoves or sloped seating areas on the outer faces.

Flexibility in design may relieve some conflicts between flood protection and the adventure playground. A narrow floodwall, rather than a wide berm, may be able to be threaded between the playground and the trees on the west side of the Slough.

Biophysical Requirements / Fish Passability – Similar to Option 1.

Maintenance/Operational Considerations – Similar to Option 1.

Impacts to Existing Park – Similar to Option 1 with the addition of changes to landscaping associated with the berm.

Permitting – Similar to Option 1.

Cost Estimate – Current cost is estimated to be $4.5 million.

Additional Considerations – The berm component of this option could be completed after completion of the Slough connection component as a response to sea level rise.

Figure 7: Option 3 – Tide Gate and Flood Berm

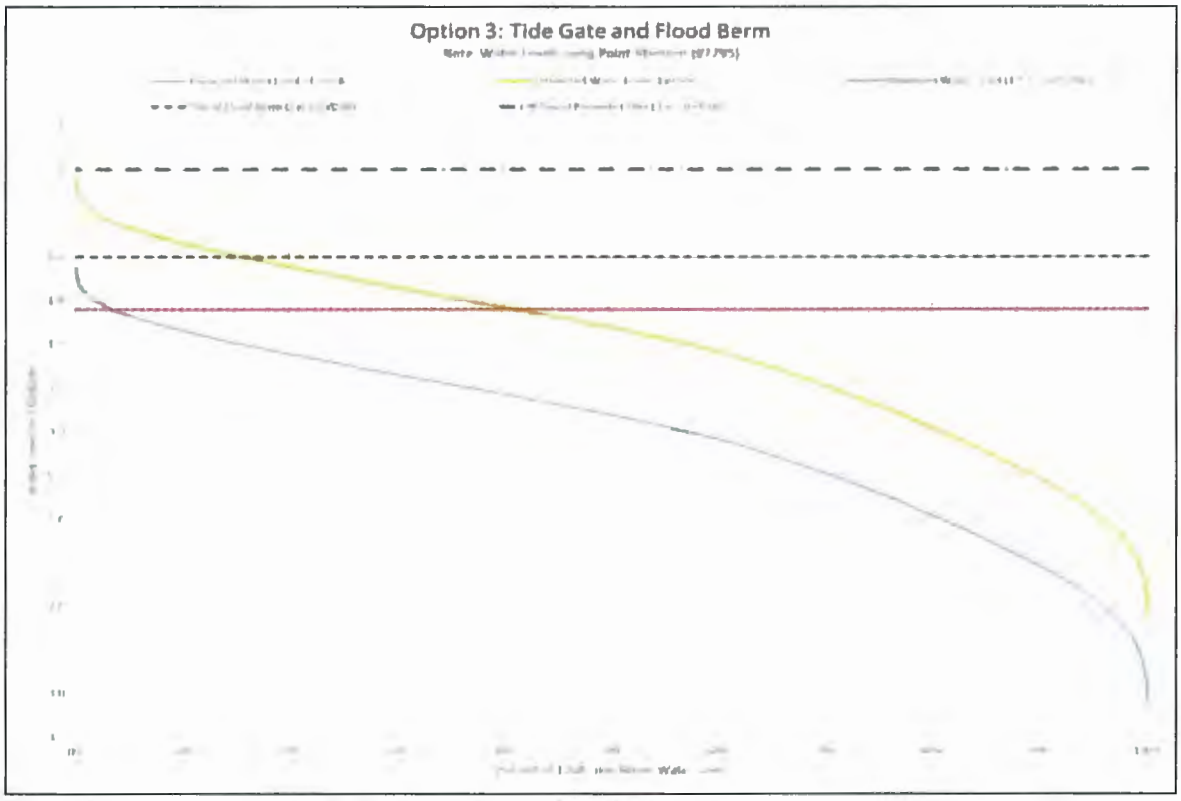

Figure 8: Option 3 – Tide Level Analysis and Gate Utilization

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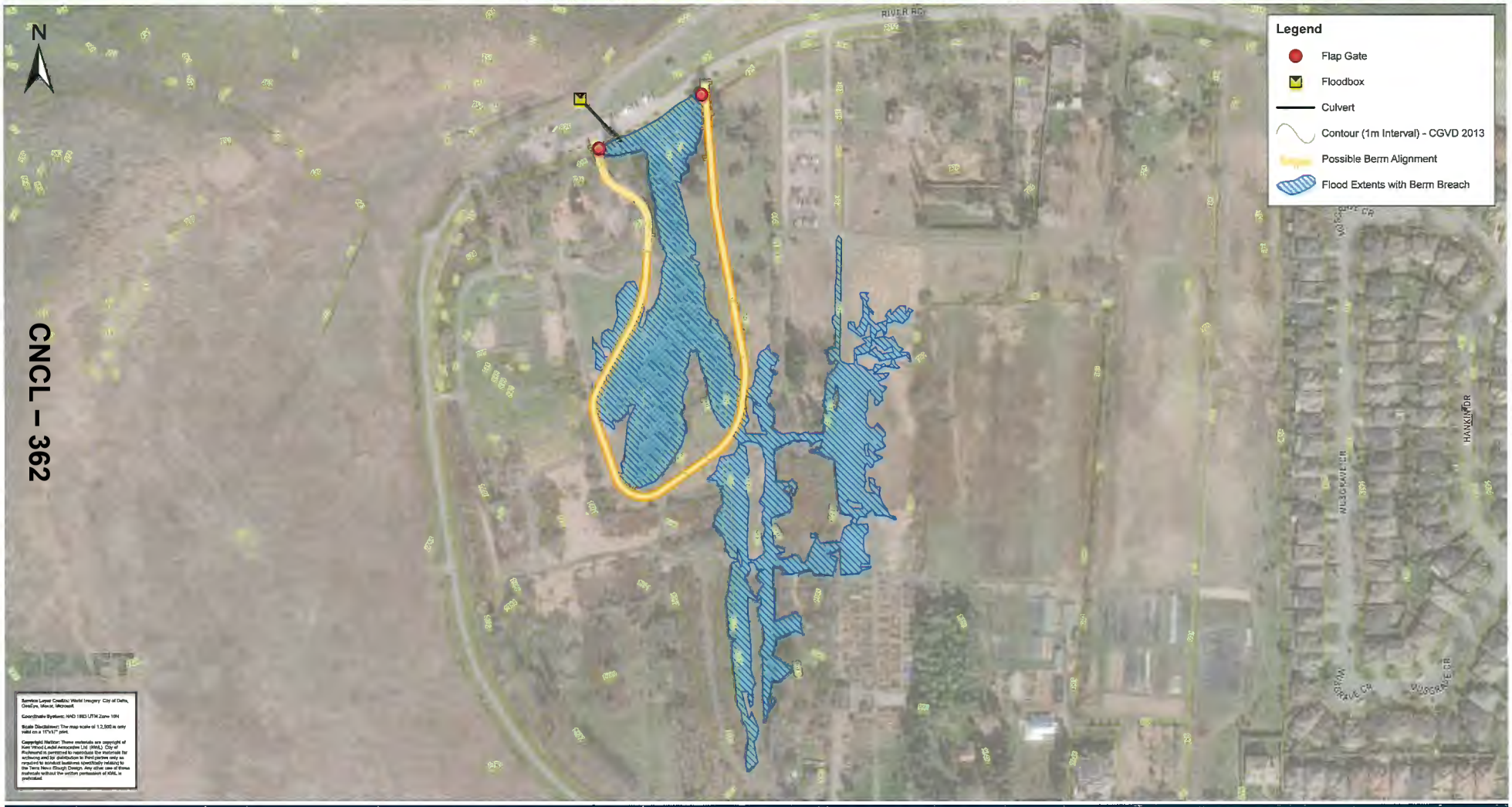
City of Richmond
Terra Nova Slough Design

KERR WOOD LEIDAL consulting engineers



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Option 3 – Inundation Analysis

Figure 9

4.2 Alternative Options Within the Terra Nova Area

Examination of the challenges, opportunities, and limitations suggest that the Slough may not be an ideal candidate for connection to the Fraser and conversion to fish habitat. Therefore, two alternative salmon habitat enhancement opportunities were also identified within Terra Nova Park (Rural and Natural Area) that do not involve connection of the Slough:

- Construct and connect a new intertidal marsh in the northeast corner of Terra Nova Rural Park; and/or
- Connect and enhance the existing wetlands in Terra Nova Natural Area.

Either of these projects could be pursued instead of, or in addition to, connecting the existing Slough to the Fraser River.

Option 4 – Alternate Intertidal Marsh Slough in Northeast Corner of Terra Nova Rural Park

Design – In order to avoid conflict with heritage landscaping, play structures, and other park assets, a dedicated salmon habitat feature could be constructed in a relatively unencumbered area of the Park. Connection to the Fraser River would pass through a park panhandle flanked by private residential properties to the east and west.

Constructing a new fish habitat feature in this area would allow optimization of the new wetted and riparian areas. This option would consist of an intertidal channel with dendritic branches and extensive marsh at preferred elevations (Figure 10). The alternative slough would be located in approximately 5.8 ha of existing heritage agricultural fields, which currently experience seasonal flooding. The new slough would include an open channel located along the east side of the park, which would connect to the Fraser River via a tide gate similar to Option 1 or 3. With this option, River Road would continue to serve as the dike and no additional flood protection around the slough would be required.

Biophysical Requirements / Fish Passability – Similar to Option 1.

Maintenance/Operational Considerations – Similar to Option 1, as a regulated tide gate and culvert would form the connection.

Impacts to Existing Park – The area of the Park proposed to marsh construction is an old field that seasonally floods and that does not contain any structures, heritage features, or park amenities. However, if this option is pursued, further investigation is needed into the existing habitat value for barn owl and bat and how these components can be incorporated into the fish habitat design.

Permitting – Similar to Option 1.

Cost Estimate – Estimated cost would be equivalent to Option 1, plus excavation of channels and marsh. Excavation would be proportionally lower cost than the original Terra Nova Slough as lower slopes and less depth would reduce the geotechnical measures required. The size of the new wetted complex would determine the final cost.

Additional Considerations - Excavated sediment could be reused, if suitable, as dike fill elsewhere in Richmond. Alternatively, a portion could be used as fill for Options 6 or 7.

Figure 10: Option 4 – Alternate Intertidal Marsh Slough in Northeast Corner of Terra Nova Rural Park

Option 5 – Connect and Enhance Existing Wetlands in Terra Nova Natural Area

Design – Terra Nova Natural Area has significant potential for restoration of intertidal marsh by reconnecting the existing wetlands within the Park to tidewater through the current perimeter sea dike on the west side of the Park. Flood protection for Richmond would be moved inland with construction of a new dike on the North, East and South park perimeter (Figure 11). The area has several attributes that lend themselves to a large-scale marsh restoration. Principal among these is the relatively unencumbered nature of the area with a lack of infrastructure or active park uses. The area is primarily old field habitat with a 0.7 ha freshwater pond and perimeter ditch. A perimeter trail could be relocated to on top of the new dike. The existing dike would remain as a breakwater and trail but have 3 openings spanned by bridges or oversized culverts.

Biophysical Requirements / Fish Passability – A purpose-built marsh could be optimized for ecological productivity and biodiversity. Excavation would create channels and variable height benches required for optimal intertidal marsh development. Lands could be shaped to support a variety of habitats ranging from low marsh intertidal through to elevated refuge islands that would be permanently dry and terrestrial in nature.

Maintenance/Operational Considerations – There would be an increase in linear dike length to be mowed, inspected, and maintained. Wave born logs may seasonally need to be removed at the seaward dike breaches.

Impacts to Existing Park – The area is relatively unencumbered with a lack of infrastructure or active park uses. The area is primarily old agricultural pasture with a 0.7 ha freshwater pond and perimeter ditch. The perimeter trail could be relocated to on top of the new dike.

This area was protected and enhanced decades ago specifically for bird habitat of the "Old Field" ecotype. The area is also home to a protected Barn Owl (*Tyto alba*) population, a federally-listed species at risk. The habitat has been maintained since with periodic plowing and reseeding with grasses to suppress tree and shrub growth. Significant study will be required to assess possible impacts from marsh construction and restoration of tidal flooding in this area. However, tidal influence may favor a grass-dominated ecosystem with suppression of woody species. Also, it is expected only about 50% of land would be tidally-influenced on a daily basis. This would provide significant land for owl foraging and prey species habitat. Historic vegetation mapping (Figure 2) shows the area as "grassland" prior to dike construction.

Figure 11: Option 5 – Connect and Enhance Existing Wetlands in Terra Nova Nature Area

Permitting – Construction of new dike would trigger a provincial *Dike Maintenance Act* review. Alteration of the existing freshwater pond would likely require a provincial *Water Sustainability Act* Change Approval.

Cost Estimate – There is significant uncertainty about cost for this option. Very high-level estimates suggest at least $10 million, with most of that allocated to dike construction. Cost may be offset if soils excavated for channels and marsh could be re-purposed for dike construction.

Additional Considerations – Terra Nova Natural Area adjoins the Grauer Lands, a conservation property jointly owned by the City of Richmond and Ducks Unlimited Canada where a large-scale log cleanup and enhancement project was undertaken in 2013. Breaching of the existing foreshore dike that separates these parcels would not only allow inflow into the Terra Nova Area but would increase tidal exchange through the existing channels with the Grauer Lands that are oversized for their respective drainage areas

Marsh restoration in this area may potentially be used for habitat banking to offset fish habitat impacts from future City projects (e.g., dike raising). Marsh restoration in this area also offers a pilot project site to test structural and ecosystem-based responses to sea level rise. The setback location of the new dike, fronted by restored marsh and portions of the existing dike, may offer substantial protection against wave energy and wave-borne debris.

4.3 Alternative Options for Existing Slough

In the event that connection of the Slough to the Fraser River is not pursued, there remains the question of how best to manage the Slough as freshwater habitat. The Slough in its present configuration is a habitat type exploited by invasive species and is filling with organic sludge. The following options have been identified to improve or alter the current condition without connection to the Fraser:

- Convert the existing Slough to ephemeral marsh without a Fraser River connection; or
- Fill in the existing Slough.

Option 6 – Convert to Ephemeral Marsh

Design – One means of addressing the existing suboptimal condition of the Slough is to partially infill it to reduce water depth and promote seasonal drying. Dry-out will address several of the existing environmental deficits of the pond: interruption of invasive frog life cycles, interruption of invasive aquatic plant growth, and potentially aerobic decomposition of organic sediments.

The existing pond would be drained and partially filled with clean mineral sediments to achieve water depths of no more than 50 cm. During filling, mineral sediments could likely be used to displace and concentrate accumulated organic sludge towards one end. A suction dredge would be required but the operation would be easier than if carried out in preparation for tidal connection.

Achieving full seasonal dewatering for aerobic decomposition of future organic sediments may be challenging. The local area water table may restrict water level fall within the pond. However, even incomplete dewatering would facilitate densification of organic matter sufficient for it to be removed by excavator. Beneficial re-use of this sediment as an organic soil amendment within the Park is possible and would reduce trucking and disposal fees.

Biophysical Requirements / Fish Passability – Invasive American bullfrog (*Lithobates catesbeianus*) and green frog (*Lithobates clamitans*) both rely on permanent water bodies for reproduction and tadpole and adult habitat. Drying in summers will be highly disruptive or lethal to all life stages. It is important to note that the drainage ditches in close proximity to the Slough will always serve as a refuge and

breeding source for these frogs to re-colonize the Slough. However, annual drying will suppress populations. Unlike the invasive frog species, native amphibian species are adapted to ponds that seasonally dry. Only the eggs and tadpoles require standing water and most tadpoles metamorphose into terrestrial adults prior to the average summer dry period. Fish are not a consideration as there is not likely an existing population as there is no surface flow connection to the Slough.

The effects of pond infill on resident or transient beavers is uncertain. The proposed depth of 50 cm would be sufficient for their needs but may decrease the attractiveness of the site. They may resort to digging canals within the substrate if depths are insufficient.

Maintenance/Operational Considerations – Same as existing maintenance, nothing additional.

Impacts to Existing Park – The partial infill would have some effect on park user experience, with the aesthetic seasonal change. Information signage to explain that drying is intentional may be beneficial.

Permitting – Conversion of the Slough to freshwater ephemeral marsh would likely require a provincial Water Sustainability Act Change Approval.

Cost Estimate – The estimated cost to convert the Slough into an ephemeral freshwater marsh is $500,000.

Additional Considerations – None.

Option 7 – Fill Slough

Design – To address freshwater habitat management issues, the Slough could also be completely filled and returned to terrestrial park use.

Biophysical Requirements / Fish Passability – As with Option 6, this would address the invasive plant and amphibian populations but would also displace native species, such as beavers, waterfowl, and wading birds. Fish are not a consideration.

Maintenance/Operational Considerations – Park management would be simplified, and the area could be used to expand existing park areas, add new programming, and/or additional terrestrial planting to the Park. However, filling the Slough would not align with current park concept plan and likely conflicts with public expectations and values.

Impacts to Existing Park – The Park would appear significantly different, although alternative planting schemes could occupy the pond footprint to frame the existing pathways.

Permitting – Filling the Slough would likely require a Provincial *Water Sustainability Act* Change Approval and may require habitat offsetting for the loss of aquatic and riparian habitat.

Cost Estimate – The estimated cost to fill the Slough is $750,000. This may be offset through tipping fees charged for import of approved fill from development sites. Alternatively, savings may be realized if sediment from Options 4 or 5 is used for fill.

Additional Considerations – Filling would require a significant volume of sediment. The existing hill of sediments excavated from the pond (located to the west) may be appropriate if the slide can be appropriately relocated.

5. Evaluation and Selection of Preferred Option(s)

5.1 Screening Criteria and Evaluation Process

To evaluate and compare the options identified, a list of screening criteria was developed:

- **Cost:** What is the approximate capital cost for design and implementation of the option? What is the per unit area cost in terms of the habitat created?
- **Flood Risk:** What is the potential impact to flooding risk to the Park and broader City of the option?
- **Habitat / Ecological Value:** What is the habitat type to be created and relative value of the habitat connected/created?
- **Park User Experience:** How will the experience of visitors to the Park be affected? What opportunities might exist to enhance the visitor experience as a result of the option?
- **Operations and Maintenance:** What are the operations and maintenance requirements that will be created by implementation of the option?
- **Fish Passability:** What is the qualitative rating of fish passage into the Slough or other habitat created that will be provided by the option?
- **Other Considerations:** Are there other considerations that should be included as part of the evaluation (e.g., regulatory approvals, climate change resilience, etc.)?

To assist with identifying a preferred option(s), each project was evaluated qualitatively against the above screening criteria. Results of the evaluation can be found in Table 1.

Table 1: Terra Nova Slough Engineering and Environmental Design – Evaluation of Concept Options

Option	Cost	Flood Risk	Habitat / Ecological Value	Park User Experience	Operations and Maintenance	Fish Passability	Other Considerations
Connect Existing Slough to the Fraser River							
1. Floodbox with Self-regulating Tide Gate	$2.5 M + $250k for slough enhancements $809/sq. m. wetted	• Some risk if debris clogs gate, thus preventing closure • Very low risk with regular O&M	• New habitat for fish • No habitat for amphibians (invasive spp.)	• Similar to present but tidal nature of slough will change aesthetics	• Increase • Regular debris clearing • Tide gate mechanical O&M	Moderate	• Slough would become subject to regulation of the *Fisheries Act* (*Water Sustainability Act* currently applies) • Future SLR will decrease the duration of flap gate open
2. Open Culvert and Ring Dike	$5.0 M + $250k for slough enhancements $1544/sq. m. wetted[1]	• Park inside dike flooded on high tide / City outside protected • Very low risk	• New habitat for fish • No habitat for amphibians (invasive spp.) • Change of upland habitat to floodplain (heritage tree loss?)	• Pond area access / use restricted when flooding • Modified sight lines and limitations to landscaping • Likely loss of trees • Playground displacement	• Increase • Dike mowing and inspection	Excellent	• *Dike Management Act* applies • Slough would become subject to regulation of the *Fisheries Act* and *Water Sustainability Act*
3. Tide Gate and Flood Berm	$4.5 M + $250k for slough enhancements $1397/sq. m. wetted	• Similar to tide gate only but additional protection from berm if debris does impair gate	• New habitat for fish • No change to terrestrial habitat (heritage tree loss?)	• Modified sight lines • Berm can be integrated into landscaping • Likely some loss of trees	• Increase • Regular debris clearing • Tide gate mechanical O&M	Moderate	• Not subject to *Dike Management Act*
Alternative Options Within the Terra Nova Area							
4. Alternate Intertidal Marsh Slough in Northeast Corner of Terra Nova Rural Park	Depends on the size of the wetted complex	• Very low risk	• New habitat for fish • No heritage tree loss • Conversion of old field to intertidal	• No impacts to existing slough, heritage trees, or play structures	• Increase • Regular debris clearing • Tide gate mechanical O&M	Moderate	• Allows for landscape design to be optimized
5. Connect and Enhance Existing Wetlands in Terra Nova Nature Area	$10.0 M $185/sq. m. wetted (50% of zone to be tidal)	• Very low risk	• New high-quality habitat for fish and improvement of fish habitat to west • Conversion of old field to intertidal • Conversion of freshwater pond to intertidal • No significant tree loss	• Similar to present but tidal nature of area will change aesthetics • Opportunities for new trails and viewing sites	• Increase • Dike mowing and inspection	Excellent	• Habitat banking advantages • SLR resiliency advantages
Alternative Options for Existing Slough							
6. Convert to Ephemeral Marsh	$500k	• No change in flood risk from existing conditions	• New habitat for native amphibians • No habitat for invasive amphibians (interruption of life cycle) • Effects on beavers are unclear	• Similar to present but ephemeral nature of area will change aesthetics	• No change • On-going management of invasive plants	None	• None at this time
7. Fill Slough	$750k	• No change in flood risk from existing conditions	• No habitat for invasive amphibians • Would displace beavers, waterfowl, and wading birds	• Opportunity for additional terrestrial park use (e.g., play structure, community agriculture)	• Decrease • Regular park maintenance	None	• None at this time

5.2 Summary of Options Review Workshop

On June 23, 2020, KWL and City of Richmond staff convened to discuss preliminary findings by KWL and review options for Terra Nova Slough. Three connection options for the Slough were presented (Options 1–3) along with a fourth offsite option for Terra Nova Nature Area (Option 5) (Options 4, 6 and 7 were developed after the workshop.). Each option was reviewed and discussed based on the above screening criteria including cost, ecological benefits, effects on Park operations and use, in addition to each project's consistency with Council direction. City staff identified their preferences and requested development of additional options. Staff feedback informed the evaluation and this report.

5.3 Preferred Options

Draft options were presented for discussion with a group of City Staff on July 23, 2020 (See Section 1.3 for names). KWL received the following verbal feedback regarding some of the options contained within this report:

- Option 1 - generally supportive with concerns about cost and management impacts.
- Option 2 - not supportive due to impacts on Park and play structures, and costs.
- Option 3 – generally supportive, with concerns about cost and management impacts.
- Option 4 – not presented in detail at meeting.
- Option 5 - strongly supportive for habitat banking, climate change resilience, and environmental benefits.
- Option 6 – not presented at meeting.
- Option 7 – not presented at meeting.

5.4 Regulatory Approvals

The federal *Fisheries Act* (FA), provincial *Water Sustainability Act* (WSA), and provincial *Dike Maintenance Act* (DMA) are the primary governing legislation applicable to the project. The federal *Species at Risk Act* (SARA) and federal *Migratory Birds Convention Act* (MBCA) have applicability but are not likely to be a significant factor in obtaining project approvals by senior government agencies. A high-level assessment of project components has identified the regulatory requirements for each option (Table 2).

Table 2: Regulatory Requirements Under Applicable Legislation for Each Option

Option	*Fisheries Act*	*Water Sustainability Act*	*Dike Maintenance Act*	*Species at Risk Act*	*Migratory Birds Convention Act*
1	X	X	X	dd	dd
2	X	X	X	dd	dd
3	X	X	X	dd	dd
4	X	X	X	dd	dd
5	X	X	X	dd	dd
6	-	X	-	dd	dd
7	-	X	-	dd	dd

X – Full regulatory review or approval
o – Notification / information submission as restoration is exempt from s35(2)
dd – Due diligence measures recommended

Enhancement and connection of the existing Slough could be used as fish habitat offsetting for another City project that involves impacts to fish and fish habitat under the *Fisheries Act* as long as the connection does not precede the acquisition of the related Section 35 Authorization. Obtaining credit for Slough connection and applying it to offset future projects would require establishing a Habitat Bank. Habitat banks are enabled by Section 42 of the *Fisheries Act* but are not common. Option 5, in particular, should be considered for inclusion in a proponent-led habitat bank.

5.5 External Funding Opportunities and Partnerships

The following potential external funding sources have been identified which could be used to assist with the implementation of the preferred option(s):

- **Environmental Damages Fund (EDF):** The Environmental Damages Fund (EDF) is a specified purpose account administered by Environment and Climate Change Canada (ECCC) to direct funds received from fines, court orders and voluntary payments to priority projects that will benefit Canada's natural environment. Available funding varies according to the number of court awards and voluntary contributions directed to the EDF. In its sentencing decision, the court may recommend the recipient, location and scope of a project funded by the fine. Funding deadlines take place twice annually.
- **Community Salmon Program (CSP): Habitat Offsetting by an External Partner:** Proponents of projects in the Lower Fraser River (e.g., Vancouver Fraser Port Authority, Metro Vancouver) that have impacts that require offsetting may be looking for sites to implement offsetting or habitat banking projects and would be willing to partner on project implementation if the habitat credit accrued from the project could be allocated towards their projects or habitat banks.
- **British Columbia Salmon Restoration and Innovation Fund (BCSRIF):** Jointly funded by the federal and provincial government, this fund support protection and restoration activities for priority wild fish stocks, including salmon, as well as projects that will ensure the fish and seafood sector in BC is positioned for long-term environmental and economic sustainability. The application deadline has passed and additional application rounds for this fund are not expected, thus this funding source may no longer be relevant.

In addition, several environmental organizations are currently working on salmon restoration projects related to tidal marshes and flood or river management infrastructure. This includes the **Resilient Waters** project on MakeWay's shared platform, **Raincoast Conservation Foundation's Lower Fraser River salmon conservation program**, and **Ducks Unlimited Canada**. It may be possible to partner with one of these organizations to share resources and project costs or pursue funding jointly.

It should be noted that habitat works financed by federal grants, such as the British Columbia Salmon Restoration and Innovation Fund and the Environmental Damages Fund do not qualify for habitat banking. Grants may not be used to fund any legally required works such as *Fisheries Act* Section 35 offsetting, Section 38(7.1) corrective measures, or works arising from enforcement actions.

Funding or co-funding with Vancouver Fraser Port Authority or another partner organization may be possible but the allocation of any realized habitat offsetting and/or banking credits would need to be negotiated with that entity.

If Slough connection is pursued by the City as a pure enhancement measure and funding is sought through grants such as BCSRIF or the EDF, an application to a competitive process will be required. It is unlikely that any grant amount would exceed $1 million.

Regardless of the funding source, the cost per unit area of Slough habitat will be comparatively high. If the Slough is connected "as is" and intensive planting of its riparian zone is not undertaken, the maximum wetted area for credit is 6000 m^2. With the most economical connection Option 1 and recommended Slough enhancement measures, unit costs are \$809/m^2. This cost is likely much higher than most other offsetting/banking projects in the region. Although not entirely analogous, a 2019 estimate for freshwater salmon habitat enhancement in Port Coquitlam was estimated at \$98–150/m^2, excluding any land costs.

6. Recommendations for Next Steps

Based on the results of the screening criteria, evaluation process, and additional feedback from City staff, KWL recommends near-term implementation of Option 1 (Floodbox with Self-regulating Tide Gate) and long-term implementation of the flood berm in Option 3 (Tide Gate and Flood Berm) for adaptation to climate change. In terms of optimal tidal fish habitat, however, Option 5 (Connect and Enhance Existing Wetlands in Terra Nova Nature Area) is preferred among all project options. Option 5 offers a large area of habitat, low unit cost, habitat banking potential, alignment with existing park uses, and received strong City staff support.

Once a preferred option is confirmed by Council, the following next steps are recommended to proceed to toward implementation:

1. Conduct feasibility studies to support project design including, but not limited to:
    - water level/hydraulic modelling,
    - water quality assessment and/or modelling, and
    - invasive plant surveys.
2. Produce, or in the case of Option 1 review and update, preliminary and detailed engineering design drawings based on additional biophysical considerations noted in this memo, as well as current engineering, seismic stability, and public safety standards.
3. If the existing Slough is to be connected:
    - Develop designs and plans for the Slough habitat enhancements including the partial pond filling, benching, and invasive species management, and
    - Further development of Option 3 berm design based on 2100 scenario and beyond to ensure Richmond remains protected from sea level rise.
4. Develop a detailed (Class A) cost estimate for the project.
5. Pursue regulatory approvals from senior government agencies.
6. If the project is not being pursued as a habitat offsetting or banking project, pursue funding and/or external partnerships to support project implementation.

Report Submission

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Statement of Limitations

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This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author
1	March 24, 2021	REVISED	Revised report issued to client	PL
0	February 10, 2021	FINAL	Final report issued to client	ARJ/SBO

OQM CERTIFIED

Option	Cost	Flood Risk	Habitat / Ecological Value	Park User Experience	Operations and Maintenance	Fish Passability	Other Considerations
Connect Existing Slough to the Fraser River							
1. Floodbox with Self-regulating Tide Gate (Recommended)	$2.5 M + $250k for slough enhancements $809/sq. m. wetted	• Some risk if debris clogs gate, thus preventing closure • Very low risk with regular O&M	• New habitat for fish • No habitat for amphibians (invasive spp.)	• Similar to present but tidal nature of slough will change aesthetics	• Increase • Regular debris clearing • Tide gate mechanical O&M	Moderate	• Slough would become subject to regulation of the *Fisheries Act* (*Water Sustainability Act* currently applies) • Future SLR will decrease the duration of flap gate open
2. Open Culvert and Ring Dike	$5.0 M + $250k for slough enhancements $1544/sq. m. wetted[1]	• Park inside dike flooded on high tide / City outside protected • Very low risk	• New habitat for fish • No habitat for amphibians (invasive spp.) • Change of upland habitat to floodplain (heritage tree loss?)	• Pond area access / use restricted when flooding • Modified sight lines and limitations to landscaping • Likely loss of trees • Playground displacement	• Increase • Dike mowing and inspection	Excellent	• *Dike Management Act* applies • Slough would become subject to regulation of the *Fisheries Act* and *Water Sustainability Act*
3. Tide Gate and Flood Berm	$4.5 M + $250k for slough enhancements $1397/sq. m. wetted	• Similar to tide gate only but additional protection from berm if debris does impair gate	• New habitat for fish • No change to terrestrial habitat (heritage tree loss?)	• Modified sight lines • Berm can be integrated into landscaping • Likely some loss of trees	• Increase • Regular debris clearing • Tide gate mechanical O&M	Moderate	• Not subject to *Dike Management Act*
Alternative Options Within the Terra Nova Area							
4. Alternate Intertidal Marsh Slough in Northeast Corner of Terra Nova Rural Park	Depends on the size of the wetted complex	• Very low risk	• New habitat for fish • No heritage tree loss • Conversion of old field to intertidal	• No impacts to existing slough, heritage trees, or play structures	• Increase • Regular debris clearing • Tide gate mechanical O&M	Moderate	• Allows for landscape design to be optimized
5. Connect and Enhance Existing Wetlands in Terra Nova Nature Area	$10.0 M $185/sq. m. wetted (50% of zone to be tidal)	• Very low risk	• New high-quality habitat for fish and improvement of fish habitat to west • Conversion of old field to intertidal • Conversion of freshwater pond to intertidal • No significant tree loss	• Similar to present but tidal nature of area will change aesthetics • Opportunities for new trails and viewing sites	• Increase • Dike mowing and inspection	Excellent	• Habitat banking advantages • SLR resiliency advantages
Alternative Options for Existing Slough							
6. Convert to Ephemeral Marsh	$500k	• No change in flood risk from existing conditions	• New habitat for native amphibians • No habitat for invasive amphibians (interruption of life cycle) • Effects on beavers are unclear	• Similar to present but ephemeral nature of area will change aesthetics	• No change • On-going management of invasive plants	None	• None at this time
7. Fill Slough	$750k	• No change in flood risk from existing conditions	• No habitat for invasive amphibians • Would displace beavers, waterfowl, and wading birds	• Opportunity for additional terrestrial park use (e.g., play structure, community agriculture)	• Decrease • Regular park maintenance	None	• None at this time