Nanaimo River Estuary Eelgrass study

Updated 2020

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Nanaimo River Estuary Eelgrass Study
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By

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ABSTRACT

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Aquaparian Environmental Consulting Ltd was retained by the Nanaimo Port Authority (NPA) and the provincial Ministry of Transportation and Infrastructure (MoTI) to complete an assessment and report of Pacific eelgrass (*Zostera marina*) distribution within the Nanaimo River Estuary, Nanaimo, BC. The Nanaimo River Estuary is part of the traditional lands of the Snuneymuxw First Nation (SFN) and was considered important as a food source for their community. The estuary has also experienced more than 100 years of industrial use, such as coal washing, gravel extraction, agricultural development, and over 70 years of use (since the late 1950s) for log storage which is thought to have resulted in impacts to sensitive fish habitat, specifically its expansive eelgrass beds. The report is intended as an update to past eelgrass studies within the estuary including the *Nanaimo Estuary Management Plan* (February 2006) produced by Catherine Berris Associates Inc. and a report produced by Precision Identification titled *Nanaimo River Estuary Eelgrass Restoration Assessment* dated June 25, 2012. When compared to the Forbes and Foreman compilation map of 1976 which was at the height of log booming activity, eelgrass distribution (2015 / 2020) appears to have increased substantially across the estuary approximately doubling in area from what was mapped in 1976. The northeast quadrant shows the most recovery of eelgrass. The Eelgrass distribution found in the 2015 / 2020 estuary study appears to be comparatively similar to findings documented within the Nanaimo Estuary Management Plan 2002 Map 5. It is the intent of this document to assist with future management decisions regarding the ecological health and wellbeing of Nanaimo River Estuary.

AQUAPARIAN
Environmental Consulting Ltd.

NANAIMO RIVER ESTUARY EELGRASS STUDY 2015
UPDATED NOVEMBER 2020

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Introduction

Aquaparian Environmental Consulting Ltd (Aquaparian) was retained by the Nanaimo Port Authority (NPA) and the provincial Ministry of Transportation and Infrastructure (MoTI) to complete an assessment and report of Pacific eelgrass (*Zostera marina*) distribution within the Nanaimo River Estuary, Nanaimo, BC. The Nanaimo River Estuary is part of the traditional lands of the Snuneymuxw First Nation (SFN) and was considered important as a food source for their community. The estuary has also experienced more than 100 years of industrial use, such as coal washing, gravel extraction, agricultural development, and over 70 years of use (since the late 1950s) for log storage which is thought to have resulted in impacts to sensitive fish habitat, specifically its expansive eelgrass beds.

As understood, the Province of British Columbia has government jurisdiction over the Nanaimo River Estuary. The NPA has an agreement with the province to manage the present log sorting tenures within the area. The MoTI funded the initial phase of this assessment in 2015 to determine the current distribution of eelgrass in the estuary in order to provide a baseline for further research, including comparisons of past studies as to how or if native eelgrass distribution has rebounded or not. Additional funds were provided by the Fisheries & Oceans Canada to complete and update the assessment over the summer of 2020.

The 2015 study included a review of background information produced on the estuary, including past government technical reports, various consultants' reports, management plans, generated maps and a review of historical aerial photographs. In addition, Aquaparian contracted the services of Bazett Land Surveying Inc. (Bazett) to complete a high resolution, GPS referenced, aerial photographic survey of the estuary. The captured images were compiled using Arc GIS to provide a detailed image of the estuary constituting a comprehensive baseline map of the study area. Aquaparian and a team of Vancouver Island University students employed by the Mount Arrowsmith Biosphere Region Research Institute (MABRI) collected field data that was then overlaid onto the aerial survey. Due to time and tide constraints, a portion of the southern extent of eelgrass in the estuary was not able to be ground checked and those areas were interpreted from the aerial survey images. As a result, the report was submitted as a draft until such time that additional funding became available to complete the study.

Between July 20-23, 2020, Aquaparian completed an additional field data collection to assess the northern extent of eelgrass distribution within the Nanaimo River Estuary, to determine if eelgrass distribution has expanded or receded since the 2015 survey and to confirm if past

eelgrass transplants completed in 2007 and 2013/2014 have successfully established. A detailed survey of eelgrass distribution within the southern portion of the estuary i.e. bordering the tidal marsh and berms, was not conducted during the study. These areas are understood to support small patches of eelgrass and the survey of these area's was beyond the extent of the 2020 survey.

This updated assessment document includes results from the 2020 eelgrass distribution survey. The report is intended as an update to past eelgrass studies within the estuary including the *Nanaimo Estuary Management Plan* (February 2006) produced by Catherine Berris Associates Inc. and a report produced by Precision Identification titled *Nanaimo River Estuary Eelgrass Restoration Assessment* dated June 25, 2012. It is the intent of this document to assist with future management decisions regarding the ecological health and wellbeing of Nanaimo River Estuary.

SCOPE OF WORK

The following identifies the scope of work Aquaparian carried out to complete this study.

Task 1: Background Information Review

A review of past government and consultants' reports produced on the Nanaimo River Estuary, collected eelgrass distribution data, and a historical review of aerial photographs.

Task 2: Project Coordination with Vancouver Island University

Collaboration with staff (Pam Shaw) and students from Vancouver Island University who were conducting a separate field survey of eelgrass distribution within the estuary during the summer of 2015. Aquaparian partnered with VIU in gathering and mapping surveyed eelgrass findings.

Task 3: Field Assessment / Eelgrass Survey

Completion of an aerial digital photographic survey by Bazett Land Surveying (Bazett) to map present conditions of the estuary during the 2015 summer low tides in order to determine eelgrass presence and absence for mapping purposes. The intention of the aerial photographic survey was to provide an updated baseline image of the entire estuary at a digital resolution that could show small scale differences in vegetation distribution and other features which could be geo-referenced if compared against a similar aerial image completed

during future surveys of the estuary. The resulting digital image allowed the survey team to collect geo-referenced information at the exact point within the estuary.

Task 4: Eelgrass Sample Site and Density

Aquaparian and a team of VIU student volunteers completed field surveys on the water using boat, kayaks and scuba to determine the extent of established eelgrass beds (depth at Chart Datum), the density of eelgrass plants (per m^2) within the beds. The surveys incorporated the use of handheld GPS to map boundaries of eelgrass beds and individual survey points.

Task 5: Map Generation

The Digital aerial imagery captured by Bazett was used to generate poster-sized maps (imagery) of the estuary. Digital geographic or GPS data collected during the field surveys by the VIU students and Aquaparian was downloaded onto digital mapping images using the GIS data mapping program Arc/Info.

Task 6: Summary Report Preparation

Report includes summary of data collected during the 2015 eelgrass survey and compilation of information from past government and consulting reports. Information used to assist in making a determination of eelgrass distribution (expansion or reduction) within the estuary.

Aquaparian collected additional field data in July 2020 to verify the southern extent of the eelgrass beds within the estuary. GPS coordinates were used to update the digital aerial imagery and to create an updated southern perimeter of the eelgrass distribution to compare to the perimeter created from VIU students and Aquaparian data from the 2015 survey. The additional field survey was used to fill information gaps from the 2015 study (primarily along the east and west channels within the estuary) and to update data where there were identified changes from 2015.

The Estuary Study area

The Nanaimo River Estuary study area is approximately 1000 ha in size consistent with the study area in the Nanaimo Estuary Management Plan prepared by Catherine Berris Associates Inc. in February 2006. It is the largest river delta on Vancouver Island and the fifth largest on the entire coast of British Columbia. The estuary receives water from several watersheds, principally the Nanaimo River, Millstone River, and Chase River (*Nanaimo Estuary Fish Habitat & Log Management Task Force 1980*). Other smaller drainages include

Wexford Creek, Beck Creek, Holden Creek, and York Creek. Together these systems have a catchment of more than 84,000 ha providing important fish habitat for more than seven Pacific salmon species (chinook salmon, chum salmon, coho salmon, steelhead salmon, cutthroat trout, Dolly Varden and rainbow trout). The main channels of the Nanaimo River within the estuary provide migratory access to the upper spawning beds for many of these species, while smaller dendritic channels found within its tidal sedge marsh provide important rearing and foraging habitat for juvenile and post juvenile fish.

Its connectivity to the marine environment and the Strait of Georgia is equally as important. Seasonal freshets during the fall rains and spring snow melt mix with the open ocean by wind and waves result in an upwelling of nutrients from the point where the Fraser River Delta spills into the Strait and from where outflowing currents from the Nanaimo River estuary meet. Changing tides bring strong surging currents from surface waters in the Nanaimo Harbour towards the deep drop off of the mudflats and shallow intertidal waters of the inner part of the estuary, accelerating the productivity of its conjoining marine ecosystem.

The eelgrass beds in the estuary are the converging zones for both fresh and salt water inhabitants. The eelgrass beds provide critical habitat for rearing, foraging, and resting for Dungeness crabs, various clams, nudibranchs, and sea stars and several marine fish species including sea perch, sculpins, gunnels, juvenile salmon, and Pacific Herring. Juvenile salmonids utilize eelgrass beds for cover and forage as they move from freshwater to the ocean. In addition, Pacific herring and other coastal fish spawn in eelgrass. Intertidal and shallow subtidal areas of the Nanaimo River estuary are characterized by eelgrass beds, specifically *Zostera marina* and *Zostera japonica* species that provide physical substrate and sources of nutrients for macroflora and fauna, adding to estuarine productivity and the yield of food organisms for fishes (*Nanaimo Estuary Fish Habitat & Log Management Task Force 1980*).

The estuary, in conjunction with the surrounding region is also used by thousands of over-wintering birds. The estuary is critical to waterfowl survival during severe winter weather and, together with the Fraser River mudflats and smaller river estuaries (i.e. Englishman River, Cowichan River, and Goldstream Creek), acts as a vital feeding, resting, and staging area for migrating birds of the Pacific flyway. More than 200 bird species are known to utilize the Nanaimo River estuary of which 15 are recognized as red-listed and 18 as blue–listed (*Catherine Berris Associates Inc. 2006*).

Several studies have been completed for the Nanaimo River Estuary, notwithstanding the most important of these being the Nanaimo Estuary Management Plan produced in 2006. The objective of the 2015/2020 study is to determine present distribution of eelgrass within the estuary and whether a determination can be made as to whether the distribution of eelgrass

has expanded or been reduced since what was documented in the Catherine Berris 2006 study.

A site location map showing the study boundary has been included as Figure 1.

Nanaimo Estuary Eelgrass Literature Review

The following is a brief summary of some of the reports reviewed in preparation for this study that provided information on Nanaimo River Estuary eelgrass.

1. **Nanaimo Estuary Management Plan**

   Author: Catherine Berris Associates Inc.
   Date: February 2006

   Summary:
   The report is an integrated process to consider all resources and all interests with the purpose of restoring the productivity and diversity of the natural resources in the estuary with consideration for social and economic returns and benefits to the community as a whole. Objectives relating to eelgrass habitats are to determine the distribution of lower intertidal habitats including substrate, vegetation, faunal communities, and man-made debris.

   The purpose of the estuary management plan is to evaluate the conditions of the estuary's natural resources and outline how they have been affected by past industrial activities, establish short-term and long-term guidelines, and to identify measures to prevent further impacts from human activities. The management document also outlines the need to develop monitoring programs used to help evaluate ongoing impacts, natural recovery progress, and measures to restore degraded habitats and to manage the estuary in the future.

2. **Inventory and Review of Studies and Data Relating to the Nanaimo River Estuary**

   Author: Karen Dunham – KAD Environmental Research
   Date: January 2000

   Summary:
   The report inventories and reviews studies and data relating to the Nanaimo River Estuary in support of an Environmental Audit and Remediation Plan for the Snuneymuxw First Nation traditional territory.

3. **Nanaimo River Stewardship Baseline Report: A Compilation of Chapters About the Values of the Nanaimo River Watershed**

Author: Nanaimo & Area Land Trust
Date: September 2011

Summary:

The Nanaimo River Baseline Report provides an overview of watershed health and the economic, cultural, and environmental significance of the Nanaimo River as a catalyst for developing long-term stewardship strategies. Restoration efforts in the estuary are summarized.

4. **Report of the Fish Habitat Sub-Committee to the Steering Committee**

Author: Nanaimo Estuary Fish Habitat & Log Management Task Force. Fisheries and Oceans Canada.
Date: June 1980

Summary:

The report details impact of log booming or storage activities on the fisheries resource and fish habitat for the Nanaimo Estuary and discusses alternatives for future use of the estuarine area.

Nanaimo River Estuary Eelgrass Restoration Assessment

Author: Andre Luis da Silva Bertoncini (VIU Graduate Student)
Produced for: Centre of Pacific Northwest Coastal and Island Communities.
Date: 2013.

Summary:

The author of this report (VIU student) attempts to update local distribution of eelgrass within the Nanaimo River Estuary, and assesses site conditions at that time of areas within the estuary considered suitable for eelgrass transplanting. Intertidal and subtidal areas were surveyed in the Nanaimo River Estuary in 2013 using ground surveys and ship surveys. Density was described as continuous or patchy. Three areas in the estuary (previously identified by Precision Identification in 2012) were delineated and described in terms of eelgrass distribution. Areas discussed for potential eelgrass transplant works were identified on the northeast side the estuary (parallel to the NPA lands), further north on the east side of the estuary and adjacent to the Duke Point Ferry Terminal and on the west side of the estuary just south of the main office of the NPA office and parking lot. The report also provides

recommendations for future eelgrass habitat studies including restoration, mapping and long-term monitoring.

HISTORICAL USE OF THE NANAIMO ESTUARY

The first human inhabitants of the Nanaimo River estuary were the people of the Snuneymuxw First Nation. Records from 1850 show that they occupied several villages on Nanaimo Harbour and the Nanaimo River, and their population was estimated to have been approximately 5,000 (*Berris 2006*). The Hudson's Bay Company established a base in Nanaimo in the mid-1850s to develop the Nanaimo coalfields. With the depletion of the coal resources in the 1950s, the economy of the area became dependent on the forest industry, forest products manufacturing, and tertiary industries. Fishing has always been conducted both commercially and recreationally out of Nanaimo (*Bell and Kallman 1976*). A small amount of farming still occurs in the watershed, limited by the availability of arable land.

Past activities that caused impacts on the estuary include:

- Washing of coal from the 1880s to the 1930s,
- Major dyking for agriculture in the 1900s and 1940s,
- Sewage disposal beginning in the 1930s, with direct disposal until the 1950s,
- Log storage starting in 1948,
- Smothering and sediment infilling from upstream timber clearing activities along the Nanaimo River including its upper watershed,
- Market hunting for waterfowl,
- Introduction of invasive and undesirable species, e.g., Scotch Broom, Varnish clam, and
- Filling and heavy industrial development, primarily due to mill construction (*Bell and Kallman 1976*).

Past land-altering development activities within and in the vicinity of the estuary that have contributed to sedimentation in the estuary include:

- Dyking of marsh habitats circa 1860s,
- Construction of an assembly wharf on the west side of the estuary in the 1930s,
- Log storage on intertidal substrate and subtidal water initiated in 1948,
- Construction of the C.I.P.A Lumber Co. Sawmill north of the assembly wharf in 1960,
- Filling of intertidal substrate and subtidal water habitat on the east side of Duke Point for construction of the Harmac pulp mill in 1950,
- Expansion of the Harmac pulp mill and assembly wharf in 1962 and 1975,
- Construction of a new shipping and assembly wharf at Duke Point in 1986,
- Construction of a new Duke Point ferry terminal with docks and access road in 1996

(*Prentice 1988* in *Inventory and Review of Studies and Data Relating to the Nanaimo River Estuary – Dunham 2000*),

- Sediment inputs to the estuary from timber harvesting in the upper Nanaimo River watershed, and,
- Natural influences on the estuary result from seasonal high tides and storm events. Seasonality, summer low flows and severity and timing of storm events may also be influenced by climate change.

The intertidal portions of the estuary are Provincially Crown owned. From 1950 to 1972, water lots in the estuary were incrementally assigned to local forest industries as the mill capacity in the area grew. The historic air photos (see Map 9 in *Berris 2006*) illustrate the progressively intensive use of the estuary for log storage, with the most intense use in the 1975 era (*Berris 2006*). As of 1980, 280ha of the Nanaimo River tidal flats were leased to four lumber companies for storage of log booms (*Nanaimo Estuary Fish Habitat & Log Storage Task Force 1980)* with 55 per cent first leased between 1950 and 1956, an additional 38.5 per cent leased during the 1960-65 period, and the remaining 6.4 per cent leased between 1968 and 1973.

Referring to a 1980 aerial photograph of the estuary, it was estimated that approximately 1,580 acres, or 73 per cent of the total estuary area, was subject to direct physical impact from log storage and towing activities (*Nanaimo Estuary Fish Habitat and Log Management Task Force 1980*). In 1984, all of the leases were reviewed and redistributed based on an environmental review of fish habitat (*Nanaimo Estuary Fish Habitat and Log Management Task Force 1980)*. The log storage area was reduced by 22.5 per cent and shifted to the west side of the estuary at that time (*Berris 2006*).

The following is a list of impacts resulting from past and current log storage in the estuary:

- Stray logs cause sediment build-up,
- Log booms tied up in the eelgrass zone cause sediment build-up over the eelgrass during low tide,
- Physical shading of habitat by booms results in decreased primary productivity by algae and eelgrass,
- Physical grounding and abrasion by booms at low tide results in compaction of sediments, scouring, and physical disruption of habitats,
- Bark and debris deposit and accumulate on bottom sediments from the working of logs against each other within the bundles,
- Towed booms scour eelgrass beds, particularly if logs are askew within the bundle underwater,
- Effects on intertidal marsh areas result from escaped logs, such as deposition and scouring,

- Propeller wash from tow boats and boom boats scour sediments, disrupt regeneration of eelgrass and other benthic organisms (estimated 1 m deep by 10 m wide area of influence) (*Nanaimo Estuary Fish Habitat & Log Management Task Force 1980*),
- Boom boats and booms increase turbidity in the water column as they pass over tidal flats,
- Logging tows catch crab trap lines and drag them through the eelgrass, and
- The positive effect of log booms that provide protection for some aquatic life from predators (*Berris 2006; Sibert & Harpham 1978*).

SUMMARY OF HISTORICAL AERIAL PHOTOS

The following table identifies historical impacts and observations from a series of historical aerial photos of the Nanaimo River Estuary. A copy of the aerial images from 1950, 1958, 1962, 1968, 1976, 1980, 1998, and 2006 has been included in Appendix A.

TABLE 1: NANAIMO RIVER ESTUARY HISTORICAL AERIAL PHOTOGRAPH SUMMARY

Date	Comments
1950	• B&W – High elevation at a Moderate tide. • No Industrial development on west or east side of estuary. • Only one small log boom located on east side of estuary near old Duke Point / Jack Point gap. • No log booms in the middle or west side of estuary. • No visible scour marks across mudflats. • Both West and East Channel significant in size. • Cannot determine extent of eelgrass to the north. • Sand bars (mudflats) between dendritic (branching) channels do not appear to have darker shading that might signify eelgrass. • Long open inlet channel on Duke Point open to the Northumberland Channel
1958	• B&W – Moderate to High elevation. • Log booms across 80 per cent of the middle width of the estuary. • Line of boom piles visible on the east side near the far outside edge of the mudflats near the bathymetric drop-off (Wave Break). • Some scarring, no visible eelgrass. No log booms present at location in photo. • Gravel build-up at confluence of east and west channels. • Abundant scour marks across the mudflats from log boom movements. • Log booms right up against east side of estuary and across open dendritic channels. • Visible dark patching in main east channel near Duke Point / Jack Point gap (possibly indicating eelgrass). • Several other small channels appear to have similar black (dark shading) patching.

1962	• B&W – High elevation (too high to assess eelgrass presence). • New sanitary sewer pipe visibly trenched across mid-line of the estuary (including gravel island in centre) and exiting on the east side and into the Northumberland Channel. • Water appears to be very cloudy outside the estuary and into Northumberland Channel. • Further upland development along the west side of the estuary (appears to be increased mill development).
1968	• B&W – Moderate to Low tide level. • Increase in visible scour marks across the entire estuary from log booms and boom boat movement. • Further increase in development along the west side of estuary. • Open inlet at Duke Point still visible. Some development near the Duke Point / Jack Point gap. • Black or dark shaded marking within channels on east side of the estuary appear to be gone. Some minor patching visible. • Some dark patching visible along the eastern edge of the estuary mudflats near drop-off (Wave Breaks). • Some dark patching near northern edge of large gravel sand bar.
1976	• B&W – High elevation. • Major log boom activity across entire middle of estuary (west to east) – visibility poor. • West shoreline Port Lands well developed and active – log booms appear to be very active.
1980	• B&W Moderate to High elevation. • Long Inlet at Duke Point predominately filled in. • Majority of log booms are located on west side of estuary. • No visible dark patches (potentially eelgrass) within channels on east side. • Significant scarring across mudflats. • Main river flows appear to have shifted towards the west channel. • No visible eelgrass on any elevated mudflats.
1998	• Colour – Moderate elevation, Low tide. Higher resolution photos than previous. • Channels on east side and the end of Duke Point and areas near the gravel shoal in the centre show darker mottling that may indicate return presence of eelgrass. • Log booms reduced from historical images – booms are located west of the gravel shoal in the centre of the estuary. None on east side. • Scouring more visible due to higher resolution image. • East side of sand flats appears to have reduced scour since removal of log booms in this area.
2002	• Google Earth image. Colour. High tide. • Log booms located on western half of estuary, west of gravel shoal. • No scouring or eelgrass visible due to tide elevation.
2006	• Google Earth image. Colour Very Low tide. • Log booms located on western half of estuary. • Scouring evident over western half of estuary. • Eelgrass visible near low tide line and in some dendritic channels.

	• Eastern half of mudflats appear to be predominantly recovered with minor amounts of old scarring; some areas near low tide line show eelgrass growing where old log booms once were.

SUMMARY OF HISTORICAL TENURE AREA MAPS

Log booming in the estuary began in the 1950s and peaked in the 1970s, spanning the central area of the estuary and within the northeast corner near the end of Jack Point Park on the Duke Point Peninsula. By 1980, the log booming areas were restricted to the western half of the estuary. Figure 2 shows the log boom tenures in 1976 compared to the current tenure areas overlaid onto the recent aerial survey image.

SUMMARY OF HISTORICAL EELGRASS DISTRIBUTION AND MAPS

The first official chart of Nanaimo Harbour and the surrounding area is dated 1862 (*Bell and Kallman 1976*). The position of the main delta front has not significantly changed since that time. The main changes since 1862 have been the placement of fill to create much of the downtown area, alterations to construct the assembly wharf, and the forestry mill yards on the west side of the estuary (*Bell and Kallman 1976*).

At the height of the log booming activity in the 1970s, Bell and Kallman (1976) identified the major environmental change that eliminated the eelgrass community from the middle portion of the estuary as the intensive log booming that began in 1948. The retreat of the eelgrass beds was also attributed to the deposition of coal washings from the old coal workings and to changes in sedimentation rates and patterns as a result of the clear-cut logging of most of the Nanaimo River watershed. The increased accretion of sediment transported into the estuary from the extensive logging during high seasonal rain events was thought to have raised the substrate levels of the mudflats in the estuary above the elevation suitable for eelgrass (*Bell and Kallman 1976*).

According to the Department of Fisheries and Oceans report from 1980, storage of logs on intertidal habitat was also found deleterious to the habitat and the biota which it supports (*Nanaimo Estuary Fish Habitat & Log Management Task Force 1980*). This report documented evidence of towboat effects from observations and aerial photographs of the estuary at low tide showing multiple striations in areas of towboat activity within and around log storage leases. Observed areas of influence include scour trenches up to 1 m deep and approximately 10 m wide and plumes of suspended sediment extending approximately 30 m from the propeller wash of tugs that had also been observed by divers.

The report documented evidence of log grounding and highly compacted sediments found when sediment samples were collected underneath booms. Numerous pits and grooves were also observed by divers under the booms. The abrasion, shading, and scouring of surficial sediments caused by log storage and log management activities cause the destruction of large epi-fauna and flora, the accumulation of debris, decreased circulation, the release of toxic leachates, and excessive biological oxygen demand (BOD) (*Nanaimo Estuary Fish Habitat & Log Management Task Force 1980*). The report notes that the relatively small numbers of fry in stream channels crossing the central and western part of the intertidal sand and mudflats suggest that these habitats are for some reason unsuitable, possibly as a result of the log storage and tugboat activities in those areas (*Nanaimo Estuary Fish Habitat & Log Management Task Force 1980*).

The estuary has not been known as a favoured spawning area for herring (*Forbes 1973*); Bell and Kallman (1976) noted that herring had not spawned within Nanaimo Harbour or along the estuary front since 1960. Due to the fact that eelgrass is a requirement of spawning herring, these observations are interesting when related to suggestions that eelgrass growth was historically prolific in the area (*Dunham 2000*). In addition, log booming in intertidal areas and the resultant compaction of sediments, decreases pore size leading to shifts in meiofaunal community structure while shading and sediment disruption decreases autotrophic production. Loss of eelgrass, benthic macroalgae, and benthic microalgae decreases inputs, and probably storage of detritus of estuarine origin, important in salmonid food chains (*Nanaimo Estuary Fish Habitat & Log Management Task Force 1980*). The production and availability of food organisms required by post-emergent rearing of juvenile salmon is reduced by the loss of estuarine integrity including eelgrass habitat.

The following is a summary of reference documents that included mapped eelgrass distribution:

The Nanaimo River Estuary Status of Environmental Knowledge to 1976. Diagrammatic representation of flora on the Nanaimo River estuary, Figure 8.1 from Forbes, 1972 and Foreman, 1975

The eelgrass beds were identified on the figure as patchy areas north of the booming tenure dolphins in a *Zostera marina* / Ulva zone between the Assembly Wharf (West shoreline) and Jack Point (East shoreline). (See attached as Figure 3.)

Nanaimo Estuary Fish Habitat: Report of the Sub-Committee to the Steering Committee, Figure 2: Nanaimo River Estuary – Major Habitat Zones (1980)

Eelgrass, *Zostera marina*, as determined by infrared aerial photo interpretation and subsequently by field inspection is distributed and shown in the figures within the report. Eelgrass was documented to occur in isolated patches in areas that are less than 2 m above

the Mean Low Low Water Mark and which are not burdened by intertidal log storage. Such patches occur in the east channel (Duke Point side) of the river at elevations up to 2.6 m. Other patches are near dolphins between booms from which logs are prevented from grounding by the presence of the dolphins.

Ducks Unlimited 1988 Nanaimo Estuarine Habitat Inventory Map

The map was produced by Fastech Services Ltd. and is a compilation of data from 1975 and 1982 and cadastral and topographic maps. Data interpretation comes from large-scale colour air photos, ground truthing, and historical reports. This map indicates Submerged Vascular plants assumed to be eelgrass within the lower intertidal mudflat areas of the estuary and up into the dendritic channels in that zone. (See attached as Figure 4.)

Nanaimo Estuary Management Plan, Map 5 & 6: Eelgrass (base maps were prepared in 2002)

The map illustrates the distribution of *Zostera marina and Zostera japonica* eelgrass species and identifies patchy and continuous distributions. This map was derived from a combination of mapping conducted by Ducks Unlimited in 1988, air photo analysis, ground spot-checking, and an eelgrass mapping project that used GPS and an underwater video camera for the subtidal areas (*Snuneymuxw First Nation 2002*). This map provides an important baseline of eelgrass distribution up to 2002. This map indicates a comparable increase in eelgrass distribution on the northeast portion of the estuary and a decrease in the northwest when compared to mapping produced for the 1988 Ducks Unlimited study. Based on visual corroboration, it appears that eelgrass growth in the subtidal area on the west side of the estuary may be limited in extent by an accumulation of logs on the sea floor and also propeller wash from over 20 years of log handling in this area (*Berris 2006*) (See attached as Figure 5).

Nanaimo River Estuary Eelgrass Restoration Assessment, BCMCA map of eelgrass distribution in the Nanaimo Estuary, Figure 2 (2012)

The map shows eelgrass distribution based on source information from 1972, 1979, and a layer identified as SSOG without a date. The polygons show an increase in area between 1972 and 1979 especially along the eastern side of the estuary. The SSOG eelgrass polygon south of the log booms extends across the Nanaimo River estuary as a continuous area within an area presently dominated by emergent sedge marsh vegetation. This data may have been derived from the British Columbia Marine Conservation Analysis Atlas: Marine Plants – Priority Eelgrass Habitat. The atlas illustrates the distribution of priority eelgrass habitat. Eelgrass polygons were identified as areas that have known importance to eelgrass plus several other ecologically sensitive or endangered species. Eelgrass polygons do not necessarily coincide with recent surveys. Ground surveys have found eelgrass presence only in isolated channels of Nanaimo River and Holden Creek in this area. Data displayed on the map was collected over a wide date range (*BCMCA: 1890 to 2008; Shorezone Mapping*

System: 1979 to 2008) by many people for different purposes, and using different survey techniques and methods. Survey effort is not consistent throughout all areas. Areas with no data may not have been surveyed; these data gaps are not necessarily indicative of an absence of eelgrass.

Precision Identification (2012), Nanaimo River Estuary Eelgrass Restoration Assessment, Figure 5: Field Survey Locations

A field survey report was completed in April 2012 and eelgrass distribution was described for three major areas within the estuary by Precision Identification. The survey was conducted on foot and using a kayak. Area 1 on the western side of the estuary and north of the log booms (near new NPA office) was described as a mosaic of tidal flats that were mostly un-vegetated and sparsely vegetated (1 shoot of eelgrass/10 m^2) or were hummocks colonized by dense patches of eelgrass. Area 2 on the north-eastern side of the estuary is described as either very sparsely vegetated or un-vegetated (note: the April survey was too early in the year to identify *Zostera japonica*). Area 3 along the eastern shoreline near Duke Point describes small patches of eelgrass within the main drainage channels and their bank (See Map attached as Figure 6).

Vancouver Island University (VIU), Nanaimo River Estuary Eelgrass Restoration Assessment, Image 1: Eelgrass distribution map (2013)

Eelgrass occurrence areas were mapped in three main areas. Area 1 is located on the west side of the estuary close to the log storage region and was observed to be comprised of several small eelgrass patches with sparse distribution and a larger subtidal meadow to the north of the log booms which was described as dense. Area 2 is a large polygon in the northeast corner of the estuary described as being densely vegetated. This area was disturbed by only one log storage area in the past. Area 3 is located in the southeast portion of the estuary where small side channels were vegetated with small beds and a main channel vegetated with dense meadows and dense patches located in the margins. Mapped eelgrass information was used to generate a 2015 eelgrass distribution map. A digital copy of the 2013 image of the eelgrass distribution mapped by VIU has been included as Figure 7.

Current Use OF THE Nanaimo Estuary and adjacent upland

The Nanaimo Port and the forest products industry are the principal industrial users of the study area. The estuary is used extensively for log storage as well as recreation (*Berris 2006)*. The log storage area of the Nanaimo River estuary is designated as Port Transportation under the Nanaimo Port Authority, and the remainder of the intertidal area in the estuary is

designated as Environmental Protection/Recreational (*Berris 2006, cited in Nanaimo Estuary Management Plan*).

Current activities and land uses continuing to cause impacts include the following:

- Natural influence on the estuary from seasonal high tides and major storm events,
- Land uses in the watershed including residential, industrial, and agricultural,
- Dredging of mill pockets,
- Siltation and sediment erosion resulting from timber harvesting (including road construction) in the Nanaimo River Watershed,
- Extraction of water for various purposes along the rivers and major creeks
- Waterfowl hunting,
- Recreational use of the estuary by people and their dogs (*Berris 2006*),
- A 40-acre deep-sea terminal on the northwest corner of the estuary,
- Western Forest Products Inc. log storage grounds located on the assembly wharf adjacent to the terminal,
- Coastland Wood Industries Ltd. located on the west shore of the estuary,
- A 350-acre industrial park on Duke Point including four mills with log storage in the estuary: WFP Duke Point Sawmill, WFP Duke Point Log Merchandizer, Harmac Pacific Pulp & Paper, and Cascadia's (formerly Weyerhaeuser's) Island Phoenix Division Sawmill,
- Snuneymuxw First Nation lands: IR #1 the primary community of residences, administration building, and associated uses is located on the west shore of the estuary. At IR #3, there is a small residential community along Raines Road. IR #2 is west of the Nanaimo River, and IR #4 is east of IR #3. The large property west of IR #3 (previously owned by the Inuit) has been purchased by the Crown and is being held pending treaty negotiation,
- Additional residential development and use within the City of Nanaimo in the form of single and multi-residential housing and mobile home developments across Haliburton and Esplanade Roads from the estuary, and in the Chase River/Wexford Creek area, and,
- Other land uses including a forested private campground/retreat centre just east of the mouth of the Chase River, agricultural land, some of which is managed by The Nature Trust for wildlife, and two municipal parks. Biggs Park on the south-west shoreline of Duke Point is inaccessible and Jack Point Park on the north-west shoreline of Duke Point has a trail that goes out to the point (*Bell and Kallman 1976*).

Eelgrass DISTRIBUTION Mapping 2015 and 2020

The following section describes the methodology and results to date of the Nanaimo River Estuary eelgrass surveys primarily collected in 2015 and updated in 2020.

2015 STUDY METHODOLOGY

The 2015 Nanaimo River Estuary eelgrass study was confined within the following physical boundaries:

- The high water mark along the estuary's entire western and eastern shoreline,
- South to the division between the Nanaimo River's west and east river channels located immediately south of the parking lot for the Nanaimo River Estuary Park and the end of Raines Road, and,
- The 10 m bathymetric contour along the seaward edge of the estuary.

Bazett Aerial Photography Survey (2015)

A base map was completed by aerial photography produced by Bazett Land Surveying on July 3, 2015. The survey included the use of a Super Cub airplane equipped with a Haselbald medium digital camera system mounted from the wing of the plane. Following a designated flight path that formed a grid pattern over the estuary, a series of GPS referenced, (overlapping) high resolution aerial photographs were taken with the camera.

The captured digital images were then scanned and uploaded into GIS software, and then formatted into a single seamless image of the estuary. The images were then stitched together to form one large, aerial photo mosaic. The high resolution of the photographs allowed for the single image to be enlarged to poster size while still retaining clarity and allowing for on-screen analysis to outline polygons of potential eelgrass beds for further confirmation on the ground. Image points can also be scaled on the map to actual size using this method. Individual points on the aerial image could then be checked by ground/boat using a simple handheld GPS to direct the surveyor to the point. The resulting image was used as a base map for the 2015 study and enabled GPS data overlays to make easy comparisons over time.

Aquaparian staff biologist Chris Zamora accompanied Dave Bazett during the survey and took additional digital photographs to document specific areas of the estuary.

Vancouver Island University (VIU) Study (2015)

Aquaparian and a team of volunteers from Vancouver Island University (VIU) undertook field data collection using a combination of kayaks, ground truthing during low tides, and by underwater transects using scuba. Initial field data collection sites were determined based on

review of existing eelgrass presence information provided in past consultant's report and generated maps. More detailed information was also gathered to document the growing conditions and eelgrass coverage. Due to the late start of the project, the 2015 field season was limited to the last week of July through to the month of September. The VIU students completed most of their field collection during the month of July. Optimum field conditions for ground truthing (during low tides) within the estuary was determined to be between June and July.

Aquaparian provided direction on methodologies to be incorporated in documenting eelgrass presence during the survey. General survey methods were adapted from Precision Identification Biological Consultants. Methods were referenced in the document titled *Mapping and Monitoring Eelgrass Habitat in British Columbia, Draft 4, December 2002*. The level of information gathered within the eelgrass beds also had to be reduced due to limited survey time available to the team.

The strategy of this study included Level 2 and part of Level 3 parameters as identified in the Precision document. Parameters included:

- Location of eelgrass meadows (polygons – aerial mapping interpretation);
- Distribution (patchy or continuous);
- Shoot density within polygons;
- Substrate type within polygons; and
- Photographs of each polygon and sample site.

Data was overlaid on the aerial base map to show:

- Delineation of eelgrass distribution – polygons;
- Maximum and minimum depth of eelgrass; and
- Distribution and density of eelgrass using colour shading.

Aerial photo interpretation to delineate eelgrass polygons was completed using a combination of previous studies of the estuary, Google Earth images, and the aerial survey completed by Bazett Land Surveying.

The intent of using aerial photo interpretation was to try and identify the distribution of native Pacific eelgrass (*Zostera marina*), the invasive Japanese eelgrass (*Z. japonica) and* sea lettuce *(Ulva sp)* distribution in the estuary before going out to collect data in order to target areas for further field data collection. Areas that appear green (shading) on the aerial photo image may be eelgrass or algae, therefore field identification is necessary to confirm aerial interpretation as well as to document density, distribution, and substrate type within the polygon. Based on a review of past reports on the Nanaimo River Estuary, eelgrass appears to be concentrated in three locations. The first concentration is in the northern third of the

estuary between the low intertidal / high subtidal zones. The second is at the northern edge of the mudflat to a depth of -3 to -5 m. The third is confined within the main drainage channels along the east side of the estuary, the northern middle of the estuary, and the northern section of the main west channel (west side of the estuary).

Patches of eelgrass separated by open sand were identified as Polygons on the aerial map and given a unique number (P1, P2, etc.). The size and location of the polygon defined the field data collection method (foot, kayak, scuba) and number of sample sites within each polygon to determine shoot density, substrate type, and other information. In the intertidal areas of the estuary, field data was collected on foot or by kayak. Sub-tidal areas of the estuary required scuba and drop-camera to determine maximum depth of eelgrass growth.

Using the aerial interpretation as a guide, boundaries of the individual polygons (eelgrass beds) were confirmed in the field as accurately as was feasible. Using a GPS, the eelgrass polygons were recorded at approximately 15 m intervals around the perimeter of the bed.

Within the polygons, the distribution of eelgrass was defined as patchy or continuous. Patchy beds contain isolated groups or patches of plants. Continuous beds are either roughly homogeneous in distribution or a bed that contains some bare patches within it.

There are typically 2 or 3 zones within an eelgrass bed that may be characterized as sparse, moderate, or dense in appearance. The zones blend into one another and are identified as transition zones. Density was estimated within the zones where possible.

Quadrate data included photographs, GPS location, shoot density, substrate type (mud, sand, gravel, cobble, bark waste) and incidental observations such as marine organisms, archaeological evidence, and evidence of impacts (log booms, prop wash). Eelgrass presence was characterized as either “Patchy” or “Continuous.”

Patchy – Distribution referred to eelgrass observed in clusters of individual plants followed by open exposed gaps of the seabed typically greater than 2 m^2. The density of eelgrass plants within a 1 m^2 quadrate would also be low and generally between 1 to 10 stems found within the quadrate. These could be found where changes to sediment conditions changed or from a physical disturbance to the bed. Areas identified included the northern middle section of the low intertidal and high subtidal zones and on sections of elevated mudflat within the northern section of the mudflat.

Continuous – Eelgrass distribution typically referred to continuous eelgrass meadows. Eelgrass beds are found to have abundant individual plant growth with no open gaps. Eelgrass beds are found to extend from the low intertidal zone with continuous expansion

down-slope into the high subtidal depth. The density of eelgrass plants within a 1 m^2 quadrate would generally be greater than 10 stems/m^2. Transect dives in the northeast section of the mudflat observed eelgrass meadows with plant densities between 40 to < 60 stems/m^2.

2015 DISTRIBUTION RESULTS

The Bazett aerial survey images were compiled into one large base map using ArcGIS to produce a high-resolution base map. This map is geo-referenced so that additional studies and data collections that are recorded using GPS coordinates can be plotted accurately. The high resolution and the ability to zoom in on-screen allowed for interpretation of eelgrass distribution to outline polygons for ground assessment. A copy of the base map has been included as Figure 8.

Following the aerial survey, field data collection was initiated by students from VIU and primarily included traversing the northern portion of the estuary by kayaks during low tide conditions. The students used google earth aerial images and an aerial map of the estuary generated during the 2006 estuary study.

The northern boundary and the eastern half of the eelgrass perimeter were field checked and mapped using GPS coordinates. Transects using an underwater drop camera and one day of scuba by Aquaparian were completed along the northern boundary to document eelgrass density and distribution. An eelgrass distribution polygon was overlaid onto the aerial image including photo interpretation and the field data that was collected. A copy of the 2015 eelgrass distribution map has been included as Figure 9.

Due to the delay in starting the project in 2015, most of the very low daytime tides which occur in June and July were missed. The poor tide cycles during data collection resulted in insufficient time to complete proper ground-truthing of the southwestern portion of the estuary to confirm observations of eelgrass presence from the aerial imagery produced by Bazzet Surveying. It also prevented the team from properly inspecting the dendritic drainage channels that braid across the central part of the mudflats (which are typically exposed during the low tides) and also inspecting near and around the log booms.

The poor tide conditions thus resulted in the incomplete collection of field data for the 2015 season. Additional field survey efforts were recommended in the draft version of this report for June / July 2016 to confirm the boundary of eelgrass distribution in the estuary, as well as collection of more detailed information of density and growth and a general survey of elevations within estuary that may influence growth conditions.

From information and maps compiled during the 2015 study, it does appear that management changes implemented in the 1980s to reduce and confine log storage in the estuary and the re-growth of previously cleared forests within the upper Nanaimo River watershed has resulted in the re-growth and colonization of eelgrass within the northern half of the estuary.

The 2006 management report documented eelgrass presence within three relatively distinct zones in the Nanaimo estuary: the subtidal, the lower intertidal, and along channels in the upper intertidal area. Results from the 2015 field study indicate the upper intertidal zone appears to have a lower density of eelgrass and is mostly colonized by *Zostera japonica* at 10-20 shoots per m^2. The lower intertidal and subtidal zone near the outer edge of the mudflats is dominated by mostly *Zostera marina* at densities approximately 40-60 shoots per m^2, and between a water depth of 0m to -4m below (LLW). The northern boundary of the mudflat was found to have a continuous eelgrass meadow or bed. Dense growth of eelgrass also extends up into the main permanent tidal channels in the estuary concentrated on both the west and east side of the estuary and in the middle near the northern third of the estuary. Aquaparian also completed a survey immediately south of the cruise ship terminal pier and along the shoreline edge of the Nanaimo Port Authority office as well as the near shore area fronting the Western Forest Products mill site. An extensive strip of continuous eelgrass > 30 m in width was observed by drop camera within the three areas in 2015.

2020 STUDY METHODOLOGY

The 2020 Nanaimo River Estuary eelgrass study was focussed on following the southern perimeter of the eelgrass distribution across the estuary. The northern extent (subtidal) was not verified in this survey. The survey was confined within the following physical boundaries:

- Survey of the northern and central portion of the estuary; excluding the salt marsh;
- The high-water mark along the estuary's entire western and eastern shoreline,
- South to the main river channel located off of the Living Forest Campground (located off of Maki Road), and
- South along the eastern shoreline (Jack's Point Park).

The 2020 survey excluded a survey of the tidal salt marsh and the subtidal / intertidal interface located at the northern extent of the Nanaimo River Estuary.

Aquaparian undertook field data collection using a combination of kayak and on foot over a total of four days during low tides (0.5 m-1.3 m). The intent of the 2020 study was to complete field data collection of eelgrass distribution within the northern and central portion of the estuary, to compare it to its distribution interpreted by aerial imagery in the 2015 survey and to determine if the eelgrass beds have expanded or receded over the past 5 years. This data provides information about the overall health of the eelgrass population and if / how the distribution has changed within the estuary over time. Figures 10 A shows the eelgrass distribution confirmed during the 2020 study and Figure 10B shows the combined data collected in 2015 and 2020.

Aquaparian used the 2015 eelgrass survey map as a guide and travelled through the estuary, in particular, the mudflats to document eelgrass beds. Plots were determined by visually identifying large eelgrass patches and roughly following (as accessible) their southern perimeter across the estuary from east to west by foot. The south edge of the patches was marked by GPS plots. Quadrats were placed in an area of the plot that appeared representative of the overall density and distribution of eelgrass within each patch. Areas with deeper channels were explored by kayaks (July 22) as the west side of the study area has several deep channels that could not be accessed by foot. The survey crew was able to plot and visually estimate eelgrass presence and density from the surface due to good water visibility at the time of the survey.

Parameters documented included:

- GPS coordinates of southern boundary of eelgrass;
- Distribution (patchy or continuous; definition consistent as identified above);
- Overall vigour of patch (Good or Poor);
- Shoot density (Sparse, Moderate or Dense with estimate of stems/m^2);
- Substrate type (mud, sand, gravel, cobble);
- Water depth (measured during survey);
- General observations; and,
- Photograph collection.

Data collected in 2020 was overlaid onto the same aerial base map generated in 2015 in order to compare and confirm the distribution of eelgrass within the study area and whether eelgrass growth had either expanded or reduced within the estuary since the 2015 study. In addition, the 2020 data of the west side of the estuary provides accurate mapping of the eelgrass distribution that was not ground-truthed in the 2015 survey, but rather interpreted from aerial imagery. A change to the 2015 Eelgrass Distribution Map (See Figure 9), and the 2015 & 2020 Combined Data Eelgrass Distribution Map (See Figure 10B) has included the deletion of single

data point illustrating a eelgrass location anomaly by the Nanaimo Cruise ship Terminal (West side).

2020 DISTRIBUTION RESULTS

The eelgrass beds within the centre of the estuary, especially east of the central cobble reef, are large, dense and healthy. They appear to have maintained distribution with two small voids (<100 m) where the eelgrass appears to have receded when compared to the data from the 2015 survey.

Previously, the team was prevented from inspecting the dendritic drainage channels that braid across the central part of the mudflats which are typically exposed during low tides, and also from inspecting near and around the log booms due to a late start on the project and poor tide cycles in 2015. During the 2020 survey, Aquaparian was able to investigate these areas. The eelgrass is confined to the northern half of the estuary and along the east shoreline adjacent to Jack's Point. The far west side of the estuary and the area surrounding the log booms were found to be void of any eelgrass. The substrate in the area of the log booms was observed to be comprised of thick, anoxic mud with minor amounts of cobble and gravel east of the deeper channel along the shoreline. The estuary floor appeared void of seaweeds and algae and only some shellfish were observed along the channel. The presence of bark waste was observed along the west channel and it appears to contribute to the significant finds and muddy substrate. A location of where Precision Identification had completed an eelgrass transplant in 2007 was again found to be devoid of eelgrass. Sedimentation transport along the section of river and silt load from the log booms may have prevented the eelgrass from maintaining and expanding along this area. A conversation with Chris Good, Councillor with the Snuneymuxw First Nation, indicated that the west channel fronting the SFN reserve lands show signs of some infilling over the past five years. Deeper waters around the northwest corner of the estuary was observed to have healthy populations of eelgrass that appear to have expanded south (Plot 20-25) as compared to the 2015 survey.

On the immediate west side of the central cobble reef, there is a fairly wide, deep channel. It appears that eelgrass between Plot 8 and Plot 26 is interrupted by deeper water flowing through the channel. This is indicated on the map (Figure 10A & 10B) as a dotted line. In 2017, Andrew McNaughton (pers. comm.), working in conjunction with the SFN, reported that he observed eelgrass developing west of this cobble reef at a density of approximately 1stem/m^2. When Aquaparian surveyed the area, no eelgrass was observed in this location. The area was dominated by cobble on muddy sand and a very dense oyster bed. Surrounding areas were exposed at low tide and appeared to be populated only by Pacific oysters (*Crassostrea gigas*).

The east side of the estuary continues to be patchy in distribution but healthy populations of eelgrass seem to be maintaining. Directly adjacent to the shoreline, the eelgrass was observed to be sparse and in relatively poor health, but increased in density and vigor further west until homogenous, dense beds were observed. A small patch south of the Aquaparian 2013/2014 eelgrass transplant location was observed from shore (by Chris Zamora) in May 2020 and appears to be confined to a small channel. The southernmost extent of the eelgrass confined to a channel along the east shoreline appears to have receded approximately a kilometer as compared to the 2015 survey. The eelgrass was observed to be patchy and moderate in density (50 stems/m^2) and it extent at approximately 200 m south of the tunnel at Jack's point. An estimated 200 m void in this eelgrass patch north of the tunnel entrance to Jack's Point Park (Plot 4) was observed which was previously continuous (according to the 2015 data). South of the tunnel, the substrate transitions from sandy mud and gravel to thick, anoxic mud. Potentially, fines have migrated from the river and in-filled areas along the east side of the estuary that were previously documented to have eelgrass beds.

Aquaparian's 2013/2014 eelgrass transplant (1250m^2 total transplant area) was inspected and documented in 2016 (Aquaparian Estuary Eelgrass Transplant Monitoring Year 2 – 750m^2 2014 Eelgrass Transplant; Monitoring Year 3 – 500m^2 2013 Eelgrass Transplant, 2016). Aquaparian observed that the donor channel located west of the transplants had in-filled significantly with sediment and the dense, mature eelgrass previously observed in 2013/2014 was absent. An inspection of the channel during the 2020 survey still found the section of channel to be absent of eelgrass. A further inspection of the Aquaparian transplant location did identify sparse patches of eelgrass but a very low density (>1-2 rooted plants per m^2). It appears that the transplants have rebounded slightly since the 2016 observations but have not yet established a dense, healthy population.

SUMMARY AND 2015 & 2020 Survey COMPARISONS

Many previous studies have been completed for the Nanaimo River Estuary for a wide range of research purposes or management decision plans using methods and technology available at the time they were completed. It can be assumed that only limited biophysical knowledge of natural resources for the Nanaimo River was ever documented prior to the 1960s and that the extent of eelgrass distribution within the estuary was never truly studied prior to the start of booming activity. Most comments on distribution were likely made through general observations. Questions on eelgrass species identification may also be a factor (i.e. whether other algal species such as *Ulva* sp. or *Zostera japonica* were thought to be Pacific eelgrass from a distance or from air photo interpretation). Questions on true distribution are identified in the following referenced reports.

A draft report prepared by KAD Environmental Research in January 2000 included a reference to *Narver 1972* that stated “prior to 1948, eelgrass was reported to be growing over two-thirds of the estuary.” A Lands Directorate report from 1974 was also cited stating that “by 1974, eelgrass beds extended only north of the booming grounds.”

A draft report by Precision Identification in 2012 included a reference to the British Columbia Marine Conservation Analysis (CMCA), a collaborative project that mapped high value marine conservation areas from various sources. The BCMCA eelgrass map of the Nanaimo Estuary includes data from 1972, 1979, and another layer labelled SSOG without a date. This layer appears on several websites (i.e. CRIMS 2009) showing a large polygon of eelgrass within the shallow upper intertidal area of the estuary. This dataset is assumed to predate 1979 mapping projects as no original reports to support the map were found. With the exception of a small area within one intertidal channel, the area identified in this polygon is currently unsuitable to support eelgrass growth. As identified in the Precision report, conditions may have been different in the past or the aerial photos available at the time of the SSOG map production may have been misinterpreted.

The KDA report also included a quote from *Forbes 1973* that they had observed “that the present topography of the estuary suggests very little suitable habitat would be available to eelgrass colonization on the higher portions of the tidal flats. Generally, eelgrass beds in the Nanaimo River estuary appear to be restricted to the lower portions of shallow topographic undulations in the estuary floor and to areas where the bases of the plants are covered by water in all but very low tidal conditions.” (*Dunham 2000*)

Even given the varying levels of confidence on past eelgrass distribution documentation, some comparisons can be made with current observations on eelgrass identified during the 2015 / 2020 survey as follows:

- 2015 / 2020 Eelgrass distribution in the estuary appears to be comparatively similar to findings documented within the Nanaimo Estuary Management Plan 2002 Map 5.
- The northern extent of eelgrass distribution extends further north and west across the estuary and more continuous than what was previously mapped. This was confirmed by kayak and drop camera surveys during 2015.
- When compared to the Forbes and Foreman compilation map of 1976 which was at the height of log booming activity, eelgrass distribution (2015 / 2020) appears to have increased substantially across the estuary approximately doubling in area from what was mapped in 1976. The northeast quadrant shows the most recovery of eelgrass.
- Aerial imagery generated by Bazett surveying (2015) shows substantial substrate scouring evident in and around the active log booms within the western half of the

estuary, however, a review of the Bazett imagery shows most substrate scour marks along the east side of the estuary to no long exist.

- The old tenures on the east side of the estuary (photo 1962) appear to have recovered for the most part showing only minor amounts of residual scarring, and eelgrass is growing in some of the dendritic channels.
- The 2015 aerial imagery shows extensive substrate scouring outside the tenure boundaries within a navigation area northward of the tenures.
- A drop camera survey along a section of the west side of the estuary near the assembly wharf in 2015 identified the presence of eelgrass along a large section of the nearshore area. Results from the 2020 survey show that some of the eelgrass to have retreated (See Figure 10b).
- Eelgrass growth along the northern boundary of the estuary, within the subtidal zone appears to grow to a maximum depth between -3.5 to -5m. However, eelgrass within the intertidal zone appears to be restricted along a specific tidal elevation (between +1.0m and 0.0m) within the estuary when the plants and/or their roots (rhizomes) are covered by water most of the time. The elevation appears to determine the present boundary where eelgrass grows and does not grow.
- The 2020 study indicates that there is a general, minor loss and/or reduction of eelgrass from the east side of the estuary since 2015 likely caused by silt load from the river or sediment redistribution. Aquaparian's 2013/2014 eelgrass transplants that had failed to establish may be re-establishing but in sparse densities and with poor vigour.
- It should be noted that the west side of the estuary was mostly assessed using aerial interpretation in the 2015 study; only the deep channel section fronting the Coastland property using an underwater drop camera. Areas where the eelgrass appears to have expanded or receded in 2020 as compared to the 2015 aerial interpretation may be the result of more accurate mapping completed in 2020 through ground-truthing rather than a true trend in distribution changes. According to the discrepancy in the southern perimeters mapped between 2015 and 2020 on the west side of the estuary, parts of the eelgrass patches would have expanded at a rate of approximately 10-20m/year, which is unlikely, as the true expansion rate is more gradual. For example, Neckles *et al.* (2005) documented a mean lateral expansion of 12cm/year. Ground-truthing is expected to produce more accurate results, as vegetation observed from high-resolution aerial imagery may not actually be *Zostera marina.* During the 2020 survey, *Ulva* and *Z. japonica* were observed in the 2020 survey growing in and around the *Z. marina.* These other species may appear similar from aerial view as the colouration is similar. The resolution of the mapping is also more accurate using a handheld GPS in the field rather than visually mapping from a photograph. Future studies of eelgrass in the Nanaimo estuary should be completed using ground-truthing methods.

- The 2020 survey indicated that there is a loss of eelgrass from the west side of the estuary that is likely a result of silt loading transported from upstream along the main river channel. Silt accumulation maybe a factor from log boom movement, increased in upstream/headwater sediment, and changes to seasonal stream flow levels. Most recent studies on Canada Goose (*Branta Canadensis*) foraging behaviour within the estuary, show heavy goose foraging activities of saltmarsh edges along the main west channel of the mudflat estuary resulting in significant erosion of vegetated islands from loss of vegetation. Erosion of the river banks and mudflat islands may have resulted in increase in downstream sediment transport and settlement along the channel where eelgrass was present.
- The documentation of large flocks of geese (as many as 400 individuals) using and foraging within the estuary during low summer tides and with increased numbers over wintering may have also resulted in poor survival of recently transplanted eelgrass sites.
- Eelgrass is still abundant and healthy in most other places in the estuary. Eelgrass populations in the centre of the estuary appear to have expanded south since 2015.

CONCLUSION

Findings, report references, map submissions, and recommendations provided in this report are based on information made available to Aquaparian at the time of this study. Results within the document are also based on a additional time to gather field data information since the 2015 study. This report is submitted to the Nanaimo Port Authority, the Ministry of Transportation and Infrastructure and Snuneymuxw First Nation for further distribution at their discretion. Aquaparian will not be held responsible for information or data contained within this report other than its intended purpose.

Conclusions are based on existing site conditions and comparisons with previous studies identified in this report. This report has been prepared based on past project experience working in and near marine environments and in accordance with generally accepted professional biological practices and natural resource management. No other warranty is made, either expressed or implied.

Any questions regarding this report or its findings, please contact the undersigned.
Aquaparian trusts that the information provided in this report meets your requirements.

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- Snuneymuxw First Nation; and,
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Appendix A figures

Figure 1. Nanaimo River Estuary Site Location Map

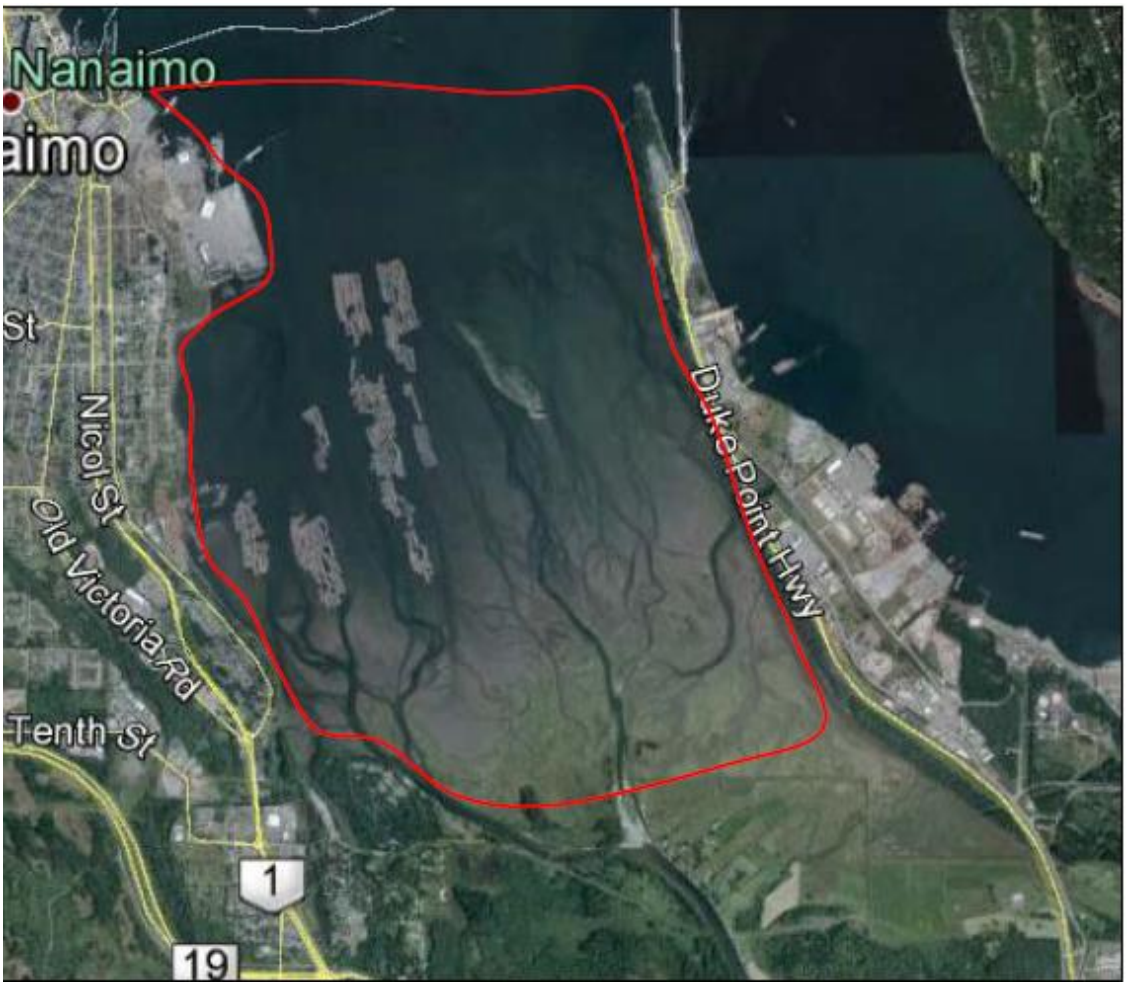
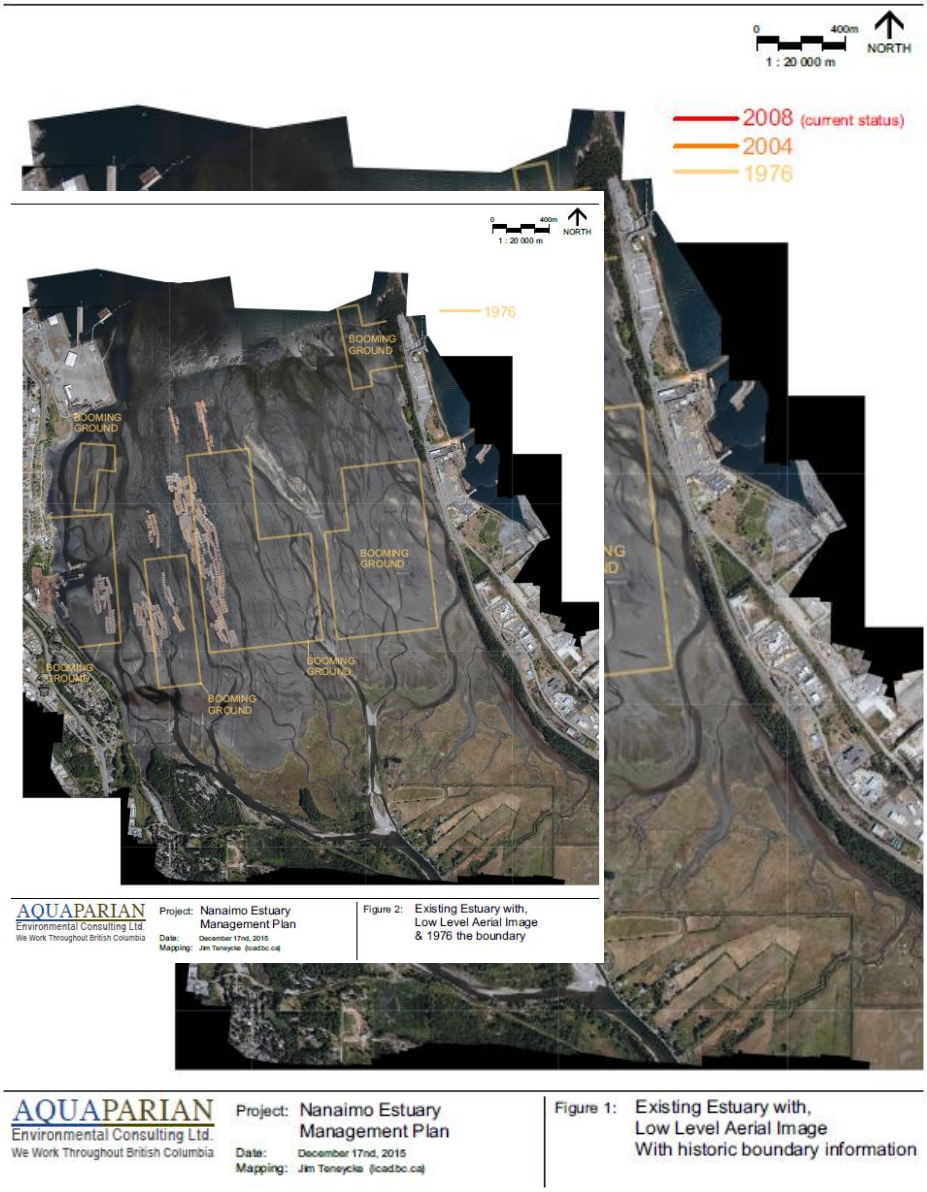


Figure 2. Historic and current log boom tenure maps



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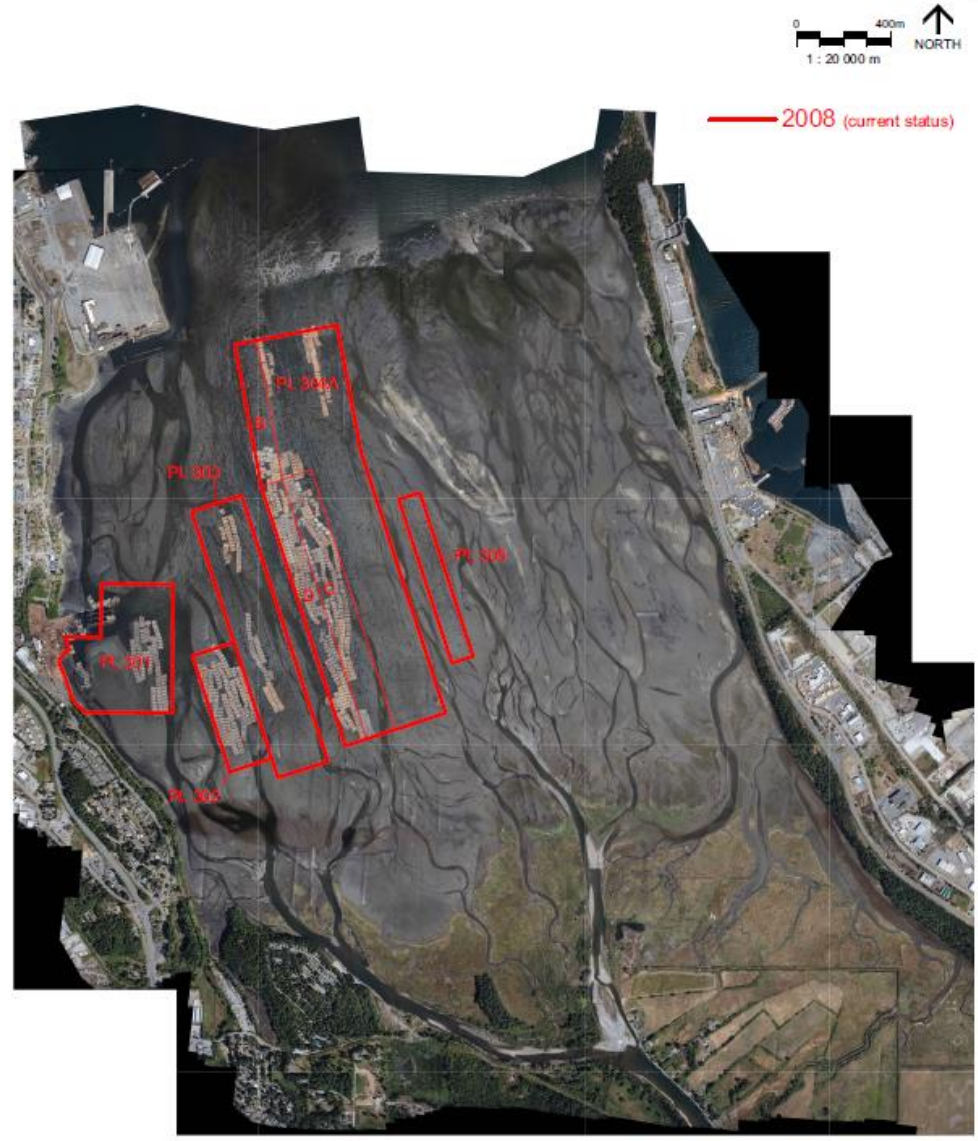
Project: Nanaimo Estuary Management Plan
Date: December 17nd, 2015
Mapping: Jim Teneycke (jcad.bc.ca)

Figure 1: Existing Estuary with, Low Level Aerial Image With historic boundary information



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Project: Nanaimo Estuary Management Plan
Date: December 17nd, 2015
Mapping: Jim Teneycke (jcadbc.ca)

Figure 4: Existing Estuary with, Low Level Aerial Image & 2008 the boundary

Figure 3. 1976 Forbes and Foreman Figure 8.1

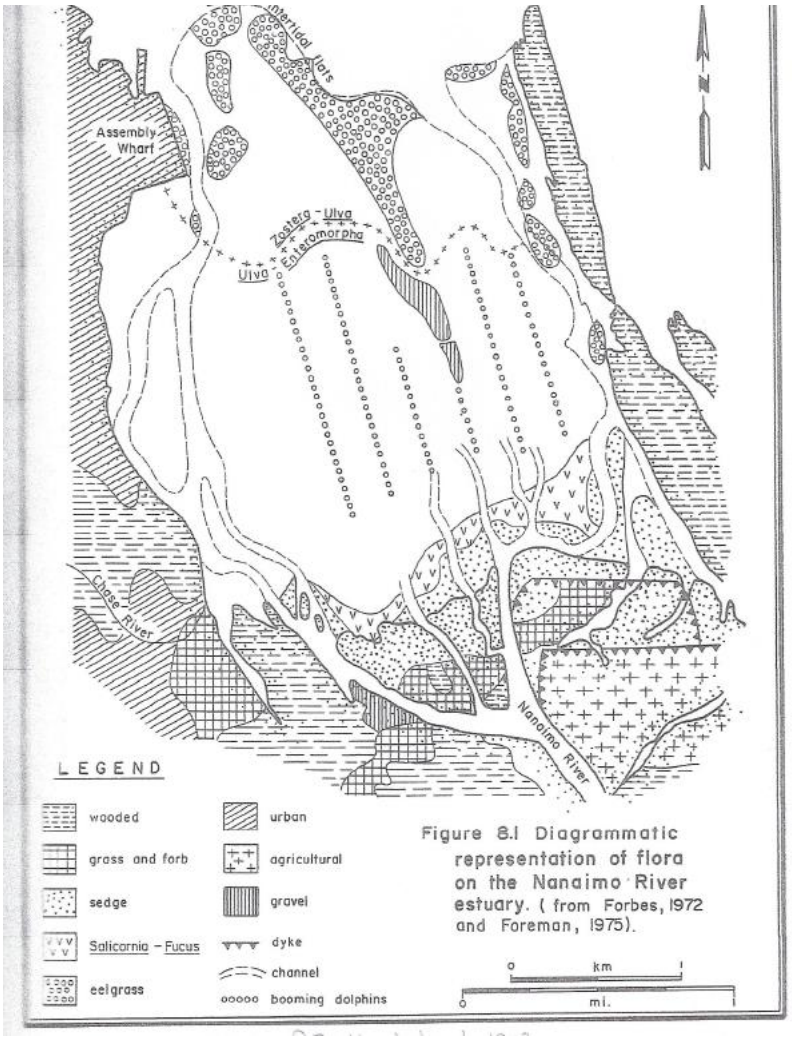


Figure 8.1 Diagrammatic representation of flora on the Nanaimo River estuary. (from Forbes, 1972 and Foreman, 1975).

Figure *4 Ducks unlimited 1988 estuary habitat map*

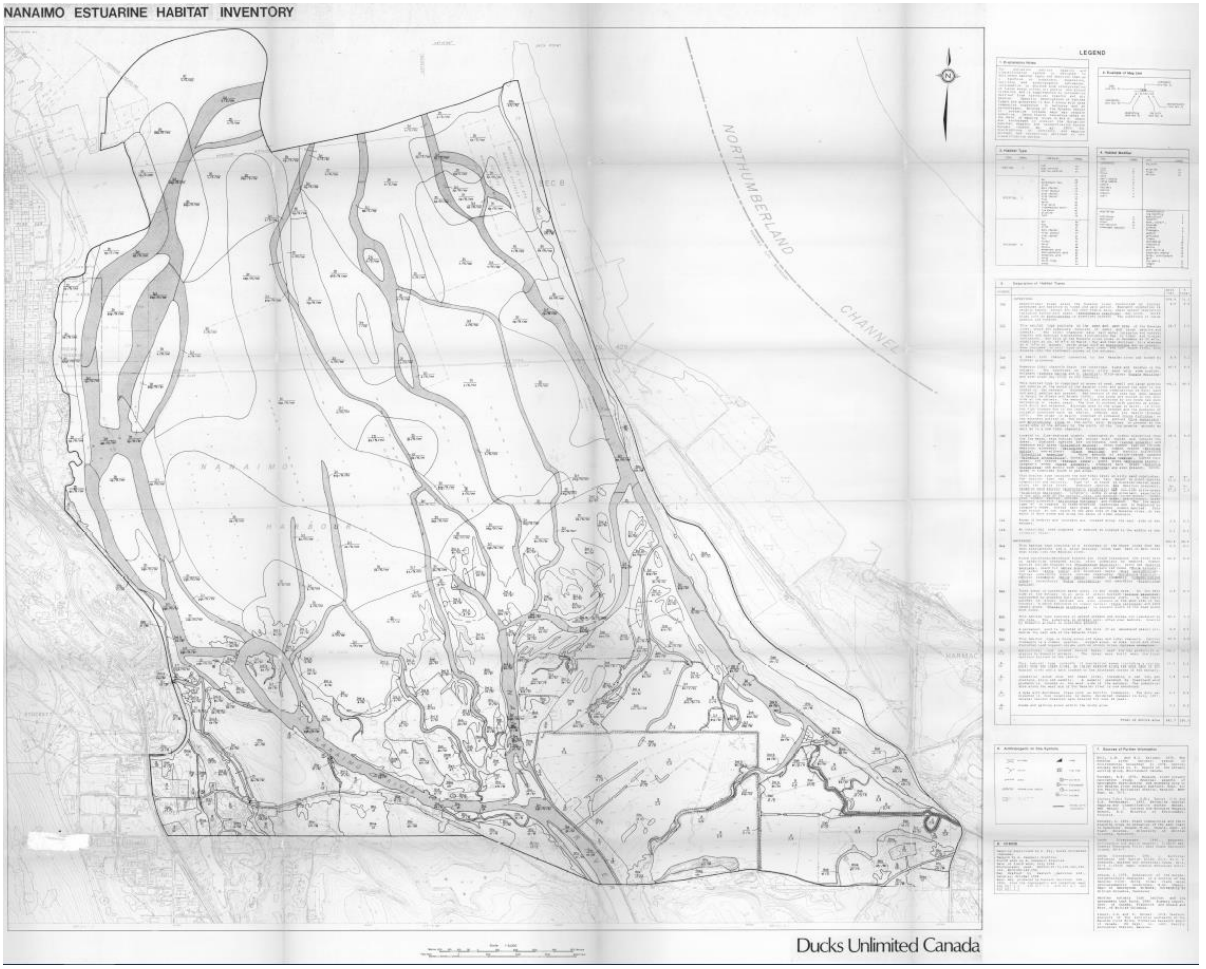


Figure 5 Nanaimo Estuary management plan – Map 5 & 6

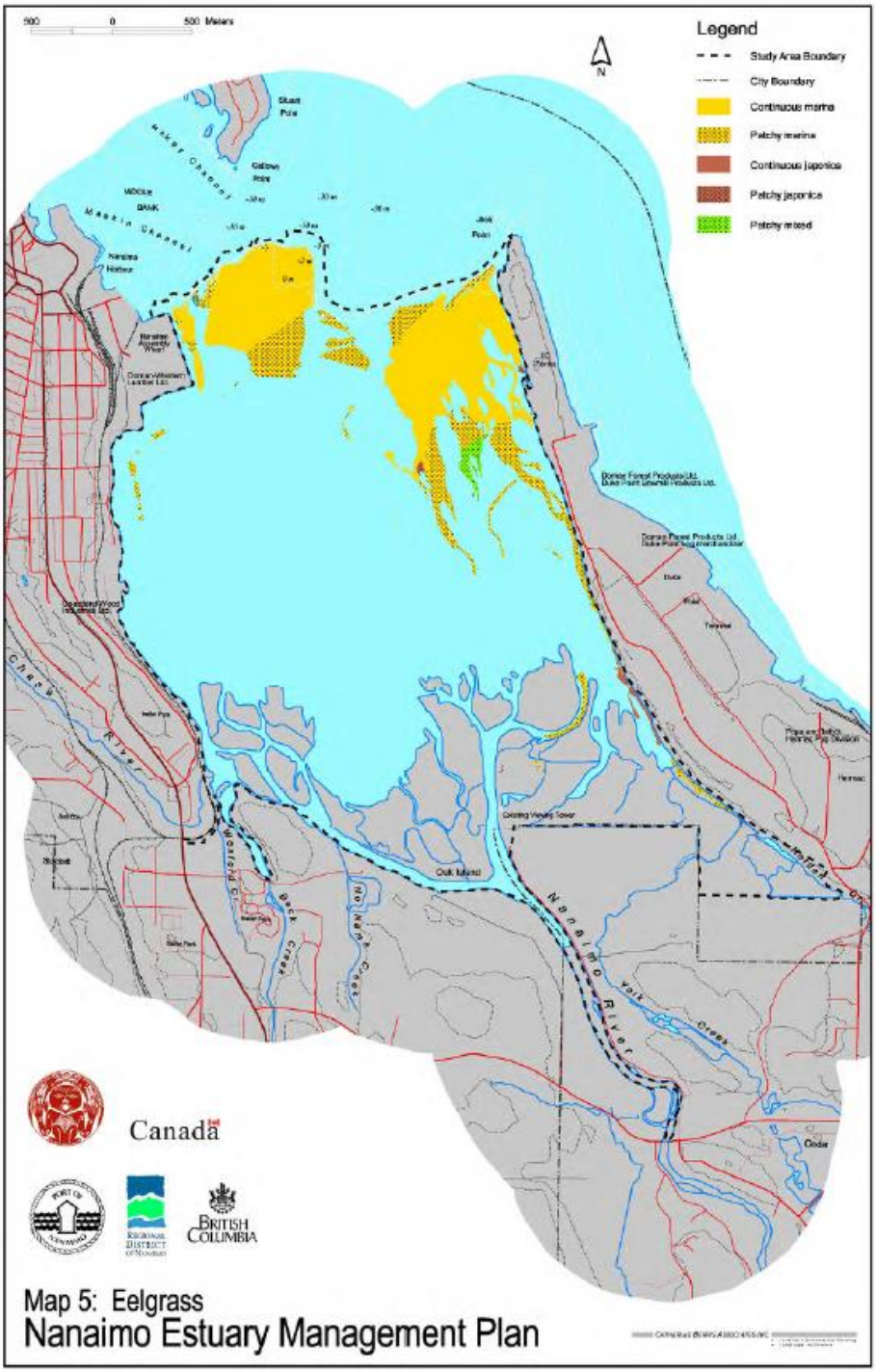


Figure 6 Precision identification 2012 field survey locations

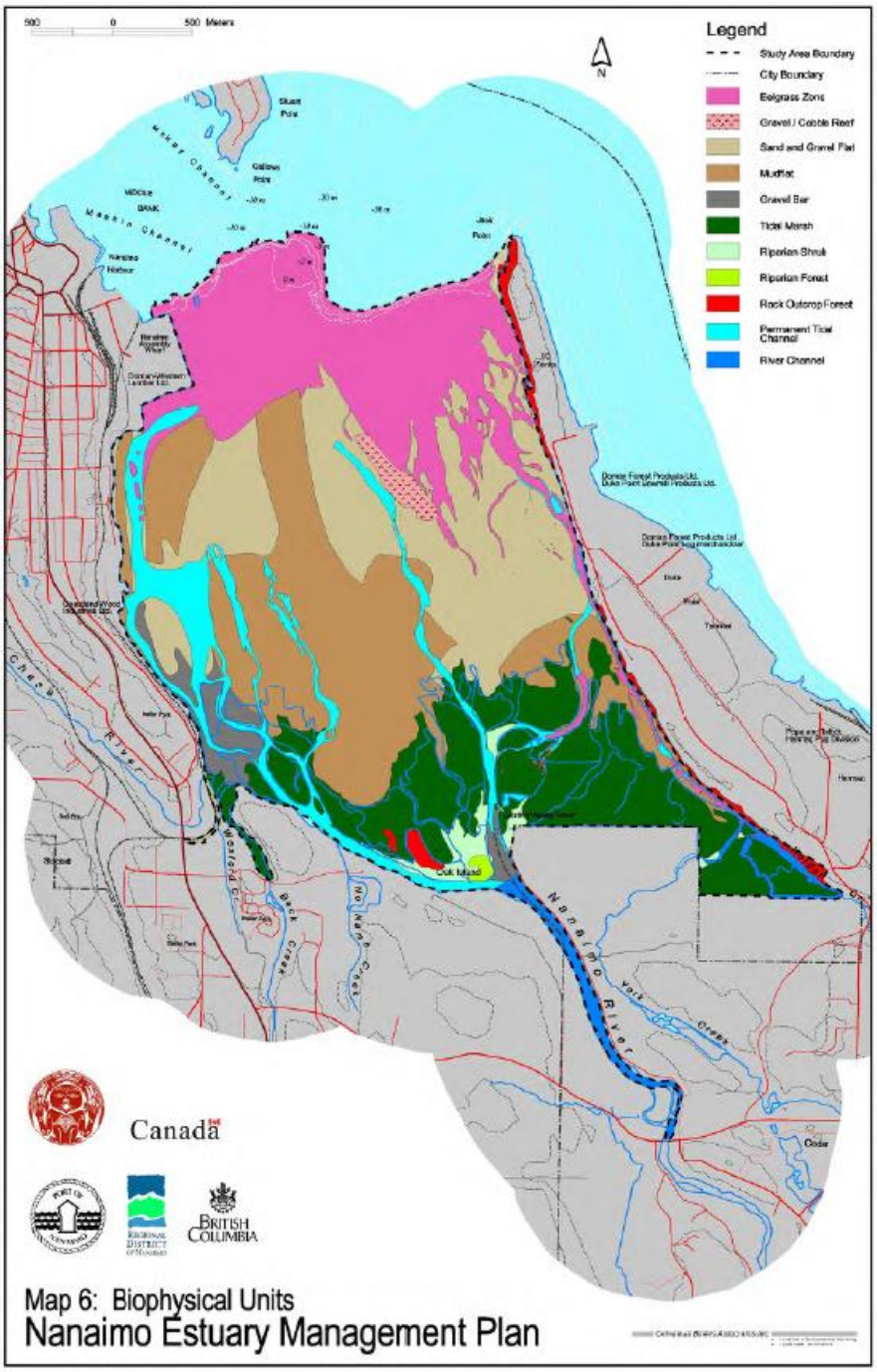


Figure 7 Vancouver Island university eelgrass distribution map Nanaimo estuary 2013

Figure 8 2019 Bazett aerial image

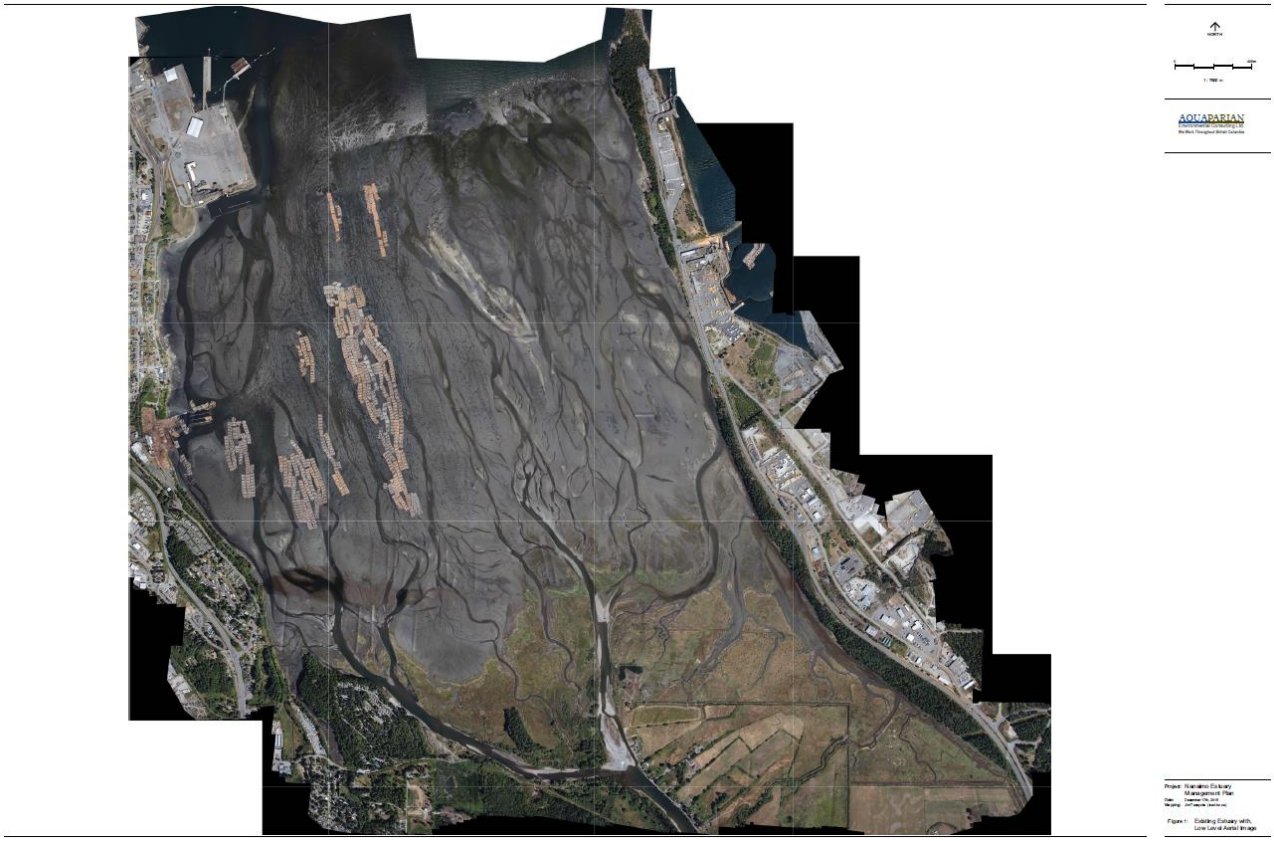


Figure 9 2015 eelgrass distribution map

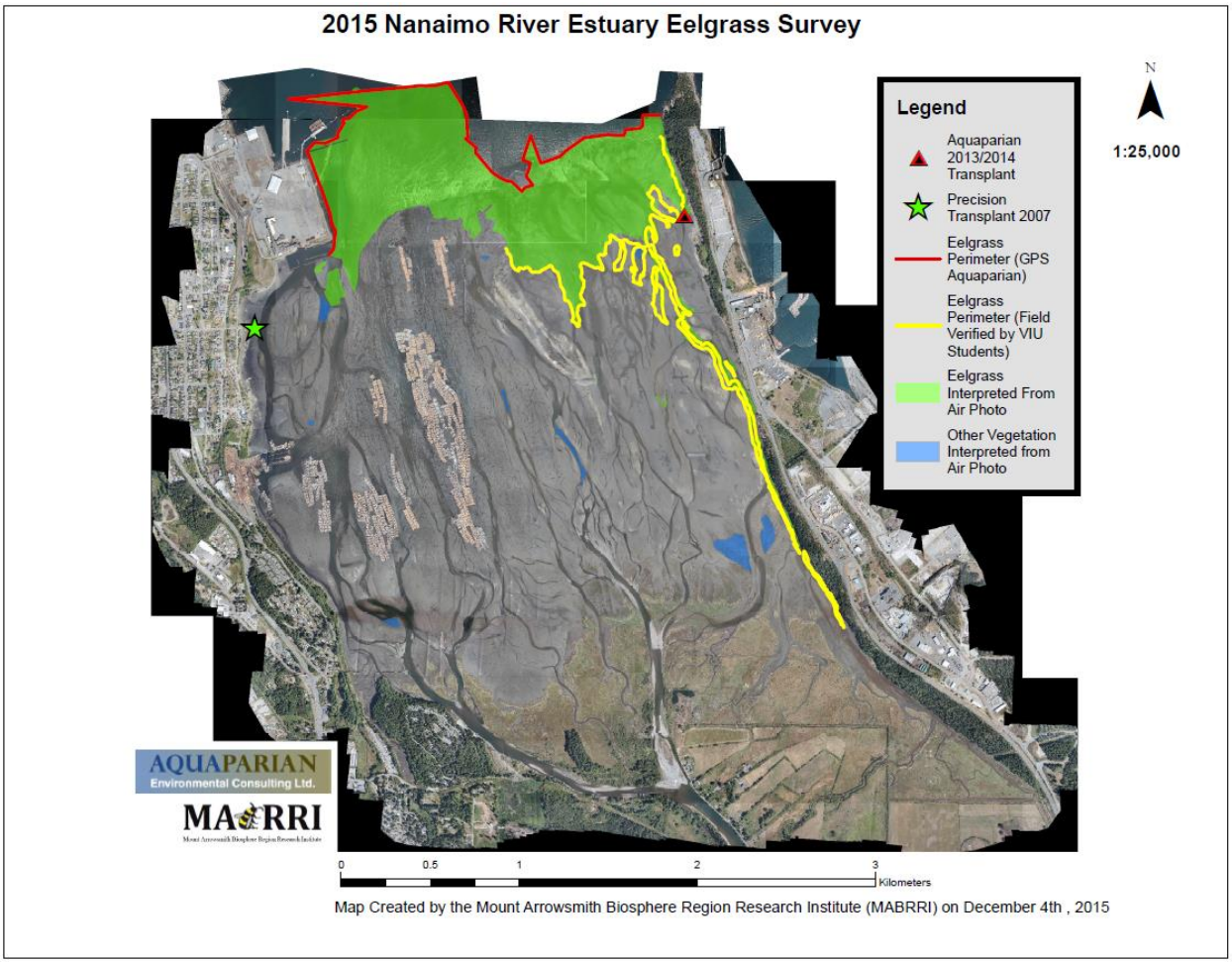
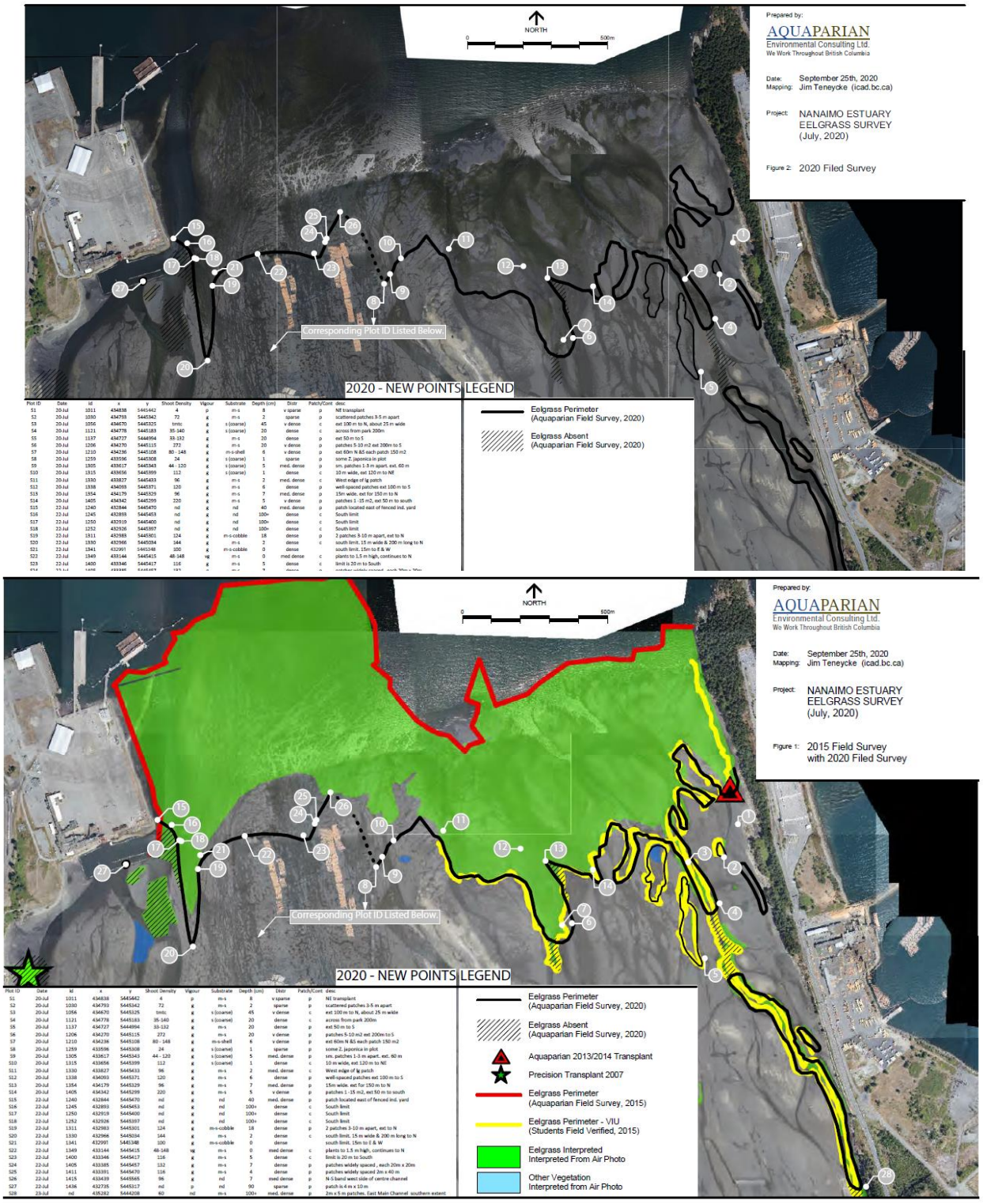


Figure 10 2020 eelgrass distribution map: 2015 & 2020 combined data



Appendix B Historical air photos

Figure 11 1950 one small log boom on the east side of the estuary.

Figure 12 1958 showing log booms across the entire middle of the estuary.

Figure 13 1962 showing log booms across middle of estuary and one along the eastern shore.

Figure 14 Two views from 1968 showing log booms across the middle of the estuary.

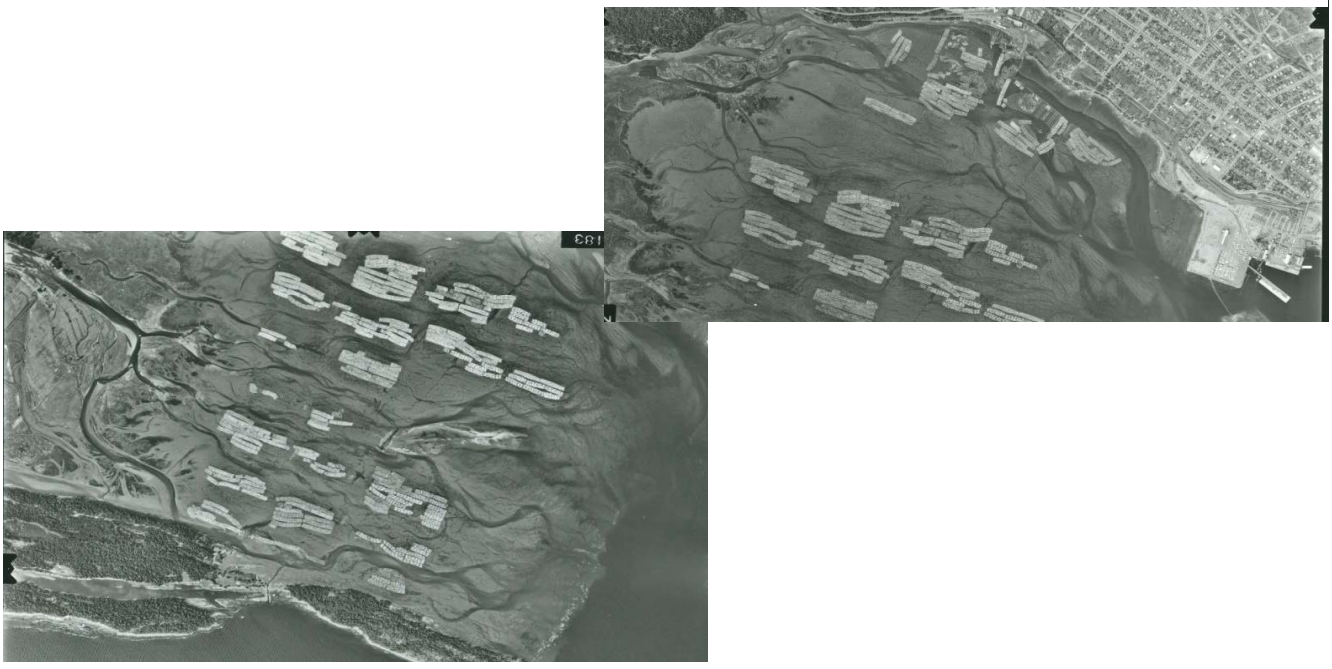


Figure 15 1976 showing the height of log booming in the estuary.

Figure 16 1980 showing a reduction in log booms on the east side.

Figure 17 1998 showing log booms restricted to the western half of the estuary.

Figure 18 2002 Google Earth image showing log booms restricted to western half of the estuary.

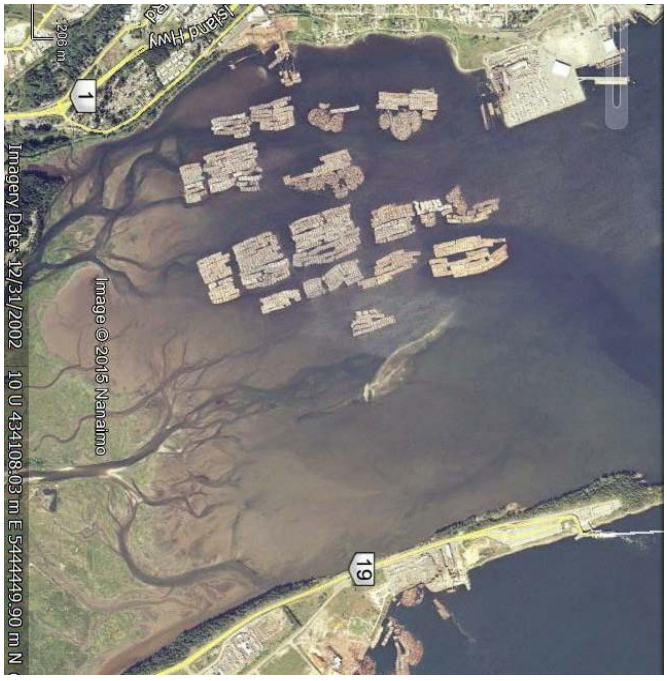
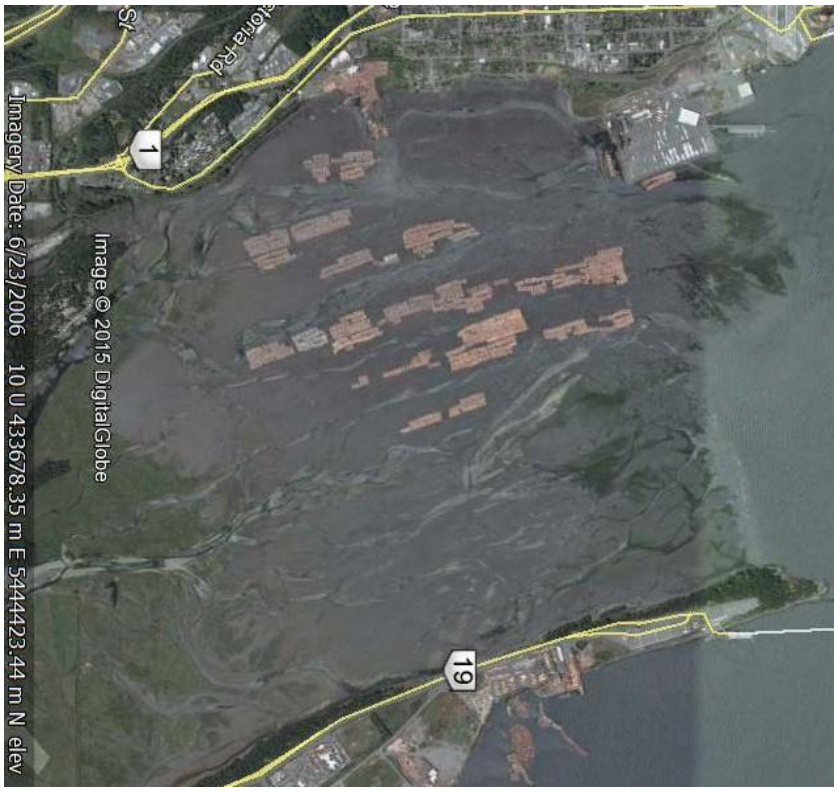


Figure 19 2006 Google Earth image at low tide. Eelgrass is visible at the low tide boundary.



Appendix C 2015 Aquaparian survey field data

AQUAPARIAN ENVIRONMENTAL CONSULTING LTD. NANAIMO ESTUARY EELGRASS SURVEY - OCT 29, 2015 METHOD: BOAT WITH DROP CAMERA, LOWRANCE SYSTEM, NORTHERN EXTENT OF EELGRASS GROWTH 10:55AM TO 1:30PM NORTHERN EXTENT SURVEY
Tide: elevation in meters, chart datum tide station Nanaimo #7917 Water: depth at way point from depth sounder

NORTH EDGE DATA				Water	Chart	
Way Pt #	Latidude	Longitude	Time	Depth (ft)	Tide (m)	Notes
1	N49 9.872	W123 53.762	10:55am	12.8	3.1	moderate to dense
2	N49 9.872	W123 53.842		15		moderate
3	N49 9.84	W123 53.842		15		sparse on edge
4	N49 9.833	W123 53.855		10		sparse on edge to continuous
5	N49 9.828	W123 53.92		13		patchy
6	N49 9.81	W123 53.928		8		sparse and patch on edge
7	N49 9.81	W123 53.966		10		patchy then moderate and continuous at 8ft deep
8	N49 9.812	W123 54		8		continuous
9	N49 9.807	W123 54.36		9		sparse and continuous
10	N49 9.799	W123 54.65		8.8		patchy and moderate
11	N49 9.802	W123 54.11		10		patchy
12	N49 9.752	W123 54.96		6		very dense along an abrupt line
13	N49 9.764	W123 54.191		8.3		patchy (1m2) along an abrupt edge
14	N49 9.744	W123 54.222	11:30am	7.2	2.9	patchy on edge to dense continuous
15	N49 9.723	W123 54.311		8		dense and continuous
16	N49 9.724	W123 54.36		10		patchy
17	N49 9.733	W123 54.395		18		**CANBOY - No elgrass**
18	N49 9.707	W123 54.365		7		dense along an abrupt edge
19	N49 9.683	W123 54.377		6.5		sparse and patchy
20	N49 9.656	W123 54.346		4.7		dense continuous along an abrupt edge
21	N49 9.653	W123 54.365		4		dense continuous along an abrupt edge
22	N49 9.648	W123 54.384		4.5		dense continuous along an abrupt edge
23	N49 9.637	W123 54.396		6.8		dense continuous , sunken logs
24	N49 9.666	W123 54.443		6.5		patchy
25	N49 9.669	W123 54.469		6.5		dense continuous along an abrupt edge
26	N49 9.678	W123 54.5		7.8		dense continuous
27	N49 9.694	W123 54.536		8.3		patchy on edge to dense continuous
28	N49 9.753	W123 54.612		13		sparse, logs and wood waste, mud
29	N49 9.768	W123 54.611		22		sparse, logs, wood waste mud
30	N49 9.794	W123 54.661		7		patchy
31	N49 9.869	W123 54.657		15		patchy along an abrupt edge, sand
32	N49 9.898	W123 54.678		10		dense continuous
33	N49 9.965	W123 54.744	12:00pm	11.3	2.7	moderate continuous
34	N49 9.953	W123 54.805		10		moderate continuous
35	N49 9.954	W123 54.879		8.3		moderate continuous
36	N49 9.948	W123 54.949		7.7		moderate continuous
37	N49 9.937	W123 55.11		13.3		moderate continuous
38	N49 9.908	W123 55.48		8.4		moderate continuous
39	N49 9.888	W123 55.117		9		moderate continuous
40	N49 9.874	W123 55.165		14		moderate continuous
41	N49 9.852	W123 55.2		8		patchy
42	N49 9.838	W123 55.221		10		patchy - by cruise ship terminal
43	N49 9.849	W123 55.23		14		abrupt drop off by cruise ship dolphins
44	N49 9.804	W123 55.254		10.8		moderate continuous patch
45	N49 9.795	W123 55.248		7.5		moderate continuous
46	N49 9.776	W123 55.308		7		moderate continuous
47	N49 9.777	W123 55.357		15		moderate continuous
48	N49 9.751	W123 55.395	12:35	8	2.6	moderate continuous - fronting NPA office - 50m off
49	N49 9.576	W123 55.267		9		dense all the way fronting riprap shoreline southward
50	N49 9.559	W123 55.29		5		dense continuous - transect about 20m from riprap
51	N49 9.53	W123 55.261		6		patchy - near corner of log dump

52	N49 9.446	W123 55.269		7		sparse patches near boom logs, sand, ulva
53	N49 9.42	W123 55.307		5.7		patchy, sparse
						No eelgrass fronting high sand bank near reserve
63	N49 9.877	W123 55.195				**Cruise Ship Terminal Dolphin End**

NANAIMO ESTUARY EELGRASS SURVEY - OCT 29, 2015

3:00PM-3:44PM TRANSECT SURVEY

	START POINT			END POINT				Water	Chart	
	WP#	Latitude	Longitude	WP#	Latitude	Longitude	Time	Depth (ft)	Tide (m)	Notes
T1	5	N49 9.828	W123 53.92	54	N49 9.767	W123 53.942	3:00pm	10	3.3	dense continuous
T2	10	N49 9.799	W123 54.65	55	N49 9.723	W123 54.48	3:04	8.8		moderate to dense continuous, open sand channel
T3	15	N49 9.723	W123 54.311	56	N49 9.637	W123 54.357	3:09	6.5		snad, sparse patchy to dense continuous
T4	23	N49 9.637	W123 54.396	57	N49 9.574	W123 54.363	3:13	6.3		dense continuous to moderate to dense
T5	25	N49 9.669	W123 54.469	58	N49 9.592	W123 54.446	3:18	9.1		dense continuous
T6	27	N49 9.694	W123 54.536	59	N49 9.62	W123 54.514	3:23	8.4		patchy to continuous, to dense continuous, sand patches
T7	28	N49 9.753	W123 54.612	60	N49 9.693	W123 54.786	3:28	10.6	3.6	sparse patchy to dense continuous with some scour
T8	33	N49 9.965	W123 54.744	61	N49 9.887	W123 54.815	3:36	11.5		moderate continuous to dense continuous
T9	40	N49 9.751	W123 55.395	62	N49 9.804	W123 55.117	3:44	9		dense continuous

Appendix D 2020 Aquaparian survey field data

July 2020: Nanaimo River Estuary Eelgrass Presence Survey Results - Aquaparian Environmental Consulting Ltd

Plot ID	Date	Time	UTM north	UTM east	Shoot Density	Vigour	Substrate	Depth (cm)	Distribution	Patch/Cont	Remarks
S1	July 20, 2020	1011	434838	5443442	4	p	m-s	8	v sparse	p	NE transplant
S2	July 20, 2020	1030	434793	5445342	72	g	m-s	2	sparse	p	scattered patches 3-5 m apart
S3	July 20, 2020	1056	434670	5445325	tmtc	g	s (coarse)	45	v dense	c	ext 100 m to N, about 25 m wide
S4	July 20, 2020	1121	434778	5445183	35-140	g	s (coarse)	20	dense	c	across from park 200m
S5	July 20, 2020	1137	434727	5444994	33-132	g	m-s	20	dense	p	ext 50 m to S
S6	July 20, 2020	1206	434270	5445115	272	g	m-s	20	v dense	p	patches 5-10 m2 ext 200m to S
S7	July 20, 2020	1210	434236	5445108	80 - 148	g	m-s-shell	6	v dense	p	ext 60m N &S each patch 150 m2
S8	July 20, 2020	1259	433596	5445308	24	g	s (coarse)	1	sparse	p	some Z. japonica in plot
S9	July 20, 2020	1305	433617	5445343	44 - 120	g	s (coarse)	5	med. dense	p	sm. patches 1-3 m apart. ext. 60 m
S10	July 20, 2020	1315	433656	5445399	112	g	s (coarse)	1	dense	c	10 m wide, ext 120 m to NE
S11	July 20, 2020	1330	433827	5445433	96	g	m-s	2	med. dense	c	West edge of lg patch
S12	July 20, 2020	1338	434093	5445371	120	g	m-s	6	dense	p	well-spaced patches ext 100 m to S
S13	July 20, 2020	1354	434179	5445329	96	g	m-s	7	med. dense	p	15m wide. ext for 150 m to N
S14	July 20, 2020	1405	434342	5445299	220	g	m-s	5	v dense	p	patches 1 -15 m2, ext 50 m to south
S15	July 22, 2020	1240	432844	5445470	nd	g	nd	40	med. dense	p	patch located east of fenced ind. yard
S16	July 22, 2020	1245	432893	5445453	nd	g	nd	100+	dense	c	South limit
S17	July 22, 2020	1250	432919	5445400	nd	g	nd	100+	dense	c	South limit
S18	July 22, 2020	1252	432926	5445397	nd	g	nd	100+	dense	c	South limit
S19	July 22, 2020	1311	432983	5445301	124	g	m-s-cobble	18	dense	p	2 patches 3-10 m apart, ext to N
S20	July 22, 2020	1330	432966	5445034	144	g	m-s	2	dense	c	south limit. 15 m wide & 200 m long to N
S21	July 22, 2020	1341	432983	5445301	100	g	m-s-cobble	0	dense		south limit. 15m to E & W
S22	July 22, 2020	1349	433144	5445415	48-148	vg	m-s	0	med dense	c	plants to 1.5 m high, continues to N
S23	July 22, 2020	1400	433346	5445417	116	g	m-s	5	dense	c	limit is 20 m to South
S24	July 22, 2020	1405	433385	5445457	132	g	m-s	7	dense	p	patches widely spaced , each 20m x 20m
S25	July 22, 2020	1411	433391	5445470	116	g	m-s	4	dense	p	patches widely spaced 2m x 40 m
S26	July 22, 2020	1415	433439	5445565	96	g	nd	7	med dense	p	N-S band west side of centre channel
S27	July 22, 2020	1436	432735	5445317	nd	p	nd	90	sparse	p	patch is 4 m x 10 m
S28	July 22, 2020	nd	435282	5444208	60	nd	m-s	100+	med. dense	p	2m x 5 m patches. East Main Channel southern extent