APPENDIX A
Shoreline Walk & History

3 Shoreline Walk - Geology, Ecology and History of West Vancouver Shoreline

3.1 Geography, Geology and Ecology of the West Vancouver Shoreline

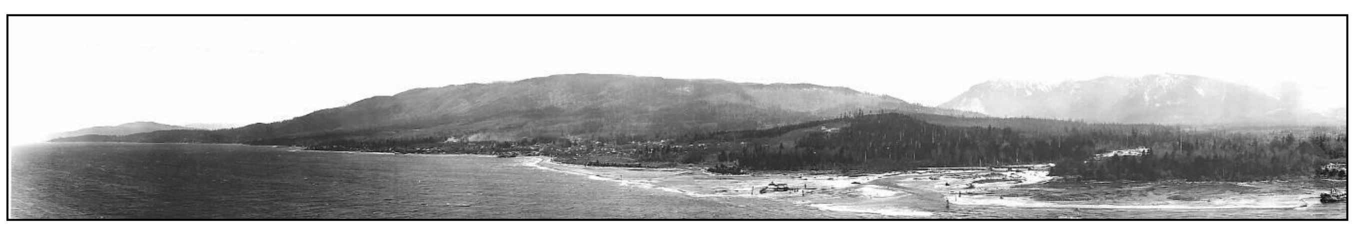
Situated on the north shore of Burrard Inlet's outer-harbour, the West Vancouver shoreline stretches 30 km between the Capilano River mouth and Point Atkinson lighthouse, and continues north into Howe Sound.

The characteristic granite of Cypress Mountain and the southern Coast Mountains provides solid bedrock, creating a steep, high-relief coastline. The natural upland terrain is primarily riparian vegetation and temperate rainforests, which extend from the shoreline to the peak of Cypress. A large amount of the upland forested area is provincial parkland. The urban and residential zone extends from the shoreline to the outer edge of Cypress Provincial Park which encompasses the Cypress Mountain group.

Aside from the Capilano River, which creates a natural border between the Districts of North and West Vancouver, there is an extensive network of creeks and streams which feed the shoreline. These watersheds range from over 13 km^2 to less than 2 km^2 providing vital habitat for wildlife including endemic and endangered plants, birds, amphibians, invertebrates and fishes. Most of the watersheds are important fish habitat, in particular spawning habitat for four species of salmon (cutthroat, coho, chum and pink) as well as trout. The watersheds also serve as key component of the sediment transport system, by supplying sediments to the coastline they help to maintain shoreline structures and habitats.

3.2 History of West Vancouver Shoreline

From its first discovery by European settlers in 1791, West Vancouver was recognized as a valuable asset because of its location and natural resources. Over the next 80 years development of West Vancouver saw exploitation of its natural resources with logging and extraction of sand and gravel from the Capilano River.



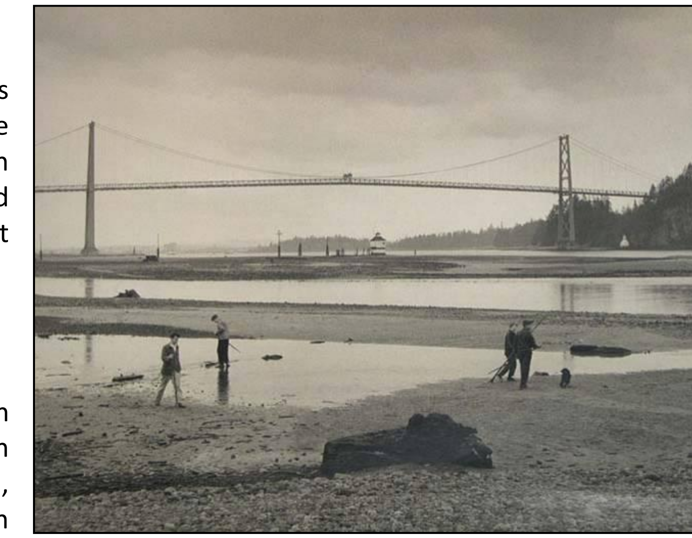
In the late 1800s European settlers began to arrive; the lack of access by land resulted in the new community being established primarily along the shoreline. Roads were created from Capilano to Eagle Harbour and construction first began on the Cleveland Dam. By the 1890s the population on the North Shore had grown to 300 and in 1891 the City of North Vancouver (which included West Vancouver), was established. The promise of new roads, and access to rich logging grounds and natural resources continued to draw residents.

West Vancouver became a Municipality in 1912 and development was rapid. Land was divided into parcels along the grid system which resulted in many steep roads and a subsequent propensity for flooding. The development of the West Vancouver shoreline also increased with the construction of piers and wharves to provide private access and public ferry services. In 1918 the newly formed West Vancouver council decided to obtain foreshore rights in an effort to gain control of the shoreline and in 1926 the council introduced laws and regulations to prevent the development of major industry in the area, ensuring that West Vancouver would remain a residential community.

With the opening of the Lions Gate Bridge to traffic in 1938, modern development of West Vancouver and its shoreline flourished and the population rose to over 8,000. In 1967 the Centennial Seawalk was opened to mark Canada's 100th anniversary. The population of West Vancouver now stands at over 40,000.

4 Shoreline Walk - Development, Coastal Dynamics and Threats to the West Vancouver Shoreline

4.1 Development and the Shoreline



The rapid development of West Vancouver has had serious consequences for the shoreline. Some of the most notable impacts have come from deforestation and urban development, the construction of Cleveland Dam and alteration of the Capilano River flow, and development along the shoreline itself.

4.1.1 Urbanization

Prior to development, West Vancouver was blanketed with primary temperate rainforest, the thick vegetation absorbed rainfall along the steep slopes. Deforestation, removal of vegetation, and replacement of soil with impermeable concrete, asphalt and roof tiles areas create problems with run-off; rainfall normally absorbed and slowed was channelled directly into storm drains, culverts and creeks.

During heavy rainfall events, typical of the area, run-off results in extremely high velocity water flows through storm drains which open directly onto the foreshore resulting in severe localized erosion of the shoreline profile. Furthermore, sediments from upland areas that should replenish the shoreline are now swept out to deep water by tides and currents, or are trapped along man-made topographic plateaus such as streets and the railway line and never reach the shore.

4.1.2 Cleveland Dam & Capilano River

The first attempt to dam the Capilano River occurred in the late 1800s and in 1950 Cleveland Dam was constructed. Prior to construction of the dam, the steep slopes of the hanging valley, the rapid descent of the river and high seasonal flows would have contributed a lot of sediment to the West Vancouver shoreline (WVSPS, 2006). Sand, sediments and gravel from the upper reaches of the Capilano River now settle in the reservoir basin and are not carried downstream. This reduction in available sediments is thought to be a major contributor to shoreline erosion.

4.1.3 Shoreline Development

There has been considerable physical development of the West Vancouver shoreline, including residential and commercial waterfront construction, the development of the Centennial Seawalk and the creation of piers, boat ramps and wharves. The development has resulted in the significant loss of riparian vegetation and the restructuring of creek flows, both of which have reduced sediment deposition on the shoreline contributing substantially to erosion.

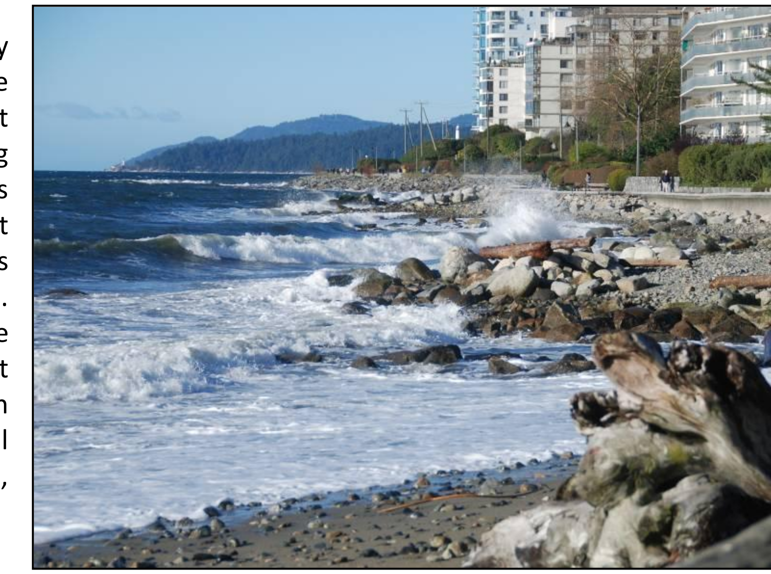
Although hard-faced sea walls can provide short term protection for shoreline developments they almost inevitably have a negative impact on geo-physical coastal processes such as sediment transport and wave dynamics, which in the long term serve to put the development at greater risk. These processes are outlined in the following sections.
In addition, many of the shoreline developments, including buildings on the foreshore and the Centennial Seawalk itself serve to disconnect the public from the shoreline by limiting access. Walking along the waterfront is not akin to experiencing the shoreline.

4.2 Coastal Dynamics and Shoreline Erosion

A natural shoreline is managed, maintained and slowly altered through a range of complex geophysical and oceanographic processes including the ebb and flow of tides, wave actions and long-shore drift, which move sediments along the shoreline. When the flow of the sediments to the shoreline is reduced or wave energy increases these processes can become out of balance, resulting in the loss of shoreline.

Waves are the primary mode of sediment transport along the shore, as they reach the upper shore they collect sand, silt and gravel and redistribute them as they recede. Under natural circumstances, as waves approach the shore they are slowed by the long slope of the beach. By reducing the energy of the wave as it travels inshore, the suction load of the wave (the capacity of the wave to carry sediments as it ebbs) is greatly reduced and the sediments are trapped on the beach. During storms and high-water events waves may not be slowed by the incline of the beach and physical structures such as rocky reefs, sand dunes, breakwaters or sea walls are needed to stop or slow waves.

Along a developed shoreline such as West Vancouver, sand dunes and rocky cliffs have been replaced with hard-faced concrete sea walls to protect developments. Instead of absorbing or dissipating wave energy and suction load, hard-faced structures reflect waves back down the shore. The deflected waves, aided by gravity, carry more sediment as they travel down the sloping shore to deeper waters. As this process continues and more sediment is lost from the upper shore, the beach loses its natural slope and no longer slows waves as they approach. The waves reach the concrete sea wall with greater force and are therefore deflected with even more energy, and so the cycle escalates. Eventually waves may erode the beach to a point where the structure of the sea wall itself is undermined and no longer able to effectively protect the shoreline.



The West Vancouver shoreline is particularly vulnerable to longshore drift, which occurs because the waves approach the shore from the Strait of Georgia at an oblique angle. Waves typically move laterally along the beach from west to east, carrying fine sediments along the shoreline until they reach a structure that blocks their path causing them to settle or until there is no more shoreline and they drift to deeper waters. Rocks, groynes, piers and wharves can create a stable toe along the shoreline, interrupting long-shore drift and trapping sediments thereby preventing beach erosion upstream. However, a misplaced structure will cut off sediment supply to the rest of the beach, causing erosion downstream.

In an environment where the sediment supply is greatly reduced and the shoreline is heavily developed these processes of wave-generated erosion, longshore drift and interruption of sediment transport can threaten the physical and ecological integrity of the entire shoreline. These issues may be amplified by the effects of climate change. By returning the shoreline to its natural state, the very same coastal processes can be used to rebuild and maintain the shoreline naturally, in a manner that will adjust to future environmental changes accordingly while supporting healthy coastal and marine ecosystems.

4.3 Climate Change and Sea Level Rise

There is a broad consensus between scientists and world governments that climate change, and the associated effect on sea levels and global weather patterns, poses a real and serious threat. Rising sea levels are the result of melting glaciers and ice caps, as well as changes in ocean temperature and salinity. During the 20th century, global sea levels rose by 15-20 cm (B.C. Ministry of Environment, 2007); predicted sea level rise for the Greater Vancouver district over the next 100 years ranges from less than 0. 2m as the extreme low estimate to more than 1 m as the extreme high estimate (Bornold, 2008). Many climate scientists believe that the current United Nations International Panel on Climate Change (IPCC) estimate of 20 -60 cm global rise in sea level by 2100 is too conservative (Thomson, et al, 2008).

Climate change has serious consequences for oceans and coasts. The effects of climate change will include the following (adapted from Thomson, et al, 2008);

- Rising sea levels from glacial melt will be amplified by the associated alterations in ocean temperature and salinity. These changes in temperature and salinity will also affect ocean circulation and productivity.
- Changes in ocean circulation and the associated oceanic currents which drive global weather systems will result in increasing frequency and severity of extreme weather events.
- Rapid glacial melt and high intensity rainfall will cause changes of river flow, in particular more frequent high-volume events.
- Rising sea levels, increasing sea temperatures and changes in seasonal events will have impacts on ecosystems and species in terms of habitat loss, food availability and timing of seasonal migrations.

Although West Vancouver has a high-relief rocky shoreline and is therefore less vulnerable than low-lying, subsiding regions, it is still at risk. The likely impacts of climate change on the West Vancouver shoreline include:

- Rising sea levels resulting in loss of shoreline, with potential impacts to waterfront developments such as residential and commercial property, parks and the Seawalk.
- Increased frequency and severity of storms and high water events along the coast with resulting damage to waterfront property and infrastructure.
- Increased frequency and severity of high intensity rainfall events causing changes of river flow and flooding.
- Impacts to ecosystems and species, for example changes in the timing and falling success rates of herring and salmon spawning runs, and the loss of surf smelt spawning habitat. Spawning events are integral to the survival of many species.

The problem of rising sea levels combines with increasing severe weather events such as seasonal storms, cyclical weather systems such as the El Nino Southern Oscillation (ENSO) and environmental effects such as atmospheric pressure and winds. Sea level rises up to 0.4 m caused by El Niño have been recorded in the Pacific Northwest, and since 1976 ENSO events have become more frequent and more severe, amplified by oceanic warming (Bornhold, 2008). Storm surges driven by winds have been recorded up to 1m (B.C. Ministry of Environment, 2007) and severe storm events are growing with frequency with major storms recorded in 2001, 2003, 2005, 2006 and 2007 (Heap, 2007).

With sea levels continuing to rise and severe weather events increasing in frequency and intensity, the restoration of the West Vancouver shoreline is a pressing issue. Vulnerable areas of the shoreline have experienced significant damage during major storm events so far. The narrowing of the shoreline, creation of hard-faced sea walls and loss of habitat have all contributed to making the West Vancouver waterfront more vulnerable to erosion, flooding and storm damage. These effects are likely to continue if restorative measures are not taken.

5 Shoreline Walk - SPP Projects 2008-2011

5.1 Ambleside Beach - Capilano & Totem Groyne

Refer to drawings 5321-D-01.1 & 5321-D-02.1 in Appendix B, Appendix C and the detailed project profiles in Appendix E.

In 1965, in response to erosion at Ambleside Recreational beach, sand and cobble were removed from the mouth of the Capilano River and used to nourish the upper shore. Two rock groynes were constructed in 1987 in a further attempt to preserve the beach, however continued gradual erosion at the site warranted a detailed review of the structures and the local coastal processes. In their 2005 assessment, the EAC noted that the toe of the groynes extended only to the low water level, providing little protection to the lower shore. The pilot project to enhance the shoreline protection and habitat features was first conceived in 2006, with work beginning in 2007. As per the suggestions of the EAC, the design involved the placement of rock at the nose of the breakwater to create intertidal and subtidal enhancement features and a stable toe.

At Capilano Groyne (see drawing 5321-D-01.1) boulders were positioned at the end of the existing toe, lengthening the groyne and creating a more gradual slope. Extending the groyne in this manner stabilized lower shore sediments and the partially buried boulders also acted as wave trips. The subtidal boulders provided a stable surface on which kelp, other algae and invertebrates could grow, creating valuable fish habitat and a dynamic, biological coastal defence system. At Totem Groyne (see drawing 5321-D-02.1), large boulders were used to create a 1 m high subtidal algae wall to extend the toe of the groyne, encourage near-shore sediment transport and provide optimal conditions for algae growth and critical fish habitat.

Key Successes

- Creation of inter- and sub-tidal habitat for kelp, invertebrates and fishes.
- Creation of a stable tidal pool adjacent to Capilano groyne.
- Stabilization of lower and upper shore.
- Use of reclaimed materials.

5.2 Ambleside Pier

Refer to drawing 5321-D-03.1 in Appendix B, Appendix C and the detailed project profile in Appendix E.

Ambleside Pier and boat ramps are popular public amenities. Immediately west of Ambleside Pier is a sloping beach with a significant coverage of fine sediments in comparison with the shoreline further west. Ambleside landing and the surrounding area was rejuvenated in the early 1990s with a provincial grant, the works involved the development of the sport-fishing pier, landing, boat ramp and upland amenities.

Long-shore drift has caused the continued deposition of sand and cobble on the 'overfull' beach on the west side of Ambleside Pier, the sediments leaked from the tip of the beach and filled the embayment to the east, but were too fine to form a stable beach below the armour rock. Chronic infilling impeded safe public access to the boat ramp and float.

To stabilize fine sediments on the upper shore rocks were reclaimed from the existing riprap wall and positioned in the low intertidal and subtidal zone creating a drift sill. The rocks also provided stable habitat for kelp, algae invertebrates and fishes. Some rocks were repositioned around the Vinson Creek outflow to optimize freshwater input to the mussel beds.

Two subtidal reefs were constructed just west of Ambleside Pier. The reefs provide stable substrate for kelp, algae and a wide range of invertebrates and fishes.

In 2009, access to the boat ramp and float was restored by removing the sand and cobble infill. The material was used to construct new habitats along the upper shore between 15th Street and Lawson Pier (see following sections). In addition to this, the riprap wall between the boat ramp and float access was reconstructed to create a habitat bench for colonization by riparian plants.

Key Successes

- Creation of subtidal habitats for kelp, invertebrates and fishes.
- Stabilization of the lower and upper shore by creation of a subtidal drift sill.
- Restore public access to the boat ramp and float.
- Creation of habitat bench for riparian vegetation.
- Reduction of riprap sea wall.
- Use of reclaimed materials.

5.3 15th Street

Refer to drawing 5321-D-04.1 in Appendix B, Appendix C and the project profile in Appendix E.

A significant stretch shoreline between Ambleside Pier and Lawson Pier was fronted by concrete sea walls and private residence. The hard-faced sea defences at the back of the beach had contributed to wave driven erosion. Public access to the beach was greatly impeded by private property and a narrowing shoreline. Lawson Pier (see Section 5.4) obstructed the transport of sediments from the west and existing sediments were carried east to Ambleside Pier. Two broken concrete culverts surfaced mid shore, creating an unsightly physical obstruction on the mid-shore.

Private properties along the sea front were purchased by DWV for the purposes of waterfront regeneration. Public access across the site was greatly improved by the removal of concrete sea wall sections and construction of a naturalized footpath along the upper shore between 15th street and Lawson Pier. The pathway was protected by logs and large boulders; salt marsh habitat was created alongside to provide additional protection, stabilization of sediments and creation of valuable natural habitat. Reclaimed sand and cobble from the dredging of Ambleside boat ramp was used in the enhancements and to nourish the upper shore.

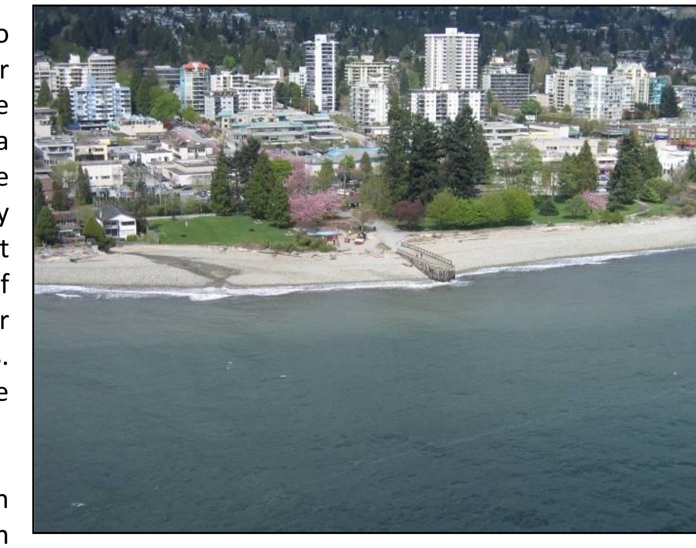
The concrete culverts were removed and replaced by boulders to reduce scouring and dissipate the fresh water flow across the mussel beds. The boulders also acted as mid-shore wave trips to prevent waves from reaching the remaining hard-faced sea walls. Patches of intertidal habitat boulders were positioned along the lower shore to act as tombolos, interfering with long-shore drift and trapping sediments along the mid shore.

Key Successes

- Creation of public footpath and improved public access to the foreshore.
- Creation of valuable upper shore salt marsh habitat.
- Replacement of concrete culverts with naturalized freshwater outflow onto mid shore.
- Improvement of intertidal habitat with habitat boulders and mussel beds.
- Creation of wave trips and tombolos to prevent erosion and promote sediment retention.
- Use of reclaimed materials.

5.4 Lawson Pier

Refer to drawing 5321-D-05.1 in Appendix B, Appendix C and the project profile in Appendix E.



Lawson Pier was built more than 100 years ago to provide the shortest access from land to deep water (EAC, 2005), just off from the nose of the pier the seabed drops to 60ft. The pier was constructed as a solid pile-wall structure; sediments to the west of the pier were blocked and carried out to deep water by waves, instead of continuing east. The beach to the east of Lawson Pier was maintained by the limited input of sediments which were able to 'leak' through the pier structure under moderate sea and weather conditions. During severe storms, sediments to the west would be eroded cutting the supply.

With the construction of the new gravel footpath stretching from 15th Street to 18th Street, salt marsh habitat was created along the upper shore to stabilize fine sediments, protect the footpath and improve the biological and aesthetic value. Large boulders and logs along the upper shore provided additional wave protection and stabilization of fine sediments. The footpath provided safe pedestrian access across the shoreline and to the children`s play area, replacing the street detour which had connected Lawson Creek and the western stretch of the Seawalk to Ambleside.

Sediment transport, from west to east, was improved by removing a number of the piles located around the perimeter of the pier. The 'opening'of the pier allowed material to pass through rather than around the off-shore end. The beach to the west of the pier was 'perched' using cobble and boulders to elevate the shoreline and provide greater protection from waves during storm events. Habitat boulders were partially buried at the nose of Lawson Pier as wave trips, to reduce the impact of storm events on the pier structure while providing critical, stable habitat for algae and marine invertebrates.

A subtidal reef was created on the east side of Lawson Pier to create stable habitat for kelp, invertebrates and fishes. A survey of the reef conducted in 2010 identified 15 species that had colonized the reef structure including bull kelp (see table 6, Section 2).

Key Successes

- Creation of safe public footpath and improved public access to the foreshore and Seawalk.
- Creation of valuable upper shore salt marsh habitat.
- Improvement of intertidal habitat with habitat boulders.
- Creation of wave trips and tombolos to prevent erosion and promote sediment retention.
- Promotion of sediment transport across the site.
- Use of reclaimed materials.

5.5 Lawson Creek

Refer to drawing 5321-D-06.1 in Appendix B, Appendix C and the project profile in Appendix E.

Bordered on either side by residences, Lawson Creek was boxed in by hard-faced concrete sea walls. The creek outflow fed onto a low profile beach, during rain events high velocity flows caused considerable scour along the channel and beach. The sediments transported in the creek were carried out to sea with little retention on the upper shore. The low-profile cobble and pebble beach offered little natural resistance to waves and the lack of stable substrate resulted in diminished intertidal habitat for invertebrates and algae.

The hard-faced concrete sea walls were replaced with an elevated upper shore, irregular riprap sea defences and high value salt marsh habitat. A new trail was created along the upper shore providing access from John Lawson Park to the foreshore and across the site. A footbridge was constructed across the creek in 2008, providing safe access across the creek and protecting the creek from disturbance with support from the Lanskail Fund.

The creek channel was stabilized with large riprap and which directed the flow laterally along the shore to promote the retention of sediments for beach nourishment. Logs and boulders were carefully placed to create riffle pools and shelter for fish, providing ideal habitat. Large boulders were dug in to the lower intertidal zone as wave trips to protect the upper shore and provide large stable attachment points for algae, and marine invertebrates.

In the year following the enhancements, the West Vancouver Pacific Streamkeepers Society caught and tagged 42 salmon in Lawson Creek (see Section 1). Although a 2008 survey of the site deemed Lawson Creek unsuitable habitat for surf smelt spawning, a 2010 smelt spawning study found eggs in the sediments that have since accumulated along the mid and upper shore. Surf smelt is an important food source for many species including salmon.

Key Successes
- Increase in spawning salmon and surf smelt populations at Lawson Creek
- Improved public access across site and to foreshore.
- Creation of log footbridge for safe access across creek and preservation of fish habitat.
- Public information signage about salmon and enhancement works to create awareness.
- Thriving salt marsh enhancement.
- Retention of fine sediments on upper shore.
- Creation of intertidal habitat for invertebrates and algae.
- Improvement of shoreline defences with elevated profile and wave trips.
- Use of reclaimed materials.

5.6 18th Street

Refer to drawing 5321-D-07.1 in Appendix B, Appendix C and the project profile in Appendix E.

A hard-faced concrete sea wall fronted the centennial Seawalk along the upper foreshore between Lawson Creek and McDonald Creek. The low profile cobble beach offered little natural resistance to waves and wave erosion posed a threat to the shoreline and structural integrity of the sea wall. The low profile beach and sea walk restricted access to the beach to two points. Small pockets of dune grass and salt marsh grew on isolated patches of upper shore with little room for available expansion.

Large habitat boulders were strategically positioned along the lower and mid- intertidal to create valuable habitat for algae and marine invertebrates along an otherwise unstable shoreline. The boulders were partially buried to act as wave trips, preventing waves from striking the concrete sea wall and reducing anthropogenic wave erosion. To improve the upper shore habitat the existing riprap was re-worked to increase the salt marsh habitat bench, allowing the dune grass patches to spread naturally. This salt marsh habitat was initially focused around the seating areas to create aesthetically and ecologically valuable habitat pockets, to increase public access to the foreshore and encourage public engagement with the shoreline.

In 2011, the DWV obtained a large amount of native rock from a construction project in the British Properties. The boulders were used to construct additional shoreline protection features. Following successful establishment of the dunegrass bench, some of the newly obtained boulders were used to extend the easterly dunegrass bench the full length of the sea wall. The bench was planted with dunegrass, beach pea, western dock and sea lupine to create high value riparian habitat to further increase biodiversity and aesthetic value at the site, while replacing the hard-faced sea wall with soft shoreline protection.

Key Successes
- Improved wave protection for upper shore.
- Creation of upper shore salt marsh and high value riparian habitat.
- Improved public access to the foreshore.
- Use of reclaimed materials.

5.7 McDonald Creek & Bypass

Refer to drawing 5321-D-08.1 in Appendix B, Appendix C and the project profile in Appendix E.

Like Lawson Creek, McDonald Creek and bypass are the primary sources of sediments to the foreshore west of the Capilano River. However, with the urbanization of West Vancouver much of the riparian watershed was removed and the creek was redirected through culverts. The creek and bypass outflows were directed on to the mid shore through a box culvert, and high velocity flows caused significant scouring of the beach. The hard-faced sea wall was covered with large riprap, which prevented safe access from the Seawalk to the foreshore. A lack of stable material along the foreshore provided little habitat for algae or invertebrates.

Surplus rock was taken from the riprap wall along the upper shore, and used to create habitat features and structure the creek and bypass flows. The creek was re-directed laterally across the shoreline to promote the retention of sand and gravel along the upper and mid shore. Following the shoreline enhancement works, a single heavy rainfall event in 2007 produced 100 truckloads of sediments which were retained on the upper shore and naturally distributed along the beach to Lawson Pier

The relocated boulders also served as wave trips, breaking waves along the lower shore to protect sediments along the upper shore. They also provided large, stable attachment points for rockweed, sea lettuce, barnacles, mussels and other marine species, improving the biodiversity of the site. Signage was created above the creek outflow which, along with a colourful art installation created by local school children, created a point of interest to engage the public with the natural environment and raise awareness of the importance of protecting fish habitat.

Key Successes

- Improved creek flow to encourage sediment retention on upper shore.
- 100 truckloads of sediments trapped on the upper shore in a single rainfall event.
- Creation of intertidal habitat boulders.
- Improvement of wave defences.
- Creation of environmental interpretation to engage the public with the environment.

5.8 Navvy Jack Point

Refer to drawing 5321-D-09.1 in Appendix B, Appendix C and the project profile in Appendix E.

For many years, Navvy Jack Point has been recognized as having a critical role in "defining and limiting" long-shore drift along the West Vancouver shoreline (EAC, 2005). Subtidal and intertidal surveys of the site conducted in preparation for the pilot projects recorded the presence of kelp and eelgrass, both of which are vulnerable keystone species and important habitat features.

The works at Navvy Jack Point were designed to create intertidal and subtidal habitat, trap near-shore sediments and create a stable toe at the site. The works conducted in 2008 were forced to be scaled back due to a lack of suitable rock, the pilot projects were designed so that they could be successfully adapted to the resources available.

The enhancement features installed at Navvy Jack Point increased the productive capacity of the site by strategically positioning boulders to provide suitable hard substrates for colonization by kelp, to create valuable fish habitat and stabilize fine sediments to protect eelgrass. The subtidal reef also created a stable toe, securing sediments along the shoreline to the west of the point, and provided wave protection for the sea wall. Because of the existing biodiversity the goal was to create features that would easily blend into the existing shoreline.

The boulders were placed to create a drift sill running perpendicular to the shoreline. The drift sill extends from the lower intertidal to the subtidal zone, creating habitat suitable for a wide range of species with differing requirements. Surveys conducted several months later found that the habitat feature had quickly become amalgamated into the existing habitat and exhibited 95% barnacle and mussel coverage, in addition to algal growth.

Due to its role as a linchpin feature of the West Vancouver shoreline, future works are planned at Navvy Jack Point and adjacent sites, including the completion of the initial design. These projects are outlined in Section 4.

Key Successes

- 95% coverage by mussels and barnacles in addition to algae within several months.
- Creation of a habitat feature specifically designed to benefit kelp and eelgrass.
- Improvement of wave defences.
- Creation of a stable toe to stabilize sediments along the shoreline.

5.9 27th Street

Refer to drawings 5321-D-10.1, 5147-D-01.1 and 5151-D-01.1 in Appendix B, Appendix C and the project profile in Appendix E.

Shoreline enhancement works at the 27th Street foreshore were another private-public partnership. The foreshore had experienced considerable erosion leaving a low profile cobble shoreline. A sub-surface culvert outflow onto the foreshore contributed to beach erosion along the mid shore and the concrete sea walls of the private residences fronting the shoreline had amplified wave erosion. A construction project at the site provided an opportunity to improve and restore the shoreline by replacing the hard-faced concrete sea walls with a more naturally protective, irregular shoreline and significantly improving the natural habitat and biodiversity.

The sub-surface culvert was 'day-lighted' which allowed the design of a creek bed and high value habitat feature. The channel was elevated and logs and boulders were used to create riffle pools which stepped the stream down to the foreshore. The creek was channelled into an S-shape to reduce the flow rate and promote the retention of sediments on the upper shore. The existing invasive vegetation was removed and native riparian habitat was planted along the banks of the stream and the upper shore. The steep footpath to the shore was replaced with a snaking trail, which followed the curve of the new stream to create a gentle gradient. The salt marsh habitat and stream were protected from pedestrian traffic by a wooden split rail fence and seating was added at the edge of the pathway.

The upper shoreline was elevated and the riparian habitat bench was extended in front of the properties neighbouring the creek. Large riprap and anchored logs were strategically positioned to protect the salt marsh, upper shore and property from waves. Drift sills and tombolas were constructed along the mid-shore to guide and trap sediments along the upper shore. Wave trips along the mid- and lower shore provided improved protection from wave erosion and impacts while providing stable substrate for colonization by algae and invertebrates. A subtidal reef (see 5147-D-01.1 and 5151-D-01.1) was created to provide stable substrate for nearby kelp beds, creating fish habitat and improving shoreline defences.

Key Successes
- Expansion of SPP into private sector.
- Establishment of a bench mark for new shoreline development projects.
- Creation of new riparian habitat.
- Creation of subtidal kelp reef and valuable fish habitat.
- Improvement of public access to the shoreline and aesthetic value of the site.
- Replacement of concrete sea walls with soft shoreline protection measures.
- Improvement of wave defences on lower and mid shore.
- Removal of invasive vegetation.

5.10 28th Street and Rodgers Creek

Refer to drawings 5266-D-01.1 to 3.1, 5147-D-01.1 and 5151-D-01.1 in Appendix B and photos in Appendix C.

The re-development of 2854 Bellevue Avenue created an opportunity for privately funded shoreline restoration work along the intertidal zone and upper shore and at the Rodgers Creek outflow. The creek is recognized as potential salmon habitat although no spawning salmon have been observed in the creek since 2006, despite fry releases in the late 1990's and 2000. The Pacific Stream Keepers Association (PSKA) considered channelization of the creek and its effect upon the flow rate as one of the major concerns (PSKA, 2009). The shoreline had experienced significant erosion, and primarily consisted of unstable cobble substrate with some mussel and green algae coverage; hard-faced sea walls along the upper shore had amplified wave erosion and the loss of fine sediments was evident in undercutting along the sea wall at 2854 Bellevue.

The property owners at 2854 and 2860 Bellevue Avenue funded restoration works to replace the hard faced sea wall with soft shoreline protection measures along the upper and lower shore, and in front of Rodgers Creek. Specially placed boulders and large woody debris were positioned in front of the sea walls of the three properties west of Rogers Creek. By creating wave trips and elevating the upper shore they disrupt wave energy and preventing overtopping of the sea wall and erosion. Native riparian vegetation will be planted between the wave trips and the sea wall where there is sufficient space. Large boulders were placed along the lower shore to create an intertidal reef, providing additional wave protection as well as increased habitat for algae, invertebrates and fish.

At the mouth of Rodgers Creek large boulders were positioned along the lower intertidal zone and backfilled with cobble to create an elevated berm. The berm will improve wave defenses, provide stable substrate for colonization by algae and invertebrates, and disseminate fresh water flow over an increased area of the intertidal zone support algae and invertebrate populations. The feature will also prevent channelization at the creek outflow, creating a staging pool for spawning salmon, improving accessibility of the creek.

A subtidal reef was created between 27th Street and 28th Street to provide stable habitat for kelp and fishes, surveys of the reef conducted in 2010 found abundant bull kelp across the reef (see table 5 in Section 2).

Key Successes
- Establishment of privately funded project.
- Replacement of hard faced sea wall with soft shoreline protection.
- Creation of riparian and salt marsh habitat.
- Strategic placement of stable substrate to create intertidal habitat for algae and invertebrates.
- Stabilization of creek outflow and improvement of fish habitat.
- Use of natural and reclaimed materials.

5.11 Ferndale

Refer to drawing 5321-D-11.1 in Appendix B, Appendix C and the project profile in Appendix E.

The shoreline enhancement works at Ferndale were the first expansion of the SPP beyond the pilot projects, into the private sector. The project, initiated in 2008, embodies the evolution and potential of the SPP. Located adjacent to the DFO Centre for Aquaculture and Environmental Research, the stretch of coastline is known to be important fish habitat.

The existing shoreline was bordered by the private residences of Ferndale Avenue and Evergreen Avenue; concrete sea walls constructed to protect the properties contributed to wave erosion. The erosion had exposed the sewer system infrastructure at the site making it vulnerable to damage. The beach was low profile and primarily cobble, with few fine sediments; a small patch supported by dune grass existed along the upper shore to the east of the site, but was vulnerable to erosion. The lower intertidal and subtidal zone had some coverage by barnacles, muscles, rockweed and green algae however a lack of large substrates reduced habitat available to broad-leaf algae and fish.

The old sewer pipe and manhole had become compromised due to beach erosion and wave impacts, the pipe and manhole were replaced. An elevated berm was created along the mid shore in front of 4270 Evergreen Avenue to trap and retain fine sediments on the upper shore. The berm was constructed using reclaimed materials, natural beach cobble and logs which were securely anchored. The seaward edge of the berm was lined with large riprap boulders for stability, to create improved wave protection for the upper shore, and to create stable lower intertidal habitat for algae, invertebrates and fish. The berm was designed to be constructed in four phases expanding eastwards along the mid-shore, with each extension blending into the previous, eventually running the extent of the concrete sea walls.

Additional large boulders were partially buried along the upper shore. In front of the sea wall, to stabilize fine sediments and provide improved wave protection by ‘tripping’ waves and diffusing wave energy before they meet the sea wall. Post-construction surveys have recorded increased sediment retention on the upper shore and almost complete coverage of the intertidal habitat boulders by invertebrates and algae.

Key Successes

- Expansion of SPP into private sector and beyond the geographical scope of the pilot projects.
- Development of a bench mark environmental standard for private developments.
- Creation of elevated berm to retain fine sediments on upper shore.
- Creation of intertidal fish habitat.

5.12 Seaside Place

Refer to drawing 5321-D-12.1 in Appendix B, Appendix C and the project profile in Appendix E.

The shoreline enhancement and protection works at Seaside Place were also privately funded. The shoreline forms a natural south-east facing embayment, encircled by steep granite bedrock cliffs. The three inner properties have concrete sea walls which had amplified wave erosion leaving a low profile shoreline that became jammed with logs and debris.

While much of the woody debris was removed from the beach, larger stumps and logs were retained on the upper shore for their habitat value. The upper shore was then covered with a mix of fine sediment and soil to elevate the beach. This new habitat was planted with dune grass to establish a natural salt marsh, increasing the biodiversity and ecological value of the site, providing safe access and an improved public amenity, and securing fine sediments. Large riprap was used to create raised berms and drift sills along the mid-shore to provide maximum protection for the upper shore during the first storm season, allowing the salt marsh to become established.

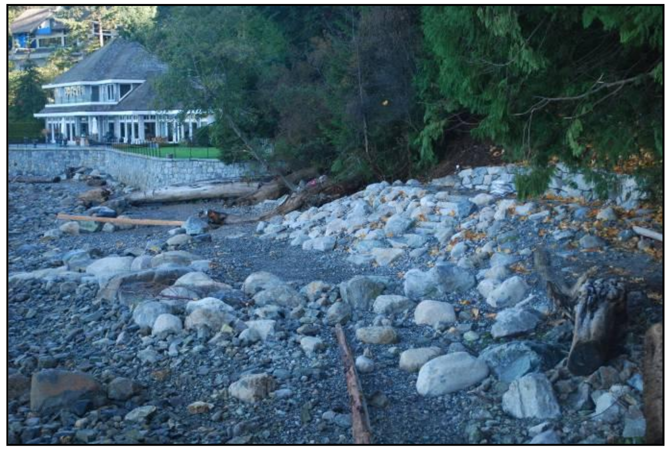
After the first winter season the upper shore features were adjusted. The salt marsh was further elevated, extended towards the mid-shore and planted with Nootka rose and ocean spray to increase the biodiversity. The riprap drift sill and berm were dismantled; the rock was placed along the mid shore and covered with cobble to increase the beach profile. Large boulders were partially buried along the lower shore as wave trips and to create valuable subtidal habitat for fish, algae and invertebrates.

Key Successes

- Establishment of privately funded project.
- Creation of salt marsh and riparian habitat, improving ecological and aesthetic value.
- Elevation of upper shore to improve retention of sediments.
- Improvement of safe access to upper shore.
- Creation of valuable sub- and intertidal fish habitat.
- Use of natural and reclaimed materials.

5.13 Nelson Avenue

Refer to drawing 5346-D-02.1 in Appendix B, and photographs in Appendix C.



The shoreline protection works and public beach access enhancements were privately funded. The shoreline at Nelson Avenue is west-facing encountering high energy wave activity from the south west and swells from daily ferry activities. The low profile shoreline was composed of small riprap and cobble that provided little resistance to wave activity, and became jammed with logs and debris.

Woody debris was removed or repositioned to improve public access across the beach. Boulders were strategically positioned to disrupt waves before they reached the upper shoreline, which was further protected and elevated by large boulders and cobble. Dune grass was planted around the boulders to stabilize fine sediments, create a natural transition between the shoreline and the riparian zone, and to create valuable habitat.

After the first winter season the features were adjusted. Boulders were repositioned to further encourage the deposition of sediments, deflect woody debris and provide protection to the upper shoreline habitat.

Key Successes

- Improvement of public beach access and safe access to the upper shore.
- Elevation of upper shore to improve the retention of sediments.
- Replacement of small riprap with stable boulders as protection features.
- Use of natural and reclaimed materials.

5.14 Horseshoe Bay

Refer to drawing 5321-D-13.1 in Appendix B, Appendix C and the project profile in Appendix E.

The shoreline enhancement works at Horseshoe Bay represented the first corporate partnership stemming from the SPP and pilot projects. The works were conducted as mitigation and compensation for works at the BC Ferries Terminal. The shoreline at Horseshoe Bay is a popular public amenity with a sandy beach, marina and busy ferry terminal.

Works were initiated to reduce the impacts of propeller wash from the launching and berthing of ferries at the terminal. To mitigate the effects of propeller wash a rock berm was constructed alongside the ferry terminal to support the existing wave deflector and prevent the propeller wash from reaching the shore. The rock berm provides large stable substrate from +5m to below -1m chart datum, providing suitable habitat for a wide range of species from kelp to sea birds. Post-construction surveys recorded the presence of kelp and lingcod, as well as this giant red dendronotid nudibranch pictured below.

Fine sediments were used to rebuild the upper shore and increase the beach profile and a series of nine semi-circular berms were constructed along the mid shore to stabilize the upper shore and trap new sediments. The berms were filled with cobble, with larger boulders positioned around the edge to reduce wave impacts on the upper shore and provide intertidal habitat for various species. Partially buried boulders were placed along the lower shore to protect the upper shore from waves and create additional attachment opportunities for invertebrates and algae. Boulders were used to reduce the flow rate of the culvert outlet on the beach to reduce scouring and to disseminate fresh water across the intertidal zone. A kayak access point was constructed on the foreshore and the area of infill in the marine was dredged to create safe boat access to the moorage facilities.

Key Successes

- Reduction of wave and propeller-wash erosion of shoreline.
- Restoration of natural upper shoreline.
- Creation of valuable intertidal and subtidal fish habitat.
- Improvement of public amenities including kayak and boat access and sandy beach.
- Creation of soft shoreline protection.