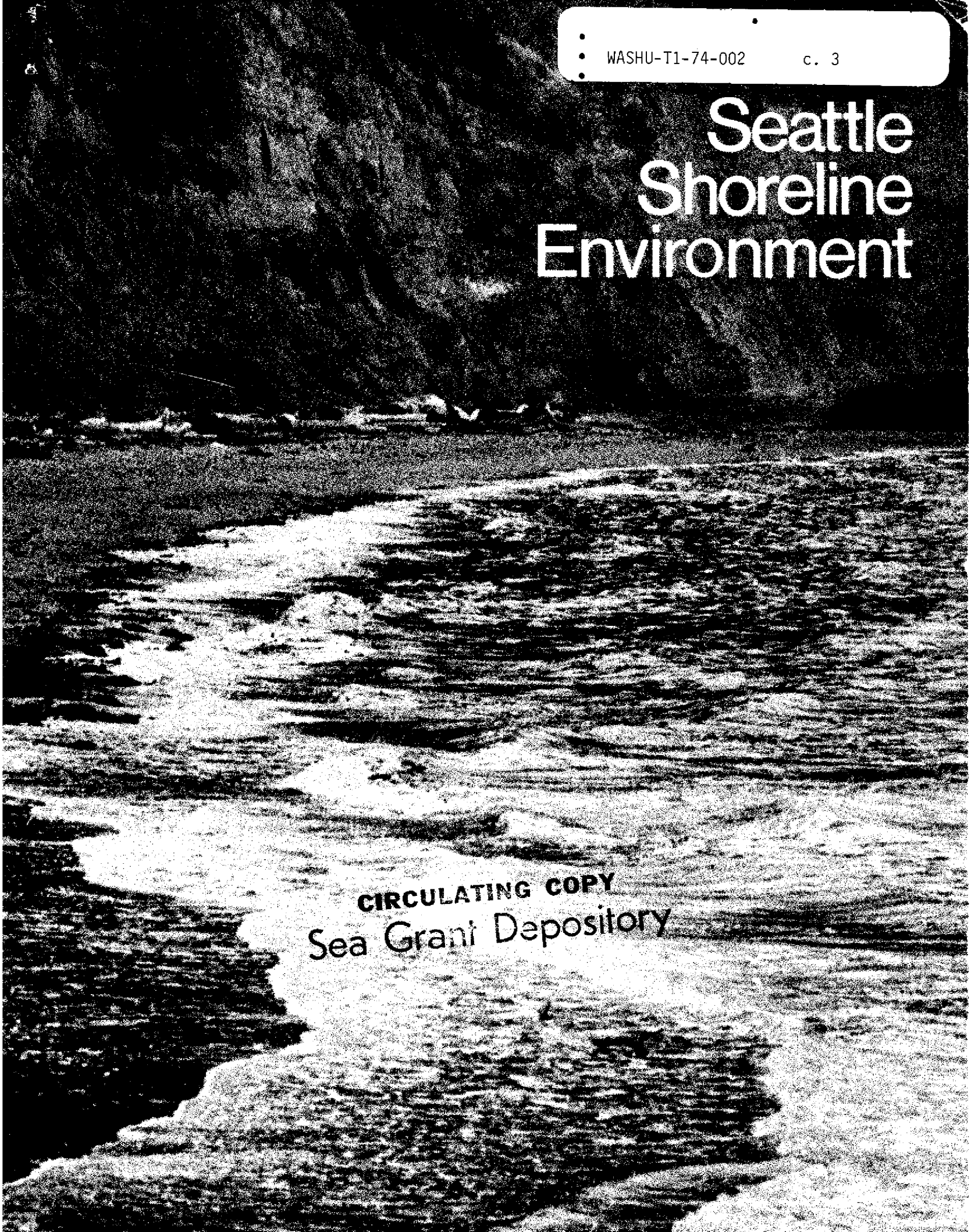
Seattle Shoreline Environment



Seattle Shoreline Environment

by Randall McGreevy

City of Seattle
Department of Community Development
and
Washington Sea Grant Program

Mayor
Wes Uhlman

City Council
George Benson
Bruce Chapman
Tim Hill
Phyllis Lamphere
Wayne Larkin
John Miller
Randy Revelle
Sam Smith
Jeanette Williams

Department of Community Development
Director . . . . . James Braman
Office of Environmental Management
Director . . . . . Robert Hintz
Contributing Staff . . . . . Mike Bonoff
Tony Puma
Dave Sucher
Graphics . . . . . Claudia Denney
Terry Good
Dawn L. Whitworth
Photographer . . . . . Terry Good

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Individuals

Wolf Bauer
Ray Buckley
Kenneth Chew
Joe Creager
James Crutchfield
Allan DeLacy
John Dermody
W. T. Edmondson
Victoria Elledge
Karen Gibbon
Larry Hanson
C. L. Hitchcock
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Robert Matsuda
Bruce Miller
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Robert Paine
Dennis Paulson
Ronald Phillips
Douglas Sheppard
Lynwood Smith
R. O. Sylvester
Frieda Taub
Percy Washington
Edward Wenk
Richard Whitney
Hazel Wolfe
Richard Wydoski

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Introduction

This booklet* is dedicated toward better identification and deeper appreciation of Seattle shoreline environment. We believe only an informed citizenry and government can effectively manage Seattle shorelines.

Geographically, the scope is focused on that part of the Seattle shoreline** that is under the jurisdiction of the Washington Shoreline Management Act. This does not mean, however, that the areas immediately outside this jurisdiction will be ignored. In the water and under it, as on land and in the air, the significance of a given element is largely determined by its relationships with many other elements; this interaction often involves elements outside the jurisdiction of the Washington Shoreline Management Act.

Because of complex and dynamic natural systems, certain natural phenomena are not clearly defined spatially and are best identified by means of a descriptive analysis. The series of descriptive analyses will act as a summary of relevant information from more detailed referenced sources. Information which lends itself to presentation in graphic form will be complementary to the text.

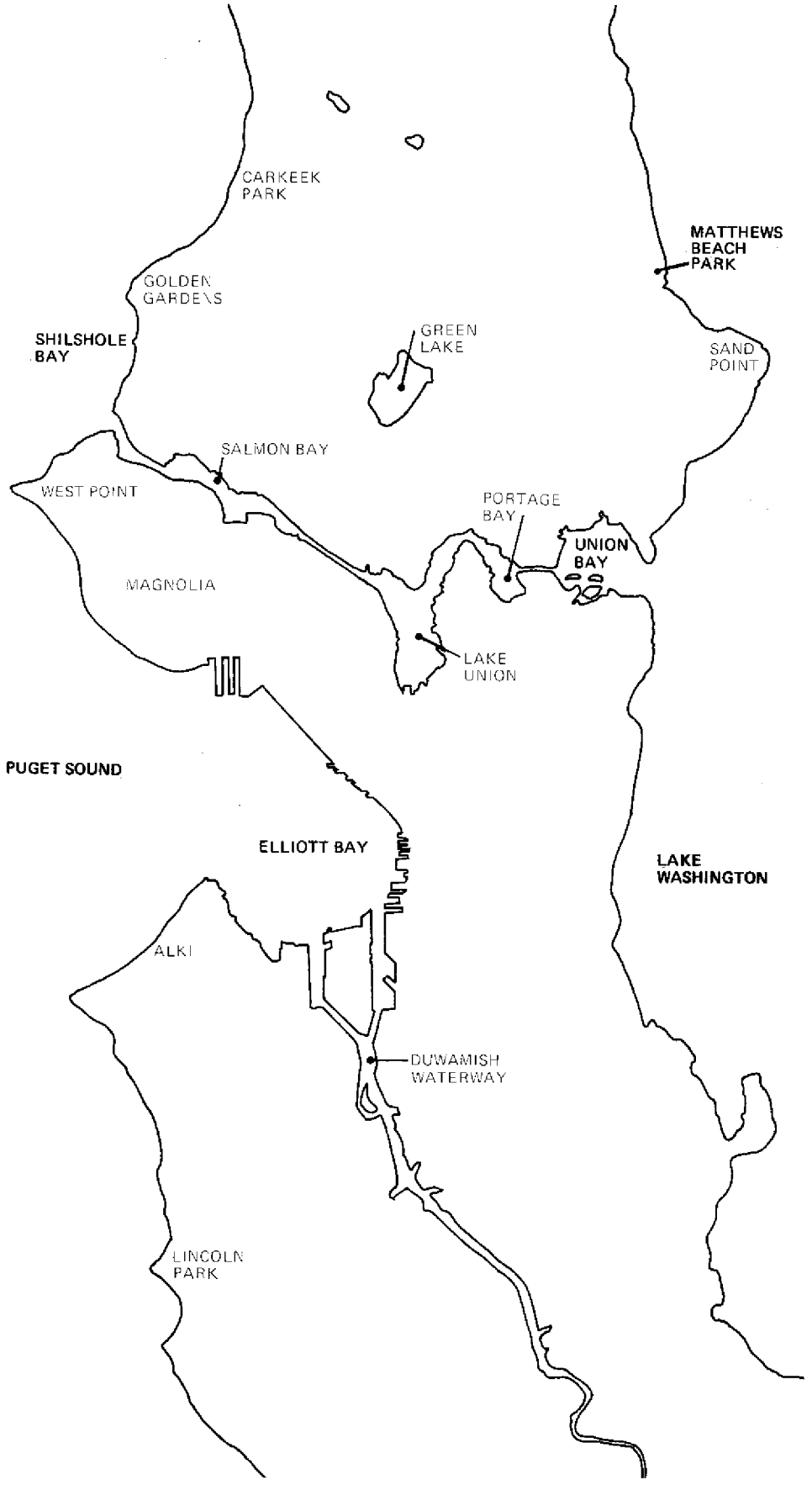
*The Seattle Shoreline Environment Booklet is a supplement to the earlier Seattle Shoreline Inventory published by the Office of Environmental Management in compliance with the Washington State Shoreline Management Act of 1971.

**Shoreline — means all the water areas of the city including:

1) Land extending for 200 feet in all directions from the ordinary high water mark of the water areas;

2) Submerged lands underlying water areas extending to the next jurisdiction boundary line (e.g. King County–Kitsap County line in the middle of Puget Sound.)

The shoreline area excludes segments of smaller streams (upstream of a point where the mean annual flow is 20 cubic feet per second or less) and smaller lakes less than 20 acres in size.



Major Alterations to the Seattle Shoreline Environment

What is now a modified and channelized waterway was once a free flowing river, meandering back and forth across its flood plain.

What is now an airfield was once an extensive mud-lake rich in wild and aquatic life.

What is now downtown Seattle and Harbor Island was once a large tidal flat daily submerged by high tides and exposed by low tides.

What is now a sanitary land fill covered with a parking lot, football stadium and other buildings was once a large marsh fed by the once free flowing Ravenna Creek.

What is now a ship canal and ship lock was once a delicate estuary environment between freshwater flows and tidal influences.

What is now a riprap shore and breakwater was once a natural marine beach.

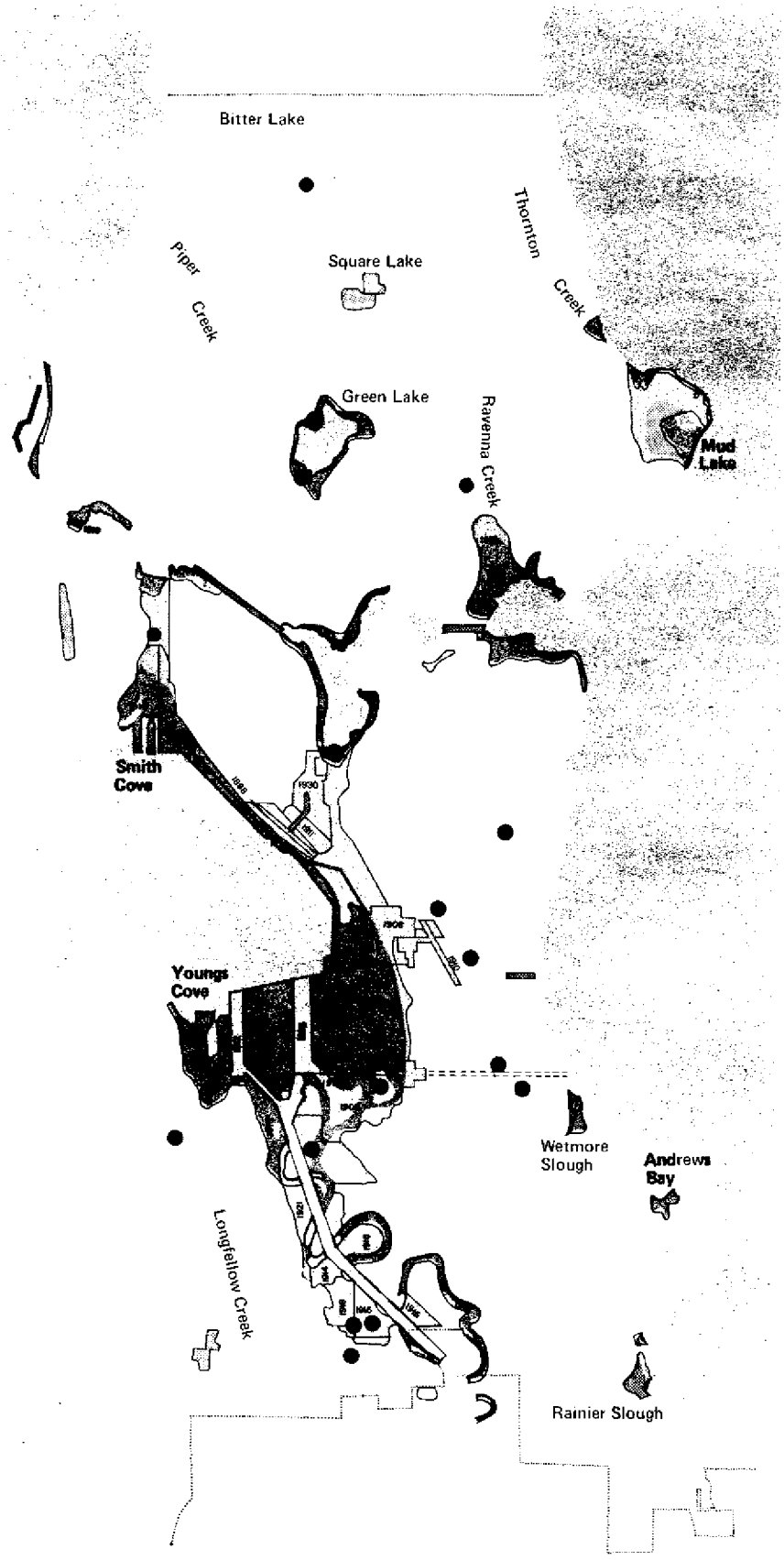
What were other estuaries, marshes, tidal flats, bogs, free-flowing creeks or natural beaches are no more.

Seattle, with its great metropolitan population and inherent forces of urbanization, has painfully imposed high and many times irreversible costs of arbitrary and irresponsible uses upon shoreline environments. The alterations have changed the character and nature of our shorelines.

Admittedly, the numerous alterations have helped enable Seattle's urban pouplation to grow and have not been totally without benefits. For example, the 1916 ship canal cuts provided a biological and navigational passageway between Lake Washington and Puget Sound. Industrial activity thrives on Lake Union, Seattle is the recreational boating capital of the world, and the largest sockeye salmon run known in Puget Sound is facilitated by the ship canal.

However, many other alterations have only served to destroy valuable natural shoreline resources. Fortunately, the dynamic resiliency of shoreline eco-systems has enabled most (but not all) shoreline resources to survive.

Seattle's altered shorelines are still ecologically abundant and diverse and will continue to be if sincere consideration is given to essential ecological requirements.


Bitter Lake
Piper Creek
Square Lake
Thornton Creek
Green Lake
Ravenna Creek
Mud Lake
Smith Cove
Youngs Cove
Wetmore Slough
Andrews Bay
Longfellow Creek
Rainier Slough
NORTH
Major Sanitary Land Fill Sites
Fills
Major Regrade
Cut and Tunnels

Puget Sound

Puget Sound is a unique resource. As an arm of the Pacific Ocean, it is the deepest and largest saltwater basin of the western United States, exclusive of Alaska (surface area - 767 square nautical miles). Its waters are productive; both shallow and deeper areas contain abundant flora and fauna. The Puget Sound shoreline is about 1,350 miles long, which is roughly equal to the rest of the western U. S. coast. Seattle possesses over 24 miles of that saltwater shoreline with the following features typical of Puget Sound:

A) Great Depths and Steep Slopes:

Along most of the Puget Sound shores, the bottom drops off sharply a short distance from shore to an average depth of about 600 feet. This is also true of much of Seattle's marine shoreline. Puget Sound's greatest depth, about 950 feet, occurs off northern Seattle.

B) Narrow Beaches:

Common in Puget Sound, including the Seattle shorelines, are the narrow beaches below bluff areas. Occasionally, there are also somewhat wider beaches adjacent to areas of lower relief. The beaches, in either case, generally consist of coarse sand or a mixture of sand and small gravel.

C) Bluffs:

The upland bluffs of Puget Sound are commonly quite precipitous and tend to have slide areas. Within Seattle, such bluffs are found in the Magnolia and West Seattle areas.

The high, nearly vertical bluffs not only limit development but also influence the shore erosional processes.

D) Sandy Points:

The seesaw action of waves, winds, and tides have created a common Puget Sound characteristic found also in Seattle – the sandy triangular point.

Meadow Point at Golden Gardens is an example of a constructional sandy shore produced by wind, wave and tidal action. Before man's alterations, Meadow Point had most likely reached a dynamic equilibrium.

However, the construction of the railroad right-of-way and the breakwater of Shilshole Marina undoubtedly altered the flow of water around Meadow Point and must have cut off supplies of sediment that had previously been available for constructing the point.

Meadow Point appears at present to be experiencing a net loss of sediment above the high tide line and unless some positive action is taken, its long-term existence is threatened.

E) Tidelands:

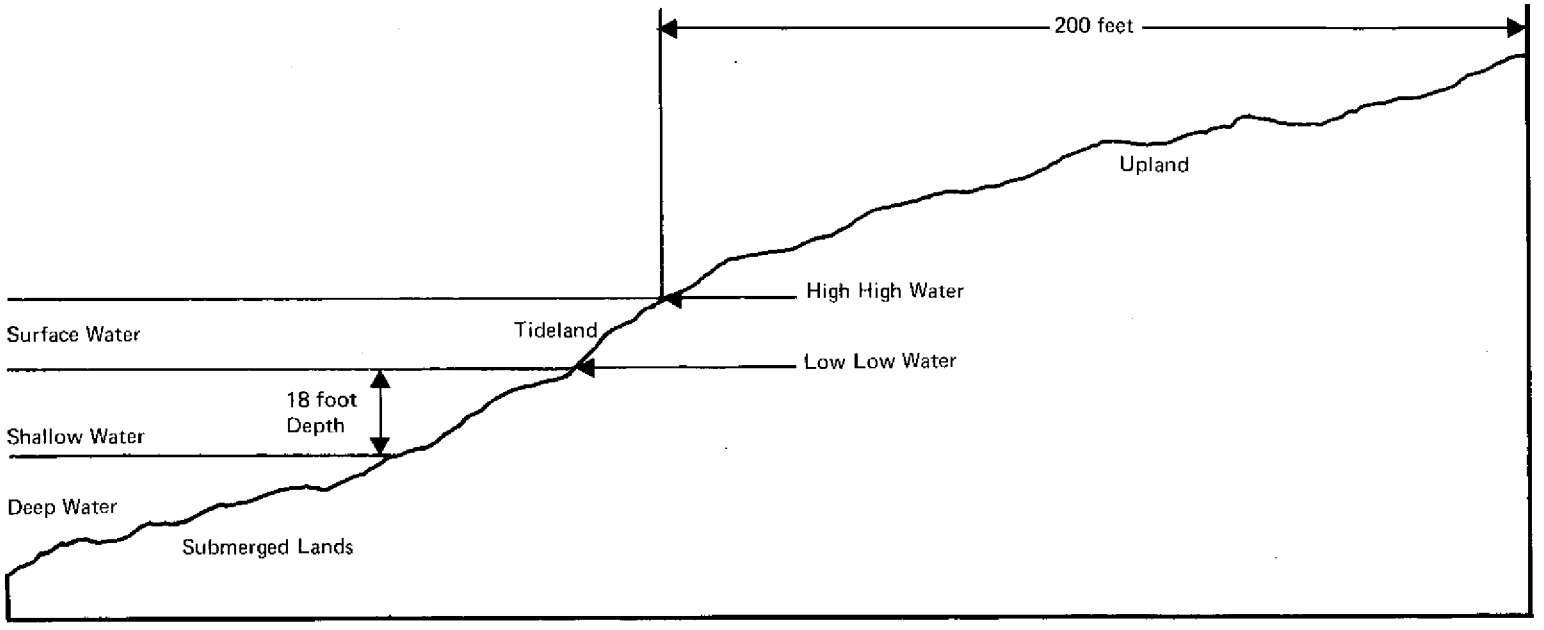
Twice a day, a strip of beach is exposed to the air then covered by water. The biological activity of such environments is related to the underlying substrate, whether mud, gravel, sand or rock. Often tidelands provide shelves that anchor offshore kelp beds or seaweed; the aquatic plants, in turn, provide the photosynthetic feeding station complex that serves to support a variety of marine life from seal to worm. The average daily tidal range at Seattle is 11.3 feet with maximum range during spring tides of 16 feet. The entire 24 mile Seattle coastline and sections of the Duwamish River are affected daily by the tides, with large areas of shoreline being exposed at low tides, such as the extensive tideland area at the South Beach of Westpoint.

F) Rivers & Streams:

Flowing into Puget Sound from the surrounding hills and mountains are numerous streams and rivers. The estuaries which they create are very important natural environments because they are feeding grounds for waterfowl and transition zones for migrating fish. Furthermore, their sediment load has, after thousands of years, built up deltas. In the glacier-formed Puget Sound landscape, these deltas are extremely valuable as industrial or agricultural tracts because of their large size, slight elevation and close proximity to water. Seattle's delta environment is located where the Duwamish River enters Puget Sound.

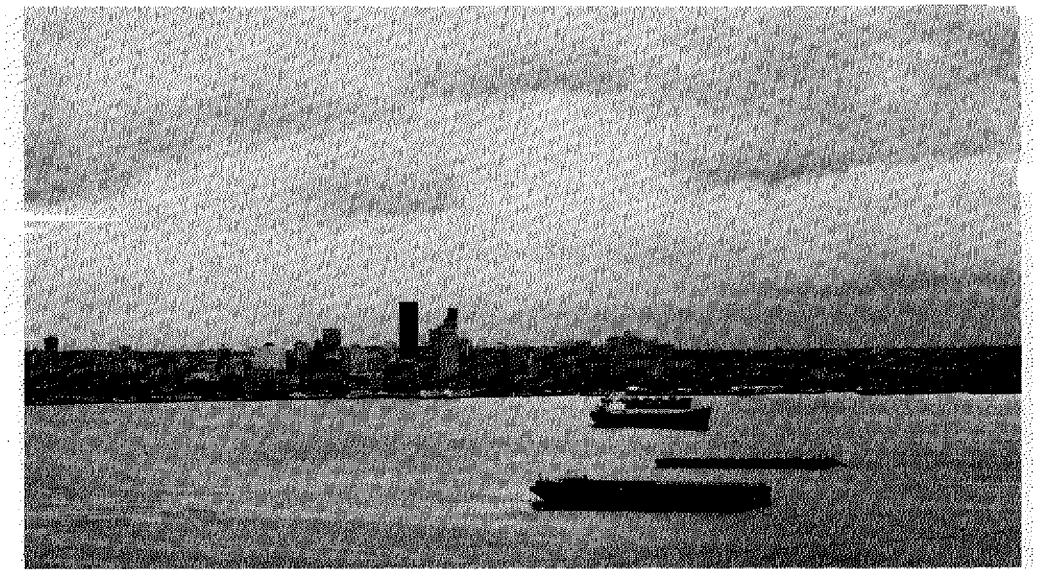
The above conditions provide environments for a great diversity of organisms to develop. The specific shore related habitats are characterized below:

1. Upland shoreline – above the high high tide mark.
2. Tideland – Between high and low low water tide mark.
3. Surface, shallow and deep water areas – waters away from the tidelands.
4. Submerged shoreline – underwater land below the low tide mark



Elliott Bay

Sheltered from the southwestern storm waves, this deep-water basin has a water circulation pattern that results from the interaction of tides, winds, and a freshwater layer over the denser saltwater in Elliott Bay. Prevailing winter winds tend to retain the freshwater surface layer against the waterfront. Eventual mixing of fresh and saltwater is primarily the result of the daily ebb and flow of tides. Elliott Bay is a "critical area" since it is a transition zone (either as a short migration zone or as an extended feeding zone) between marine and freshwater for adult and juvenile chinook, coho, and chum salmon, steelhead, searun cutthroat and searun Dolly Varden trout, threespine stickleback, and surfsmelt. If conditions are unsuitable, such as poor water quality or low river flow, the mortality and predation rate for the migrating species can substantially increase.



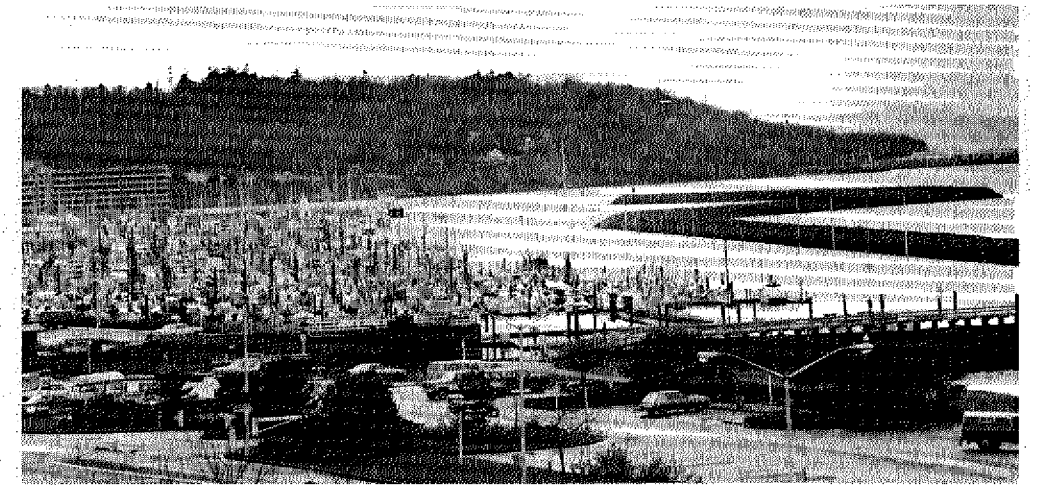
The protected harbor of Elliott Bay.

One hundred eleven varieties of fish are known to exist in Elliott Bay. The more common are perch, flounder, herring, rockfish, black cod, dogfish and hake, as well as the salmon and trout species. The Elliott Bay area also includes many interesting and valuable marine invertebrates; spot shrimp, Dungeness crab, octupus, heart urchin, starfish are examples. Marine mammals, notably harbor seals and killer whales, are occasional visitors. The waterfowl and shore birdlife is plentiful, in season, especially in the southern bay area near the mouth of the Duwamish.

Shilshole Bay

This bay serves as the transition zone between Puget Sound and the Lake Washington drainage basin. Thus, it is equally important as a navigational waterway and as a biological area. Shilshole Bay is critical for migratory fish species of the Lake Washington drainage basin and it supports many of the marine species that populate the Seattle area. Shilshole Bay is also a resting and feeding area for migratory waterbirds.

One of the finest and largest small-boat harbors along the entire West Coast is located at Shilshole. The Port of Seattle and the Army Corps of Engineers created the necessary bulkheads and breakwaters and put in parking, moorage, utility, and boat launching, facilities for over 1,600 pleasure and fishing craft.



Shilshole Marina and breakwater.

The rock breakwater (20 feet high and 4,440 feet long) protects the basin and has provided a haven for reef-loving organisms. The breakwater was completed in 1961, and shortly thereafter lingcod, cabezon, octopus, sea perch and rockfish assumed residence. Along with these rock-associated species, other fish were utilizing the newly created diverse environments immediately off the breakwater. Flounders and sole of various species moved onto the sand flats. The kelp beds which grew up along part of the breakwater created habitat for brown and copper rockfish, greenlings, and other species requiring this type of cover.

Presently, because of the human access problem, this productive area is being utilized only by a small number of scuba divers and a small number of boat fishermen. Due to the ever increasing pressure to satisfy the large number of metropolitan shore fishermen who do not own boats, the Washington State Department of Fisheries has proposed that a public fishing pier be placed atop the breakwater. With access being provided to the area by public transit and a floating shuttle system to and from the breakwater, this very feasible structure would not only provide inexpensive, interesting and productive shore fishing, but also would provide a public recreation facility for photography, sightseeing, boat watching, and waterbird study.

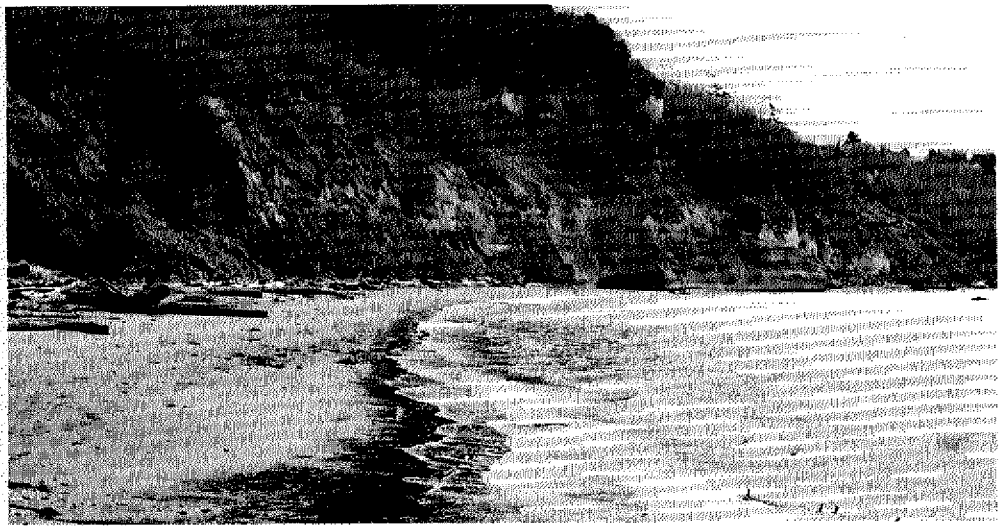
Marine Waterfront Parks

Westpoint (Discovery Park) — The area is blessed with unique, fragile and diverse biological and geological features.

Steep bluffs (250 feet above the South Beach and 150 feet above the North Beach) expose layers of the earth which tell the story of the area's geological history. Above these bluffs the land rises with small ravines and plateaus to a vista of 360 feet above sea level. The bluffs are the meeting place of geological formations which are prone to sliding and evidence of slides abound along the bluffs.

Botanically, the large Westpoint area is diverse. (Discovery Park alone is nearly 400 acres.) From ornamental and exotic landscaping on the plateau, the bluffs fall down to dense stands of second growth Douglas Fir, Western Red Cedar, Maple, Alder, Pacific Dogwood and others.

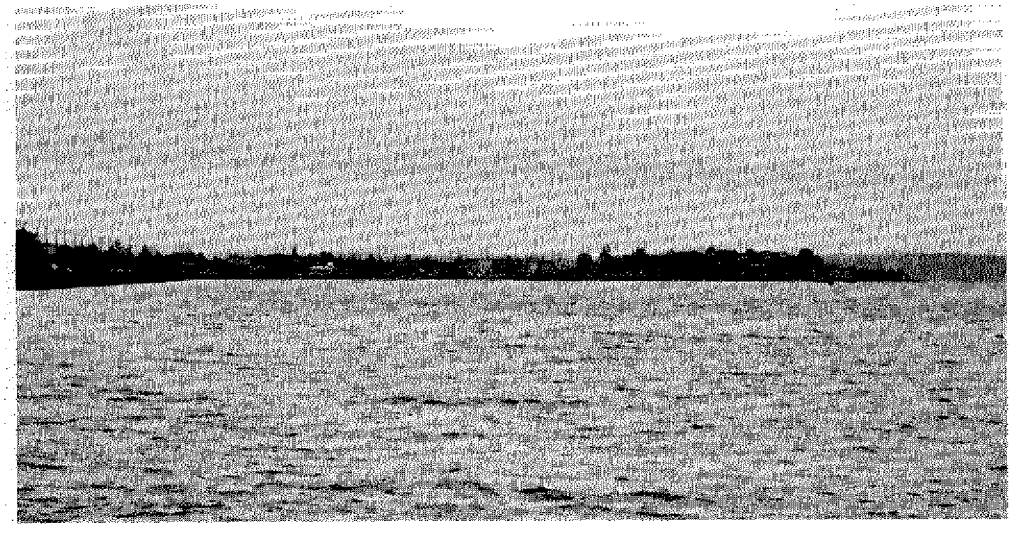
The tidelands are the area's most unique habitat. The South Beach is a very broad shelf which varies from pure sand to sand gravel to mud. The North Beach is narrower at low tides and is largely sandy gravel and cobble with a few large boulders.



The bluff above Westpoint's South Beach.

Wind and wave action are major determinants of the beach life, which on the beach and immediately off-shore, includes, hardshell clams (butter, littleneck and manila), geoducks, Dungeness crabs, rock crabs, hairy cancer crabs, ghost shrimp, sea anemones, starfish, segmented and ribbon worms, sand dollars, limpets, barnacles, red algae, brown algae (bull kelp) and green algae (sea lettuce). These and many other plant and animal forms ultimately attract diverse fish species to the area.

Alki Beach Park (79 acres) — Its sandy-gravel to rocky beaches provide diverse substrates for marine organisms and are within easy access to the public. The marine waters immediately offshore support flora and fauna in abundance. The most important known offshore resources at Alki are the extensive eel grass beds which are highly attractive to other marine organisms, ultimately making possible the commercial herring fishing, boat and shore sport fishing and underwater diving activities located off Alki Beach.



The productive offshore waters of Alki.

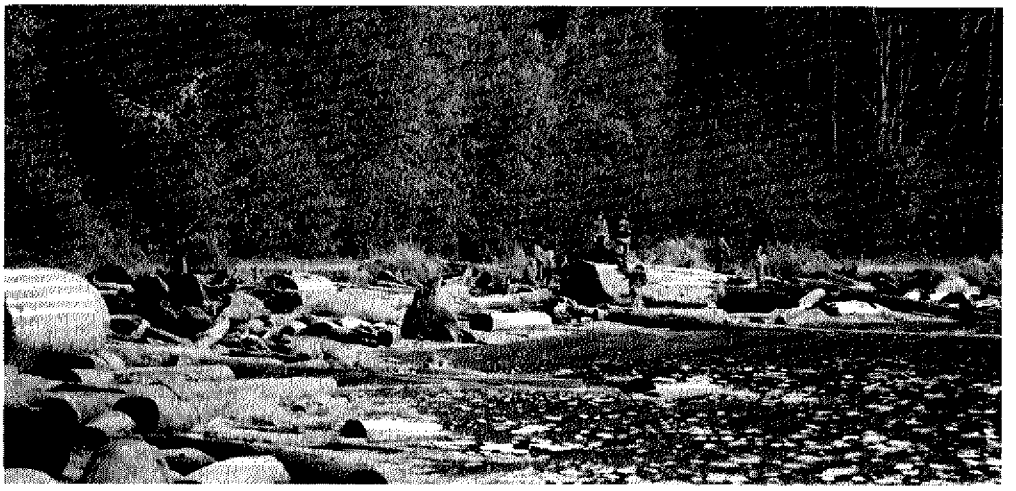
Golden Gardens Park (76 acres) — Its sandy-gravel beaches also attract people and marine organisms. The offshore area supports a kelp bed, shellfish communities, juvenile bottom fish, and various other adult fish species which are sought by the intensive sport and commercial fishing occuring off the area. The Golden Gardens shoreline is utilized heavily, in addition to its recreational activities, as an advanced scientific and elementary educational area.

Golden Garden's sandy gravel beach.

Carkeek Park (192 acres) — The subtidal beach of Carkeek Park supports a small eel grass bed and is an important nursing area for juvenile bottom fish (flounders, sole, etc.). Piper Creek, which flows out onto Carkeek Beach, is impassable to salmon migration upstream. Nonetheless, the creek is reported to support resident trout, cottids, and other stream-dwelling fish species. The undeveloped thick stands of upland trees and shrubs enable diverse and abundant wildlife and bird populations to flourish.

Piper Creek as it flows onto Carkeek Beach.

Lincoln Park (107 acres) — Relatively isolated from urban population centers, Lincoln Park has (as well as Carkeek Park) abundant upland vegetation and it provides the essential food and cover for various animal and bird species. The wildlife is limited to smaller animals that have adjusted well to nearby human pressures (squirrels, rabbits, raccoons, mice, etc.) The bird life in these areas can theoretically include any migratory or resident species known to be found in Seattle; however, because it is a waterfront park, water-associated bird species are most common (see page 34). Eel grass abounds off Lincoln Park and the marine life of the park's tidelands and subtidal lands support numerous fish and shellfish species.



Lincoln Park's natural shore area.

Lake Washington

Lake Washington has a surface area of 22,138 acres with an average depth of 108 feet and a maximum depth of 210 feet. The primary water source is the Cedar River with the secondary water source being outflow of Lake Sammamish through the Sammamish Slough. The lake drains through the Lake Washington Ship Canal, into the Chittenden Locks, and then into Puget Sound. The Ship Canal and locks were completed in 1916 and resulted in lowering Lake Washington's water level by 10 feet. Lake Washington, the Ship Canal, and Lake Union are all presently maintained at one level by the Army Corps of Engineers. The common water level does vary with the seasons, ranging from 20.0 to 21.85 feet above sea level.

Lake Washington shore is for the most part suburban-residential (64.5%). The lake's shore and water areas are heavily utilized for recreation, with 19% of the lake's shore being used for upland recreation land. Only 7% of the lake's upland shore is undeveloped. There is little industrial use along the shore of Lake Washington (2.8%). However, the lake does support commercial activity (1.6%): log storage and transfer; marinas; Indian sockeye salmon gill-netting; and a commercial crayfish fishery.

Lake Washington had significant volumes of treated sewage discharged into its waters during Seattle's post-war boom. As a result of Metro's interception and treatment of waste discharges, the nutrient enrichment, undesirable algae growth, excessive weed growth, and general eutrophication of the lake has been reversed. Metro's effect on Lake Washington has been to decrease the nutrients and to increase the water clarity and quality to such a degree that it must now be recognized as being oligotrophic (i.e., relatively low in microscopic life).

The entire lake must be considered a natural resource, for it supports diverse and abundant aquatic life, plant life and wildlife. Lake Washington is an established waterfowl and bird sanctuary. Numerous resident and migratory waterfowl use the shallow and open waters. The lake also supports various resident and migrating fish species, many of which have commercial and/or recreational value. The lake's "natural" shores support the majority of the wild animals still found around the lake. Finally, the lake's upland, shallow water and open water primary producers provide the basic photosynthetic production necessary to have such a living and valuable lake.

Lake Washington Waterfront Parks

Arboretum (Union Bay)

Both the north shore and south shore of Union Bay are marshy. The south shore of Union Bay (Arboretum) is a popular recreation area of 173 acres with nature trails and canoe routes. The north shore of Union Bay is an undeveloped land-fill and current University of Washington plans call for its restoration as an ecological study site.

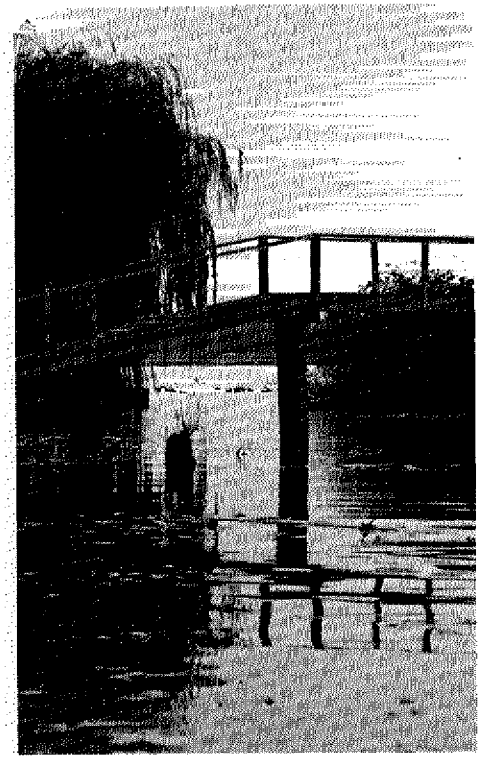
The marsh areas of Union Bay provide feeding, rearing, spawning, and nesting habitats for various finned and feathered life forms. The aquatic vegetation provides food and protection for the migrating and resident population of the following waterfowl and water-associated birds.

Waterbirds and water-associated birds of Union Bay: species that are common or fairly common.

Horned Grebe ▲
Western Grebe ▲
Pied-billed Grebe △
Double-crested Cormorant ▲
Great Blue Heron ▲
Canada Goose △
Mallard △
Gadwall △
Pintail ▲
Green-winged Teal ▲
Cinnamon Teal ●
American Widgeon ▲
Shoveler ▲
Ring-necked Duck ○
Canvasback ○
Greater Scaup ▲
Lesser Scaup ▲
Common Goldeneye ▲
Bufflehead ▲
Ruddy Duck ▲
Hooded Merganser ▲
Common Merganser ▲
Virginia Rail △
American Coot △
Killdeer △
Spotted Sandpiper ●
Glaucous-winged Gull ▲
Herring Gull ▲
Thayer's Gull ▲
California Gull ○
Ring-bill Gull ○
Mew Gull ▲
Bonaparte's Gull ○
Belted Kingfisher ▲
Long-billed Marsh Wren △
Yellowthroat ●
Red-winged Blackbird ●
Song Sparrow △

The shoreline and interior upland areas of Union Bay support a fairly diverse mammal population: muskrats, raccoons, eastern cottontail rabbits, fox squirrels, eastern gray squirrels, mice, stray cats, stray dogs and an occasional beaver.

Union Bay is heavily used as a scientific and educational site for simple and advanced studies and is also heavily used as a passive and active year-round recreational area.



Marshland at the north shore of Union Bay.

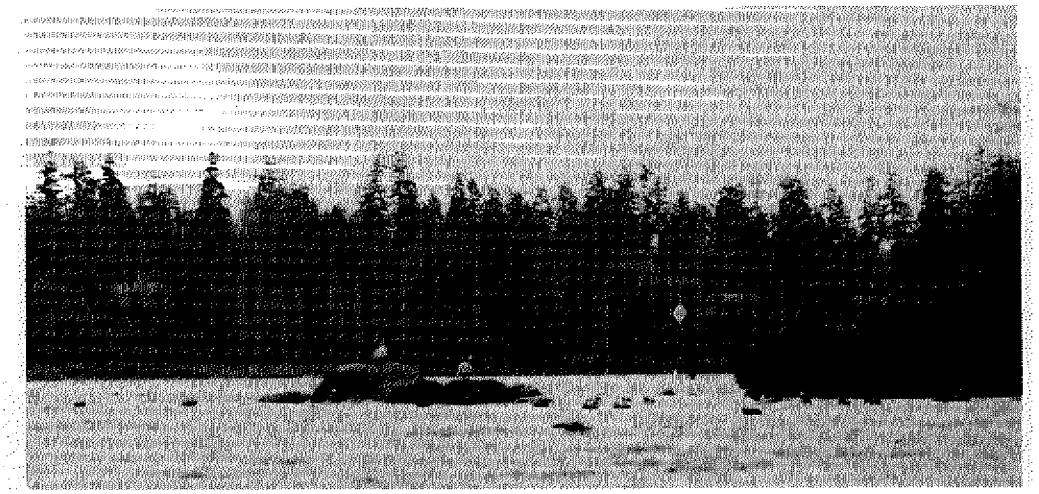
△ resident
● summer only
▲ winter only
○ migrant (spring and/or fall) only

Seward Park

Seward Park contains a fine remnant stand of virgin forest. The open areas are heavily used and the forest areas are criss-crossed by paths. Because the interior of the park is not open to motor vehicles, disturbance other than by people on foot is minimal. Seward Park's 278 acres contain a Washington State Department of Game Fish Hatchery, fishing piers, and a public beach.

Although the shoreline marsh land adjacent to Seward Park (southern Andrew Bay and northern Brighton Beach) were substantially filled by the City Park Department, limited marshy areas, which contain various wild and aquatic life forms, still exist. Seward Park's relatively undeveloped shoreline provides nursery, feeding and shelter areas for aquatic life forms, and the gravel beaches are spawning sites for sockeye and chinook salmon.

The upland shores and interior of Seward Park support a variety of mammals: vagrant shrews, Trowbridge shrews, shrew moles, deer mice, Oregon meadow mice, eastern cottontail rabbits, mountain beavers, chipmunks, Douglas squirrels, fox squirrels, eastern gray squirrels, coyotes, raccoons and weasels.



Seward Park's diverse virgin forest.

Because of its size and its unaltered state, Seward Park is able to successfully support this diversity of wild and aquatic life forms. The presence of numerous mammals, waterfowl, water-associated birds, and fish which are intimately dependent on the diverse physical characteristics of Seward Park adds to the park's wilderness value.

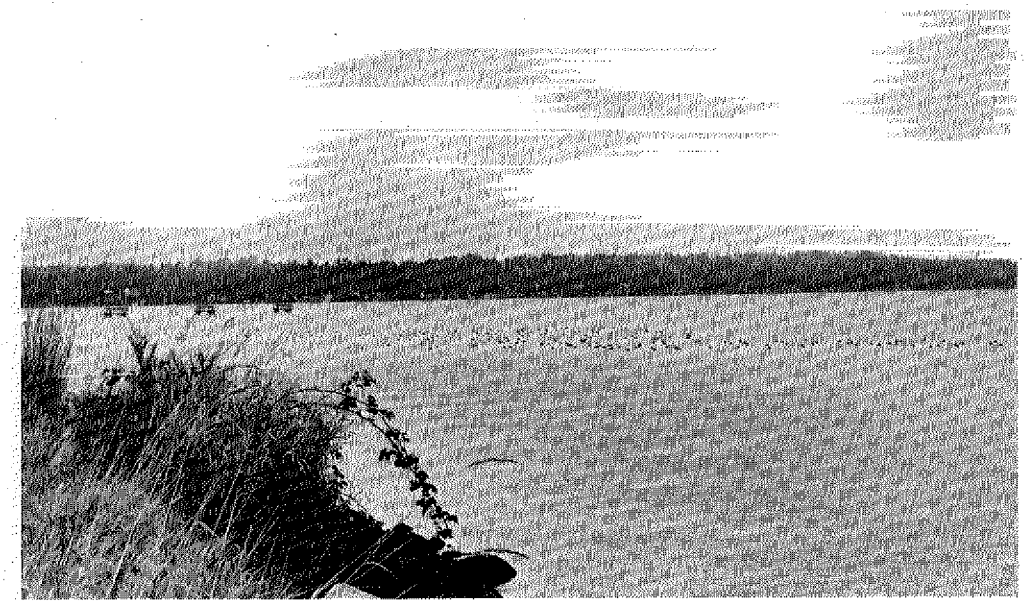
Sand Point

Over 300 acres of the Sand Point Naval Support Air Station is proposed Federal Disposal property. This portion of the naval base consists of land with 8,700 feet of low bank waterfront, one of the largest undeveloped waterfront tracts within Seattle.

The future use and activities for the disposal property is still uncertain. However, it has been proposed that the City of Seattle will receive a substantial portion of the disposal property. The City of Seattle Park Department's development objectives for the area include restoration of old Mud Lake and creation of interior play and picnic grounds with pedestrian and bike paths.

The plant life within much of the disposal property is typical of an urban military development. The bird life adjacent to the disposal property is untypical of an urban military development. Waterfowl and water-associated birds freely inhabit the undeveloped shores of Sand Point relatively undisturbed.

Also, presently within the disposal property, adjacent to the airfield, is over 100 acres of grassy ground cover maintained for a flock of Chinese ringneck pheasants. The grassy fields contain an unusually high-density pheasant population of up to three birds per acre.



Runway lights and resting waterfowl at Sand Point.

The common aquatic bottom organisms of Sand Point are similar to those in other undeveloped areas of Lake Washington in that the off-shore waters contain small populations of crayfish, shrimp, snails, worms, etc.

The gravel beaches of Sand Point are sites of sockeye salmon spawnings and the off-shore water more than likely contains many of the common fish species of Lake Washington.

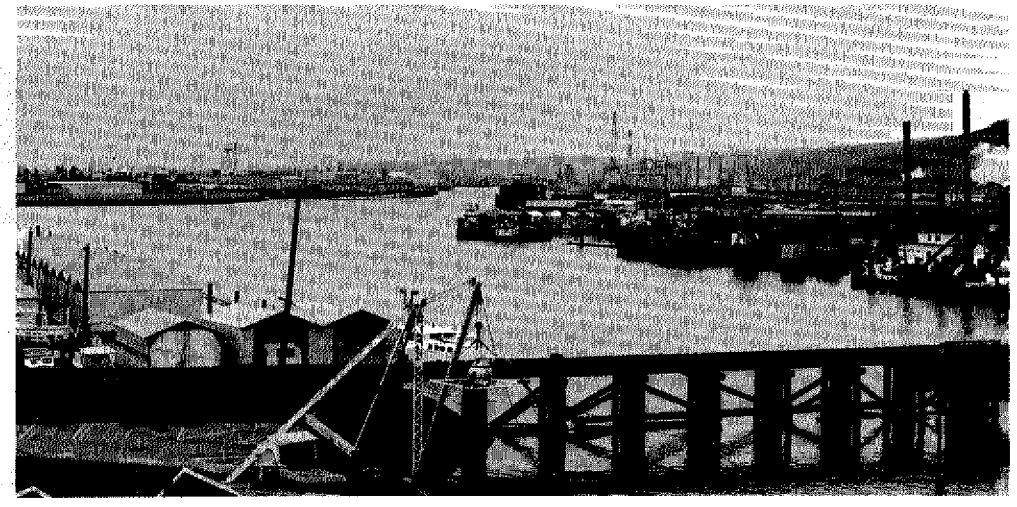
Matthews Beach Park (18 acres) – This recently expanded park is a freshwater waterfront park of recreational, educational and biological significance. The park area was once part of a cove covered by the waters of Lake Washington which became dry land when the locks were completed and the lakes level was lowered by approximately 10 feet. South of the sandy bathing beach, Thornton Creek flows into Lake Washington and numerous waterfowl and water-associated birds congregate in the aquatic plants, tall grass and small shrubs adjacent to the creek. The existing common fish species are juvenile coho and chinook salmon, speckled dace, prickly sculpin and cutthroat trout. The vegetation growth is primarily maple, oak, and other hardwoods, although a few pine trees are also found there. Only incidental wildlife inhabit the area, although the creek was formerly known as an abundant wildlife as well as waterfowl and aquatic life area. The land-fill of Square Lake, containment of the creek in culverts, and improper sewage treatment have altered and polluted the creek to such an extent that Thornton Creek has lost most of its natural character.

Thornton Creek as it flows into Lake Washington.

Duwamish Waterway

Once a free flowing river, meandering back and forth across its valley, the Duwamish waterway with its estuarine environment is now perhaps the most intruded and modified streamway within the State of Washington.

A typical flood plain, the Duwamish Valley, is rich in peat and organic soils. The river delta's flat topography and easy access to water transportation has encouraged intensive industrial use. The streamway has been restricted by landfills and channelization with extensive dike construction resulting in a river bank almost totally devoid of vegetation. The Duwamish River is now a dredged channel whose depth is maintained by the Army Corps of Engineers.



The channelized waterway of the Duwamish River.

One of the influences on life in the Duwamish River is the saltwater wedge which moves up and down the channel, varying with tidal and flow condition. This wedge has critical implications for water quality. Under the worse possible conditions, a "dead layer" of low-oxygen saltwater can be caught in the river. Because the Duwamish is an important estuarial zone for migrating fish, any decrease in water quality may increase mortality.

Fishery resources are extremely important to the Duwamish River Basin. Twenty-eight species of migratory and resident fish are known to use the waterway. An average of 35,500 adult coho and 14,000 adult chinook migrate through the Duwamish Waterway annually along with a smaller number of adult chum salmon. In addition, searun trout species also migrate through the Duwamish Waterway. The largest searun trout population is the Winter Steelhead from which an average 32,000 adult Steelhead migrate through the Duwamish Waterway annually along with smaller numbers of searun cutthroat and searun Dolly Varden trout. The common resident fish species include herring, staghorn sculpin, shiner perch and starry flounder as well as other typical estuarial species.

There is no notable wildlife habitat in the area other than portions of Kellogg Island, which is a feeding and resting ground for waterfowl and waterbirds.

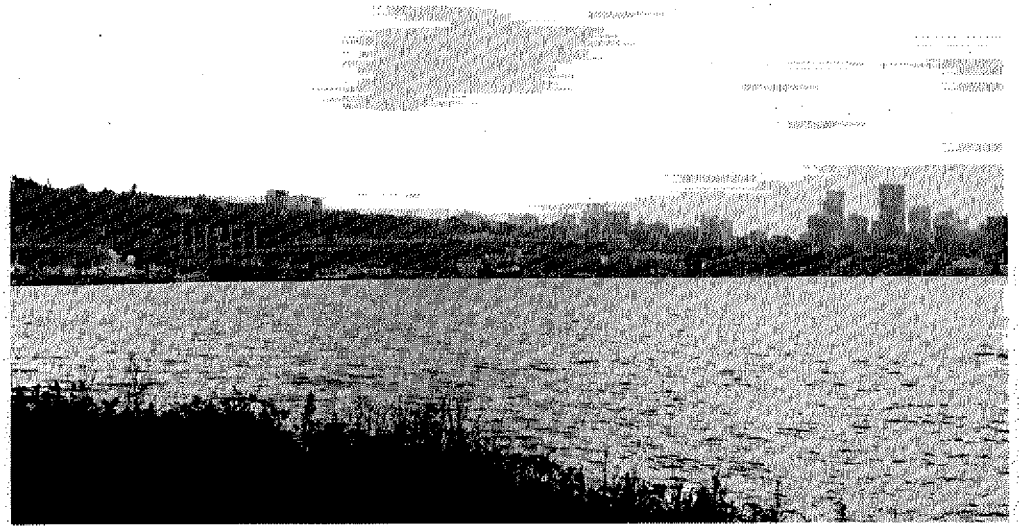
Lake Union

This inland freshwater lake is about 600 acres in size with an average depth of about 45 feet and a maximum depth of slightly over 50 feet.

Land-fill and pier extension from intense commercial and residential activity have encroached substantially into the lake's shallows. The alterations have impoverished the once abundant and diversified biological community. Furthermore, biological life in the lake is hampered by the fine, soft and polluted bottom mud, resulting from years of discharging raw sewage and other pollutants. The upper layer of the lake bed sediment is relatively non-supportive of plant life and therefore, aquatic vegetation is sparse. Although the water quality of Lake Union, in recent years, has dramatically improved through the elimination of many storm water sewers and installation of sanitary sewer collection systems and industrial separation/ treatment facilities around the lake, water quality is still threatened by:

A. Oil spills, the discharge of sanitary wastes from boats, and the remaining storm water sewer overflows; and

B. Saltwater intrusion. Because saltwater is denser than freshwater, saltwater can creep against the flow of freshwater. Saltwater from Puget Sound has intruded through the Locks and has accumulated in a layer about 2 feet deep along the bottom of Lake Union. The layer's thickness has not appeared to have changed recently. There is concern, however, that the layer provides a severe limit to biological growth. Any increase in the saltwater layer through increased Lock openings or low freshwater flow could be extremely harmful to the existing crayfish population, migrating fish, and resident fish species such as rainbow trout, large and small-mouth bass, black crappie, sculpin, sucker, and perch.



Lake Union with its waters of utility and beauty.

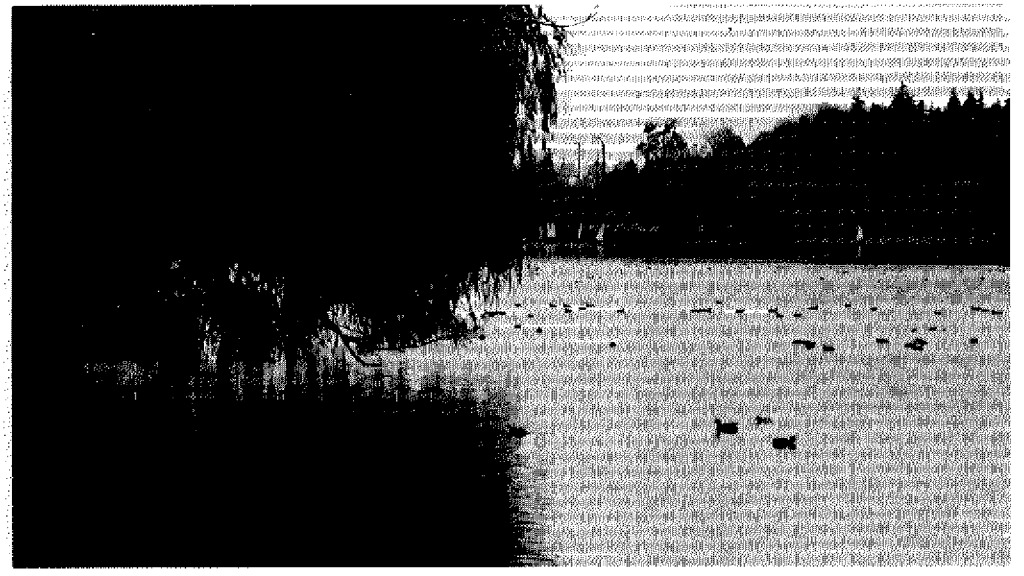
Green Lake

Green Lake lies completely within a developed residential area and is used for a wide variety of recreational uses. Green Lake is an eutrophic lake of 256 acres with an average water depth of 12.5 feet and a maximum water depth of 29 feet. The mucky bottom sediments average 10 feet in thickness and in some places exceed 21 feet.

In 1911, the water level was lowered by seven feet and work commenced on filling the lake edges with dredged material and refuse to increase the land area of Green Lake Park. In total, the water area of Green Lake has been reduced by approximately 45 acres since the turn of the century.

Green Lake has had a history of pollution problems such as algae blooms caused by nutrients entering via sub-surface seepage. Three and one-half million gallons of water per day from the Seattle Municipal water supply is presently pumped into the lake to maintain water quality by dilution.

Semi-domesticated waterfowl and various wild migrating waterfowl inhabit the lake (Green Lake Island is a Washington State Game Department Reserve established to protect the lake's waterfowl). The fish are predominantly stocked rainbow trout. There is periodic poisoning by the Game Department to remove accumulation of "rough" or undesirable fish and subsequent restocking with rainbow trout.



Sailboats, waterfowl and the Aqua Theater of Green Lake.

City Shoreline Property Outside City Limits

Engineering Department

E1. *Kent Highlands Landfill Site*. The Kent Highlands landfill site is on the Green River in the City of Kent. It has been leased from a private party and is currently being used as a sanitary landfill/garbage dump. Approximately 2700 feet of shore frontage are involved.

E2. *Ebey Island Site*. Ebey Slough is on the lower Snohomish River Delta in Snohomish County. It has been leased from a private party for a proposed sanitary landfill/garbage dump, conditioned upon the owner obtaining the necessary permits. Approximately 440 feet of shore frontage are involved. The city property is located at the northerly tip of Ebey Island. The land is undeveloped and contains deciduous, conifer and small shrub vegetation. The shore is diked to prevent flooding.

Park Department

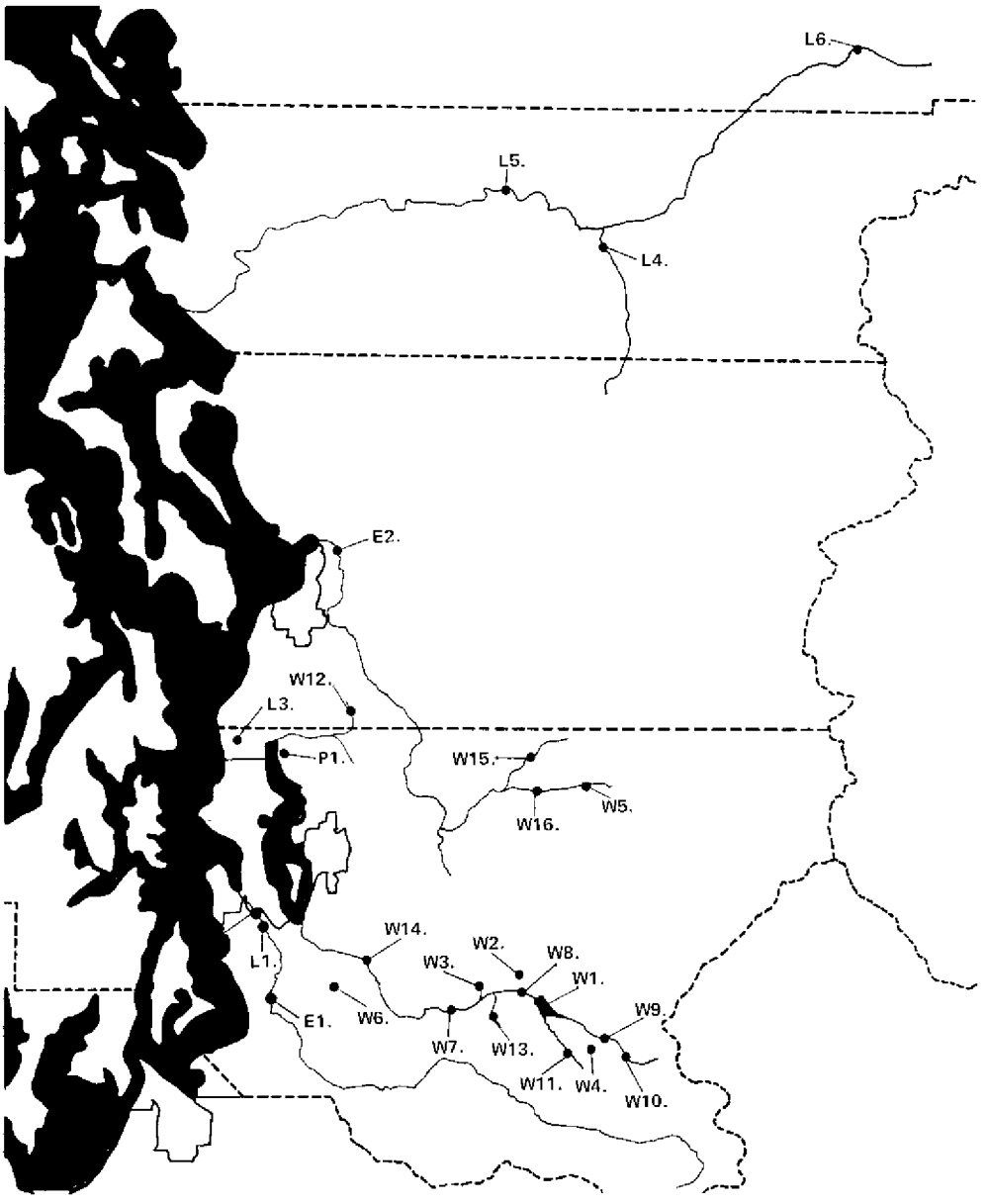
P1. *Camp O. O. Denny*. Camp O. O. Denny is a recreational facility used by local residents and organized groups. It is on Lake Washington within the jurisdiction of King County and consists of 1150 feet of shore frontage and 46 acres of land. The Beach is mostly sandy gravel and the upland is mostly grassy lawns intermixed with a predominately Douglas Fir forest.

Lighting Department

L1. *Duwamish River Crossing*. A power line crosses the Duwamish River just north of South 112th Street, and the City owns 200 feet on both sides of the river (400' total frontage). The river bank is almost devoid of vegetation.

L2. *Duwamish River Shorelands*. Approximately 1,350 feet of shoreline adjoin the Duwamish Substation near South 96th Street and West Marginal Way. The river bank is almost devoid of vegetation.

L3. *Echo Lake*. Where the old Pacific Northern Traction Co. right-of-way borders Echo Lake, the City owns approximately 300 feet of waterfront shoreline which is being used by the King County Park Department as a park. The upland shoreline is relatively low bank and is now supporting plant life.



L4. *Sauk River*. This parcel consists of approximately 300 feet of shore frontage on both sides of the Sauk River. It contains dense vegetation and has a relatively low bank.

L5. *Skagit River*. Numerous riverfront properties totaling nearly three miles are owned by the City. The vast majority is undisturbed and undeveloped though in the past some portions have been leased to private parties. River bank vegetation is particularly vigorous on the Skagit River. The common plant communities include Ponderosa Pine, Water Birch, Alpine Fir, Oregon Grape, Rhododendron and many, many more. Wildlife and aquatic life is also quite diverse and abundant.

L6. *Diablo Lake and Ross Lake Reservoirs*. The City is licensed by the Federal government to utilize Diablo and Ross Lakes for power purposes. These reservoirs act as the ecological focus point for surrounding areas which contain a diverse mixture of aquatic, plant and wildlife.

Water Department

The Water Department owns numerous properties related to its function of providing water to the Seattle metropolitan area.

W1. *Chester Morse Lake* – 13.25 miles. The shoreline of Morse Lake is very typical of a mountain lake of this elevation. The beach is quite rocky and moderately

steep. The vegetation surrounding the lake is primarily second growth Douglas Fir.

W2. *Rattlesnake Lake* – 1.6 miles. The level of Rattlesnake Lake is influenced by seepage from Morse Lake, resulting in extreme elevation fluctuation during the year. Approximately one-half of the lake is open to recreation. The shoreline is generally sandy to rocky in nature with relatively level banks.

W3. *Walsh Lake* – 1.1 miles. The shoreline of Walsh Lake is very swampy to the south and east. Except for this area, the shoreline above the high water mark consists of second growth Douglas Fir, hemlock and alder.

W4. *Findley Lake* – 0.8 miles. The area to the west of Findley Lake is extremely steep and rocky. However, the remaining shoreline is gentle and forested with old growth timber. Findley Lake is a remote mountain lake which is inaccessible by motor vehicle.

W5. *Tolt Reservoir* – 8.2 miles. The beach area surrounding the reservoir is generally moderate in slope. The entire area above the high water mark is forested with a fairly uniform stand of young Douglas Fir. Most of the reservoir is readily accessible.

W6. *Lake Youngs Reservoir* – 6.75 miles. A perimeter dike road constructed within 20 feet of the high water level follows the entire shoreline of Lake Youngs. The beach area is fairly steep and rocky at higher lake elevations. Except for several small plantations, the area beyond the dike road consists of 40 year old Douglas Fir.

W7. *Cedar River* – below Masonry Dam – 13.5 miles. The 12 miles of shoreline from Cedar Falls to Landsburg is extremely brushy above the high water level. The 1.5 miles of streams above Cedar Falls runs through precipitous terrain. River banks are extremely steep and rocky. Vegetation along this stretch of river consists of 45 year old Douglas Fir and Hemlock.

W8. *Cedar River* – above Masonry Dam – 6.7 miles. This stretch of the Cedar River winds through young stands of Douglas Fir, Hemlock and Alder. The area above the high water mark is generally quite brushy along its entire length. The shoreline is relatively level but quite rocky in nature.

W9. *Cedar River* – North Fork – 0.75 miles. The North Fork of the Cedar River flows through approximately 1.1 miles of old growth timber and 2.0 miles of young Douglas Fir reproduction. The topography of the bank is generally moderate. The character of this shoreline varies from rolling to broken.

W10. *Cedar River* – South Fork – 2.0 miles. The shoreline of the South Fork of the Cedar River is very similar to the North Fork. Except for 0.25 miles of old growth, the adjacent area consists of young Douglas Fir and true fir stands.

W11. *Rex River* – 5.5 miles. The terrain immediately adjacent to Rex River is generally steep and rocky. Extremely thick young stands of Douglas Fir and Hemlock extend to the waters' edge.

W12. *Bear Creek* – 0.4 miles. Bear Creek flows through a second growth stand consisting of Douglas Fir and Hemlock. This stream is much smaller than the rivers described above. The stand in this area extends to the high water level. Terrain is generally level.

W13. *Taylor Creek* – 0.7 miles. Generally, the stream banks adjacent to this portion of Taylor Creek are steep and rocky. Forest stands adjacent to the stream consist primarily of 45 year old Douglas Fir and Hemlock and extend to the waters' edge.

W14. *Rock Creek* – 1.3 miles. Rock Creek is a small stream located in lower Cedar River Watershed. The terrain is fairly moderate along its entire length. Vegetation immediately adjacent to Rock Creek generally consists of thick brush. A fine stand of Douglas Fir exists along the banks at the higher elevations.

W15. *Tolt River* – North Fork – 2.3 miles. For the most part, the shoreline of the North Fork of the Tolt River is extremely rugged with steep, rocky banks. Only 1/2 of the shoreline controlled by the City is readily accessible. Except for one small stand of old growth, the stream banks generally consist of stands of young Red Alder and Hemlock.

W16. *Tolt River* – South Fork – 0.6 miles. The shoreline of the South Fork of the Tolt River is very typical of a mountain stream. The stream banks are quite rocky and covered with conifer reproduction and brush. This stream is generally readily accessible. However, the portion west of the Tolt River Dam passes through a deep canyon and is only accessible from a road system located to the south of the river.

Environments

Upland Shoreline:

This environment provides the necessary conditions for waterfowl, shore bird, and mammal populations. Undeveloped lands usually contain the most dense wildlife populations because they can provide the necessary food and cover. As upland vegetation is destroyed, the wildlife diversity is also substantially destroyed.

Tideland:

This environment is submerged by high tides and exposed by low tides. The biological life forms adapted to the daily fluctuating conditions are both fragile and diverse. The representative biological communities existing in Seattle's common tideland environments are discussed in further detail on page 23.

Shallow Water (over submerged land):

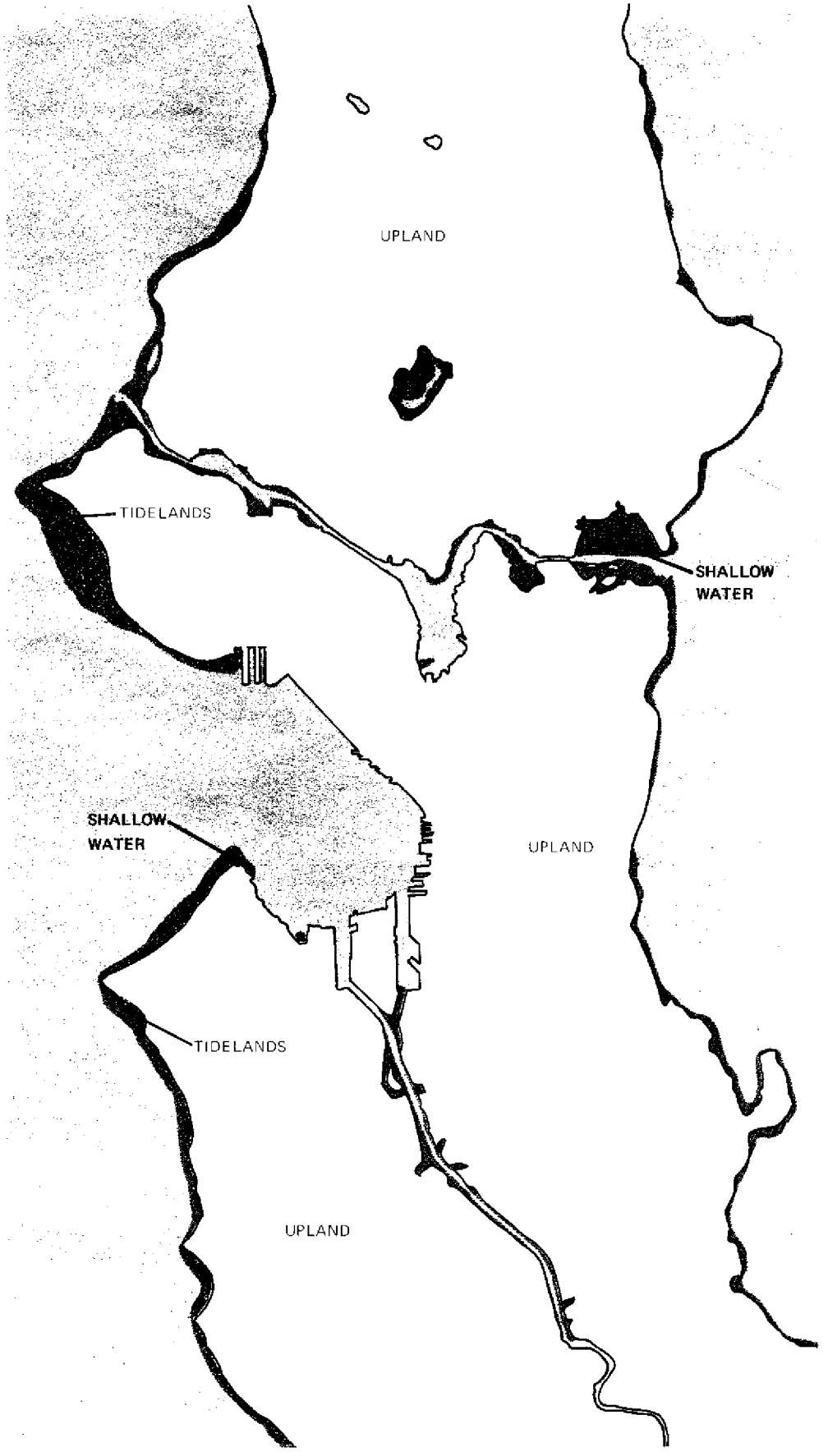
This environment is by far the most productive area. Light is able to penetrate, permitting aquatic plants to flourish. The aquatic plants, either emersed, submerged, or floating, enable populations of invertebrates, fish and waterfowl to exist. The most significant shallow water shoreline areas are the nutrient rich brackish waters or protected coves where the necessary food and/or shelter for juvenile and adult organisms is especially abundant.

Surface, mid, and deep water:

These environments contribute greatly to the productivity of the waters. Sunlight penetration enables plankton to abound near the surface, thus attracting larger organisms. Mid and deep water habitats support diverse, yet unknown quantities of aquatic life.

Submerged Land:

This environment extends from the low low water mark outward and downward to the middle of Puget Sound and Lake Washington. Submerged lands of shallow depths enable plants to receive sunlight, and thus begin the food-complex. Submerged lands, beyond sunlight penetration, support benthic organisms, (invertebrate and vertebrate), and deep water plants (red algae).



Marine Fish

Nearly 150 species of fish are reported to live in the marine waters of Seattle, with over 45 species considered abundant. Most of these fish live between the surface and the 60 foot contour, because in this area the phyto-plankton and zoo-plankton are concentrated and can provide the basic source of fish nutrition.

The most abundant saltwater fish species -- either seasonally or throughout the year--include:

Poachers

sturgeon
pygmy
blacktip

Salmon

pink
chum
coho
sockeye
chinook

Trout

steelhead
searun cutthroat

Cod

Pacific cod
Pacific Hake
Pacific tomcod
Walleye Pollock

Stickleback

Tube-snout
Threespine

Rockfish

black
copper

Flounder

arrowtooth
starry

Sole

rex
rock
slender
Dover
English
C - O
sand

Sanddab

Pacific
speckled

Greenlings

kelp
whitespotted
lingcod

Surf Perches

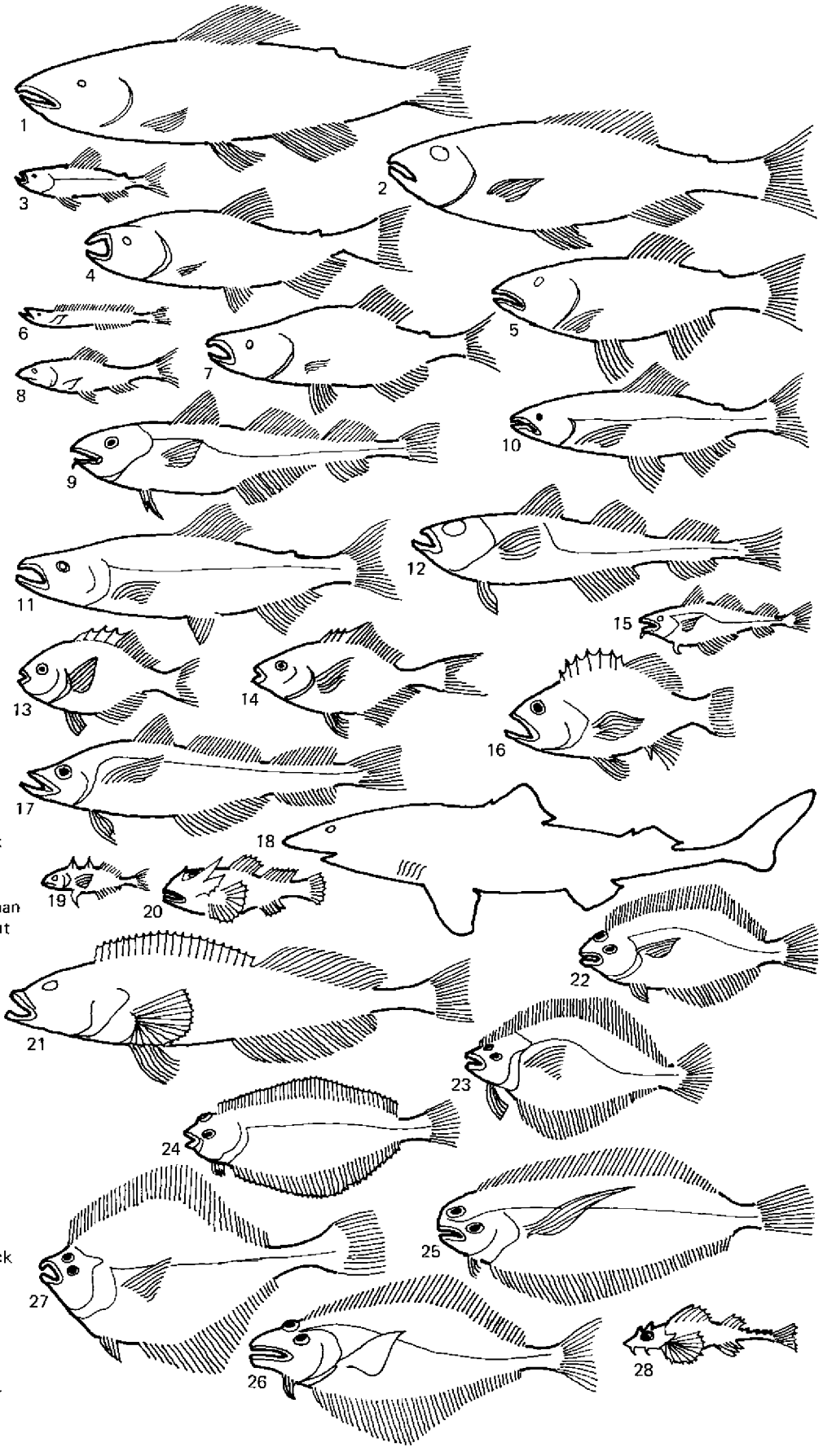
shiner
striped
pile

Sculpin

padded
smoothhead
roughback
buffalo
spotfin
staghorn
sailfin
slim

Others

Spiny dogfish
ratfish
Pacific herring
Surf smelt
Bay pipe-fish
Snake prickleback
penpoint gunnel
Pacific sand lance
Plainfin Midshipman
black belly eelpout
Northern ronquic



MARINE FISH SPECIES

1	Chinook Salmon	15	Pacific Tomcod
2	Steelhead Trout	16	Black Rockfish
3	Surf Smelt	17	Pacific Hake
4	Coho Salmon	18	Pacific Dogfish
5	Cutthroat Trout	19	Threespine Stickleback
6	Pacific Sandlance	20	Buffalo Sculpin
7	Sockeye Salmon	21	Lingcod
8	Pacific Herring	22	English Sole
9	Pacific Cod	23	Rock Sole
10	Pink Salmon	24	Dover Sole
11	Chum Salmon	25	Rex Sole
12	Walleye Pollock	26	Arrowtooth Flounder
13	Striped Seaperch	27	Starry Flounder
14	Pile Perch	28	Sturgeon Poacher

Freshwater Fish

Thirty-six fish species occur in the Lake Washington drainage at this time. The six species in greatest abundance are:

sockeye salmon
peamouth
northern squawfish
yellow perch
brown bullhead
prickly sculpin

The common species are:

chinook salmon
coho salmon
kokanee trout
(landlocked sockeye salmon)
rainbow trout
steelhead trout
searun cutthroat trout
threespine stickleback
largemouth bass
longfin smelt
mountain whitefish
speckled dace
carp
largescale sucker
pumpkinseed sunfish
black crappie
five species of sculpins

Lake Washington is used extensively for nearly all forms of water-associated recreational activities including a valuable and rapidly expanding sport fishery. The Washington State Department of Game recognizes the rainbow, steelhead and cutthroat trout, sockeye, coho and chinook salmon, brown bullhead, largemouth bass, pumpkinseed sunfish, mountain whitefish, black crappie and yellow perch as being desirable Lake Washington game fish.

However, Lake Washington also contains species considered undesirable from a sport fisherman's view (poor eating and poor fighting fish), although they may be of value in the overall natural balance as forage fish. The abundant species in the so-called undesirable category are: prickly sculpin, peamouth, and northern squawfish. The common "undesirable" fish are: carp, speckled dace, largescale sucker, threespine stickleback, and the other four species of sculpins.

The most valuable fish in the Lake Washington system are the Pacific salmon and searun trout species. Presently, the most important of these migrating species are the sockeye, coho, and chinook salmon.

The sport fishing map on page 28 indicates intensive angling in both the northern and southern reaches of Lake Washington. The autumn coho and chinook sport fishery in the north end of the lake must now share its role as the most popular Lake Washington sport fishery with the summer sockeye sport fishery in the south end of the lake.

The Pacific salmon sport fisheries are dependent on the successful escapement of adult salmon to their spawning grounds. Estimates of adults returning to their natural spawning grounds or hatcheries are as follows:

Pacific Salmon Escapements:

	Sockeye	Coho	Chinook
1966	46,000	33,700	15,200
1967	190,000	15,800	14,200
1968	160,000	20,600	9,700
1969	200,000	20,200	8,300
1970	124,000	59,300	12,100
1971	183,000	INA*	INA*
1972	249,000	INA*	INA*

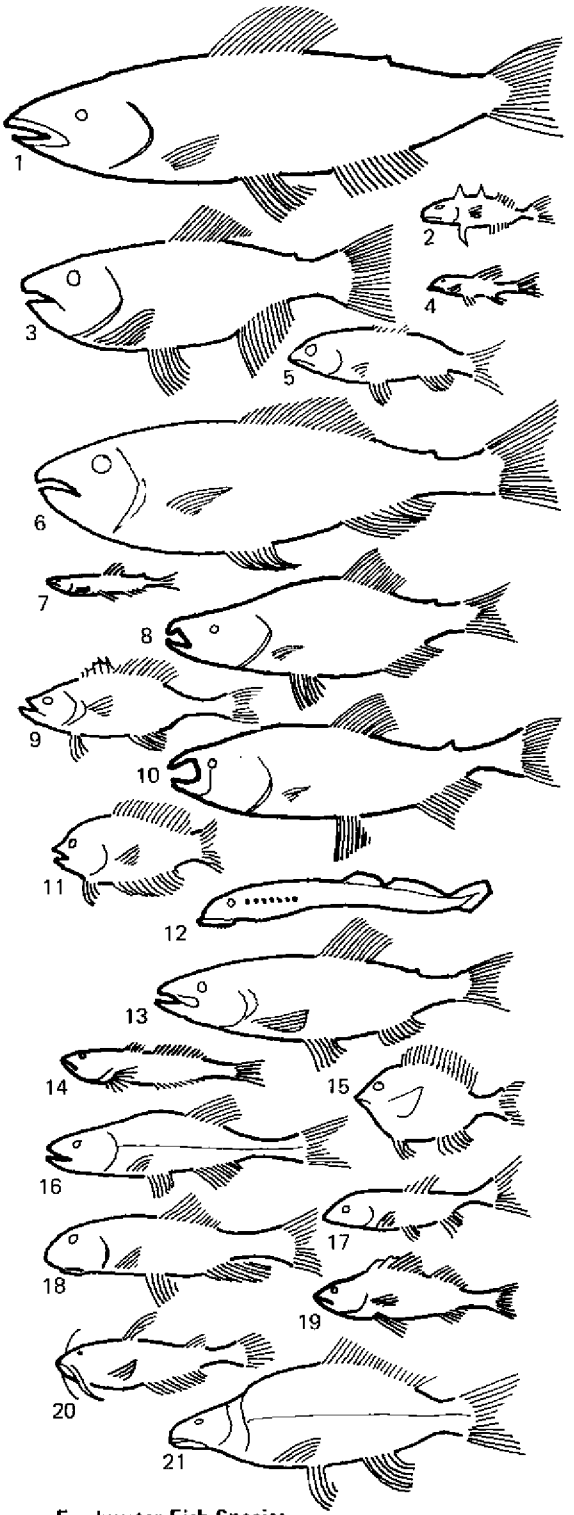
*Information Not Available

The above figures represent those salmon that escape the intense commercial and sport fisheries of the Pacific Ocean, Puget Sound and Lake Washington. According to tagging and marking studies the total catch for Puget Sound and Pacific Ocean fisheries are figured to be 4 times the escapement level for chinook salmon, and more than 3 times the escapement level for coho salmon. Thus, the approximate "total run size" for chinook salmon in the Lake Washington drainage is (for any given year) the escapement level plus the total catch (4 X escapement) and the "total run size" for coho salmon is the escapement level plus the total catch (3 x escapement). The total run sizes (total catch and escapement) for the sockeye salmon can be determined more precisely because they are caught mostly within Puget Sound and are as follows:

Sockeye Salmon Total Run Sizes:

1966	49,000
1967	194,000
1968	185,000
1969	270,000
1970	135,000
1971	553,000
1972	296,000

Special consideration must be given to the fact that the Lake Washington Pacific salmon production and potential Pacific salmon production is a valuable natural resource. To destroy or to place severe limitations on the salmon's potential in face of the future demands for these fish would create a large and irreplaceable loss.



Freshwater Fish Species

1 Chinook Salmon
2 Threespine Stickleback
3 Cutthroat Trout
4 Speckled Dace
5 Whitefish
6 Steelhead Trout
7 Smelt
8 Sockeye Salmon
9 Largemouth Bass
10 Coho Salmon
11 Black Crappie
12 Pacific Lamprey
13 Kokanee
14 Sculpin
15 Pumpkinseed
16 Northern Squawfish
17 Peamouth
18 Sucker
19 Yellow Perch
20 Brown Bullhead
21 Carp

Migrating Fish

CRITICAL AREAS

The lower Duwamish River, Elliott Bay, Lake Union, Salmon Bay and Shilshole Bay serve as critical transition zones where homeward migrating adult fish and outward migrating juvenile fish acclimate to changing salinity of the water. Adult migrating fish will stay briefly in these passageways and for them it is not an extremely critical area. Certain migrating species have juveniles that may spend weeks or months in these zones, using them as feeding and rearing grounds. Juveniles of other species use these transition zones only briefly as a passageway to the Sound.

A. Affected juvenile species in the Duwamish-Elliott Bay areas:

(1) Chum salmon juveniles go to sea during their first spring as very small fish. The lower Duwamish-Elliott Bay area is a critical transition zone for these extremely small juveniles.

(2) Coho salmon juveniles do not go directly to sea; the great majority of the juveniles remain one year in fresh water and migrate to sea in the spring of their second year. However, they may feed for a considerable time period in the estuary.

(3) Chinook salmon juveniles may go to sea during the first year or remain up to fifteen months in freshwater. They may feed for a considerable time period in the estuary.

(4) Searun steelhead trout juveniles go to sea, usually after two or three years in freshwater.

(5) Searun cutthroat trout juveniles go to sea usually in their second or third years.

(6) Searun Dolly Varden trout juveniles go to sea usually in the spring of their first or second year.

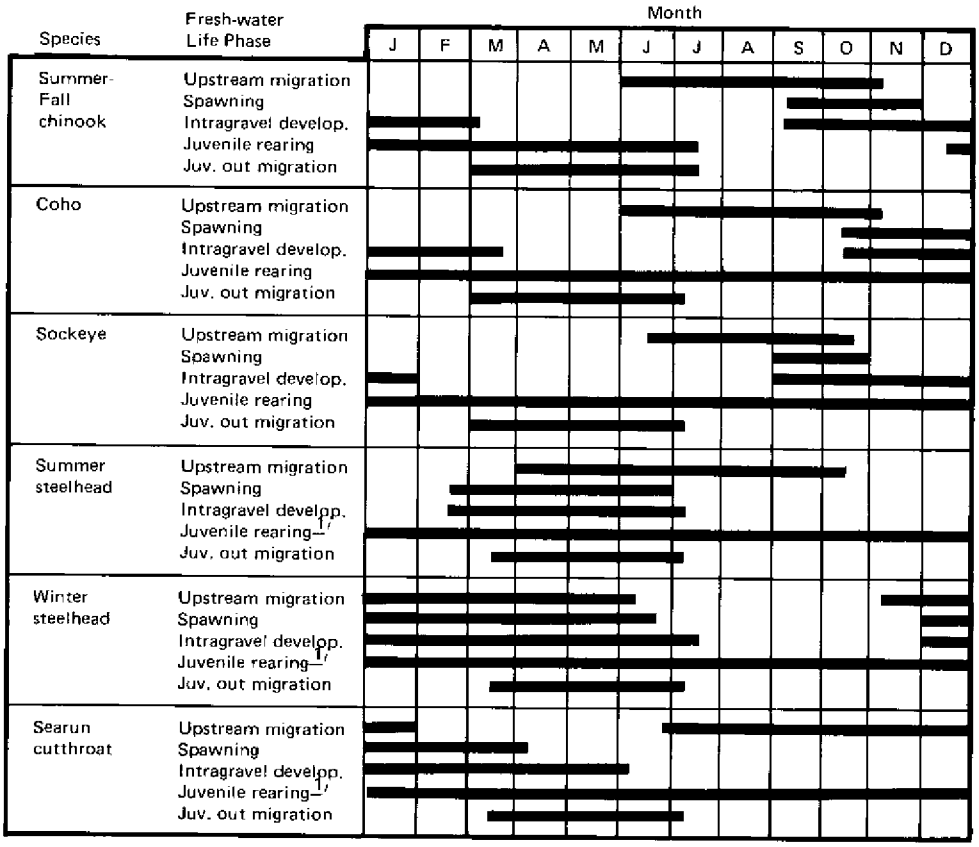
(7A) Surf smelt juveniles go to sea two weeks after the eggs are laid during the summer months.

B. Affected juvenile species in the Salmon Bay-Shilshole Bay areas:

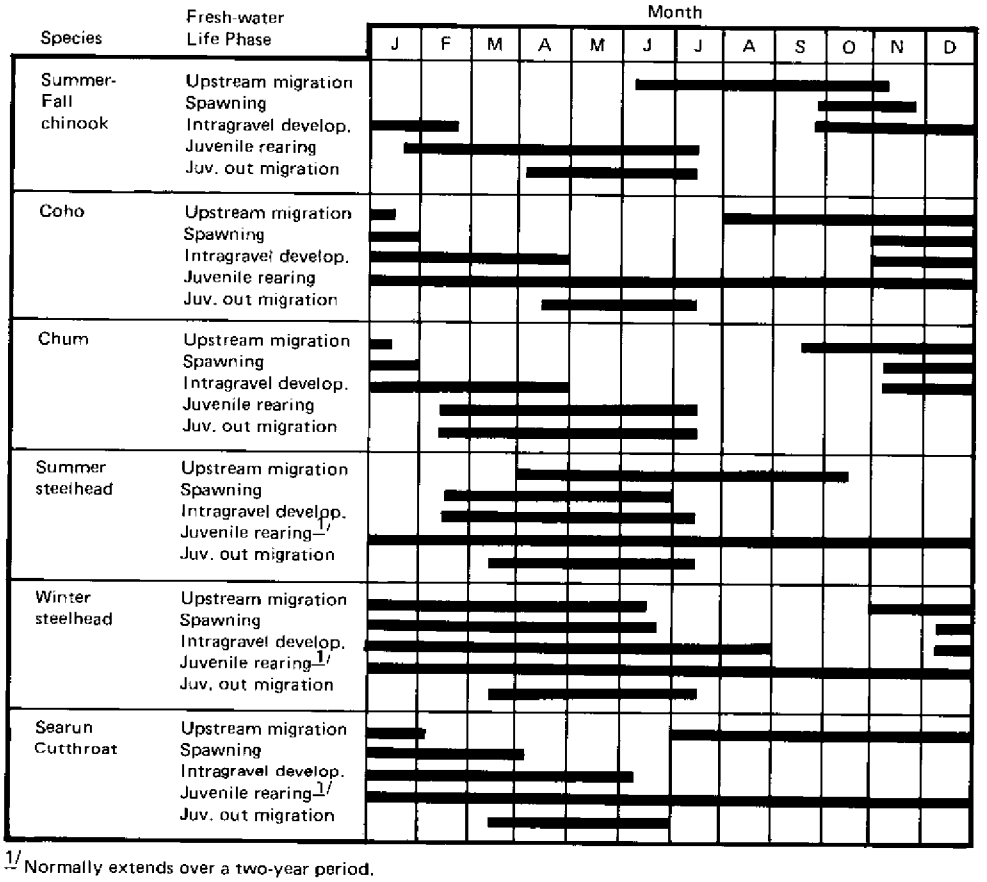
The affected migrating juvenile fish in the Salmon Bay-Shilshole Bay area are the same species as the Duwamish-Elliott Bay area juveniles, (1) through (6).

(7B) Sockeye salmon juveniles usually

Timing of salmon and searun trout fresh-water life phases in Cedar Basin



Timing of salmon and searun trout fresh-water life phases in Green-Duwamish Basin



1/ Normally extends over a two-year period.

spend fifteen months in the open water feeding and rearing grounds of Lake Washington until they start to migrate to sea during the spring months.

Again, the Lake Union, Salmon Bay, and Shilshole Bay areas are critical zones for all juveniles migrating from the Lake Washington drainage system to the Sound. The lower Duwamish-Elliott Bay areas are critical zones for all juveniles migrating from the Duwamish-Green River system to the Sound.

C. Major factors influencing the mortality and predation of migrating fish in the critical areas:

Homeward-migrating adults adjusting to the freshwater environment and out-migrating juveniles adjusting to the saltwater environment, are under physiological stress during this habitat transition. The out-migrants, being so small, are highly vulnerable to mortality and predation during the acclimation periods. It is suspected that any of the following factors in the critical areas may increase the fish susceptibility to natural mortality and predation:

(1) Increases of temperature in the critical areas may result in the adults and juveniles being more susceptible to diseases (Vibrio sp.);

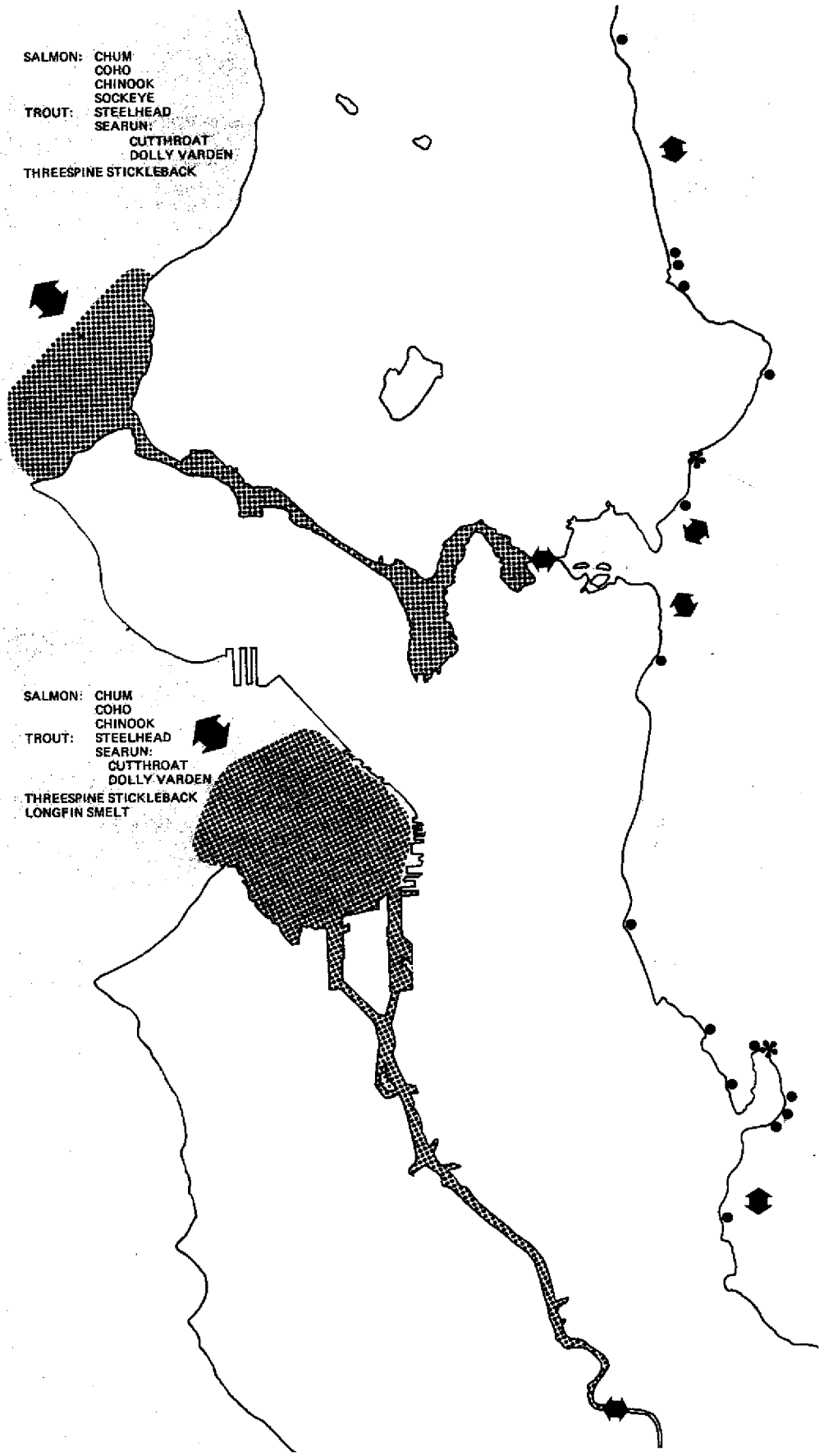
(2) Decreases in waterflow or impediments to water circulation will decrease the swiftness of movement out of the critical areas, and may increase the predation on the out-migrants. Low water flow and poor circulation may also increase the water temperature and, therefore, as mentioned above, may increase the susceptibility to diseases;

(3) Increases in pollution may affect water quality and hamper the adult and juvenile acclimation to the changing water environment, perhaps increasing mortality;

(4) Alterations to natural shores may destroy feeding and protection areas of the juveniles and thus force them out into deeper water where predation will increase.

D. Lake Washington's Salmon Spawning Sites

The sockeye beach spawning sites are places where spawning salmon have been observed by helicopter surveys conducted in the past five years, (1968-1972) by the Washington State Department of Fisheries.



There are two types of lake spawning areas:

(1) Shallow water areas of gravel near up-welling groundwater seepage.

(2) Exposed gravel beaches.

There are also two types of Lake Washington sockeye salmon:

(1) A large population of Cedar River spawners.

(2) A smaller population of lake spawners.

The lake spawning sockeye are believed to enter Lake Washington in the early summer along with the sockeye Cedar River spawners. Both populations generally hold in the lake in the same areas (mid to deep water depths) for the entire summer months. However, the sockeye lake spawners begin spawning activity well after the peak spawning activity of the Cedar River sockeye. Lake spawners begin spawning on selective beaches usually in late November to mid-December. Incubation of the eggs in the gravel continues through the winter with the juveniles emerging from the gravel in April or early May. Unfortunately, information is lacking on their early life history. Information is also lacking on the early life history of the large number of fry coming out of the Cedar River.

The study done on chinook spawning sites is by no means conclusive. The observed spawning sites were determined by personal communication with shoreline owners and by somewhat limited boat surveys. This does not lessen the value of the information, for it gives the general physical characteristics needed for chinook spawning.

It was found that Chinook spawning occurs in water depths of one to eight feet where there is gravel, sand, and ground water seepage. Admittedly, the sites indicated do not represent the only chinook beach spawning, but the localities do indicate the general type of shore utilized by beach spawning chinook.

Chart taken from Puget Sound Task Force of the Pacific Northwest River Basins Commission — Puget Sound and Adjacent Waters, Comprehensive Study of Water and Related Land Resources, App. XI: Fish and Wildlife.

NORTH

Migration Paths

Critical Migration Areas

Salmon Spawning Sites

Sockeye

Chinook

Aquatic Animal Life

A. Marine Shellfish

The marine shellfish populations in Seattle are in scattered to moderate abundance, with only the spot shrimp being in sufficient quantities to support a small Seattle commercial fishery. However, many of the shellfish are being taken recreationally. The marine shellfish populations found in Seattle include:

1. The Geoduck is the largest clam (commonly 6 pounds and 9 inches long) in the Northwest. Geoduck are found in soft mud or loose sand at the lower portion of the intertidal zone, out to depths of 200 feet. They are usually buried two to four feet deep in the substrate and are very sparse in Seattle.

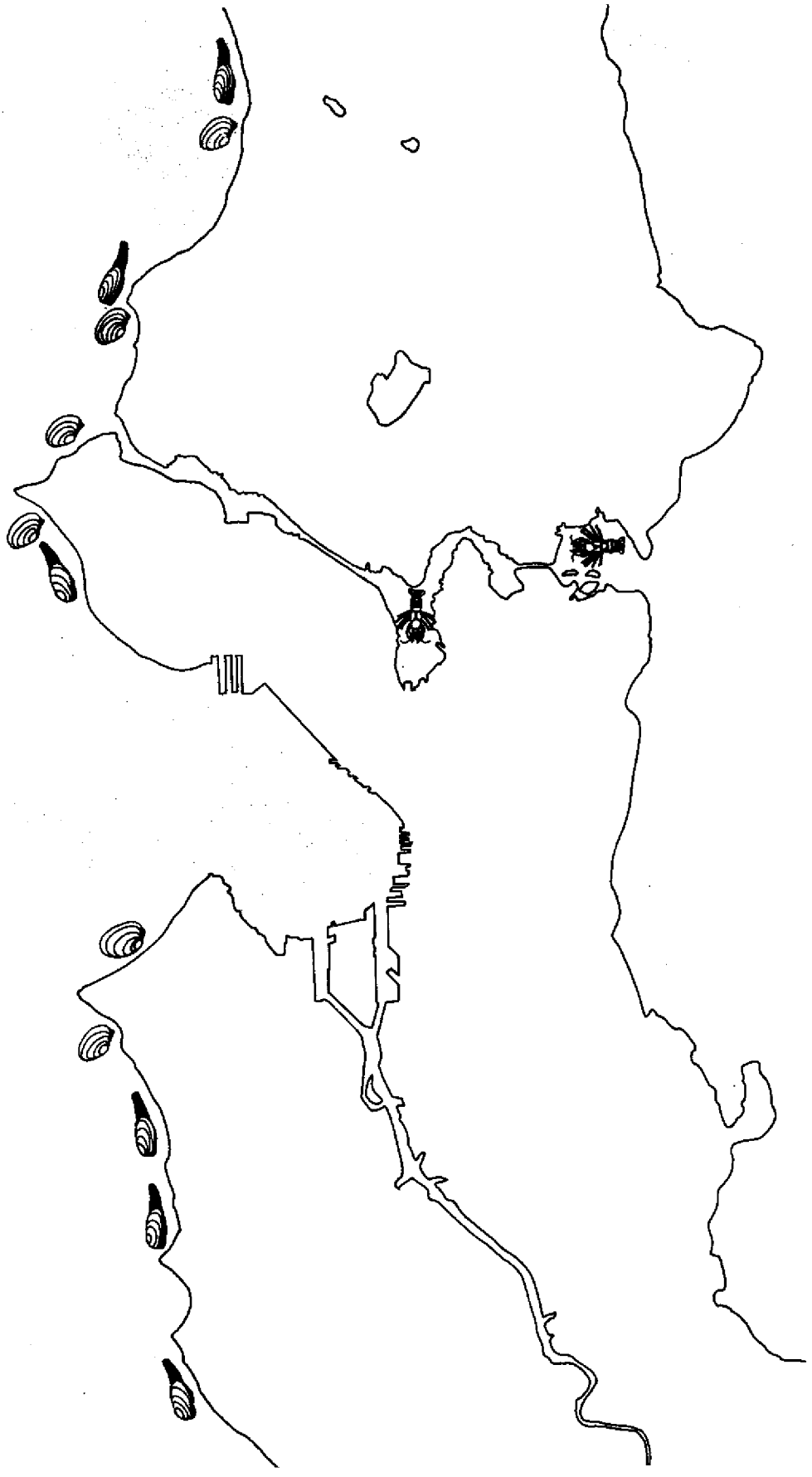
2. Manila clams are inhabitants of muddy-gravel beaches above the mid-tide level, with most found about six inches deep in a porous mixture of gravel, sand, and mud just firm enough to resist wave action.

3. Butter clams are inhabitants of sandy-gravel flats or muddy-gravel beaches in the lower third of the intertidal zone, or shallow subtidal zone, where they burrow to a depth of 8-14 inches.

4. Littleneck clams are found buried 8-10 inches in gravel-mud substrate, usually on protected beaches in the lower third of the intertidal zone or shallow subtidal zone. Manila, butter, and littleneck clams are commonly known as "hardshell" clams.

5. Horse clams are found in the lowest intertidal region outward into waters as deep as 50-60 feet. They are usually buried twelve to thirty inches deep in sand or mud bottom substrate.

6. Bent-nose clams are usually found buried 6-12 inches deep in muddier beaches, where they inhabit the intertidal and subtidal zones.



NORTH

Geoducks

Hardshell Clams

Crayfish

7. Eastern soft shelled clams are also found on Seattle beaches. They burrow into sand and mud beaches and are commonly found above the midtide level.

   The clam species in the Seattle area are fairly scattered and located in various environments. All the above clam species are exploited by recreational diggers and, because the populations are scarce and scattered, their survival is threatened.

8. The Dungeness crab stocks in the Seattle area are at moderate population levels. They are found along the entire marine shoreline from the low water mark out to depths of fifty fathoms or more. Eelgrass beds and similar habitats (eg. widgeon grass) provide rearing grounds for juvenile crabs. The crabs are heavily exploited for recreational use and occasionally for commercial use. Other common crab species include the rock or red crab, purple shore crab, green crab, porcelain crab, kelp crab and decorator crab. Red crabs are a species of minor recreational use.

9. Spot shrimp are harvested commercially in southern Elliott Bay. However, the landings have decreased from a 1961-65 average annual production of 2,341 pounds to a 1966-70 average annual production of 425 pounds. These shrimp rarely grow over 6 inches. The young are found in shallow water until they migrate to deep water as adults.

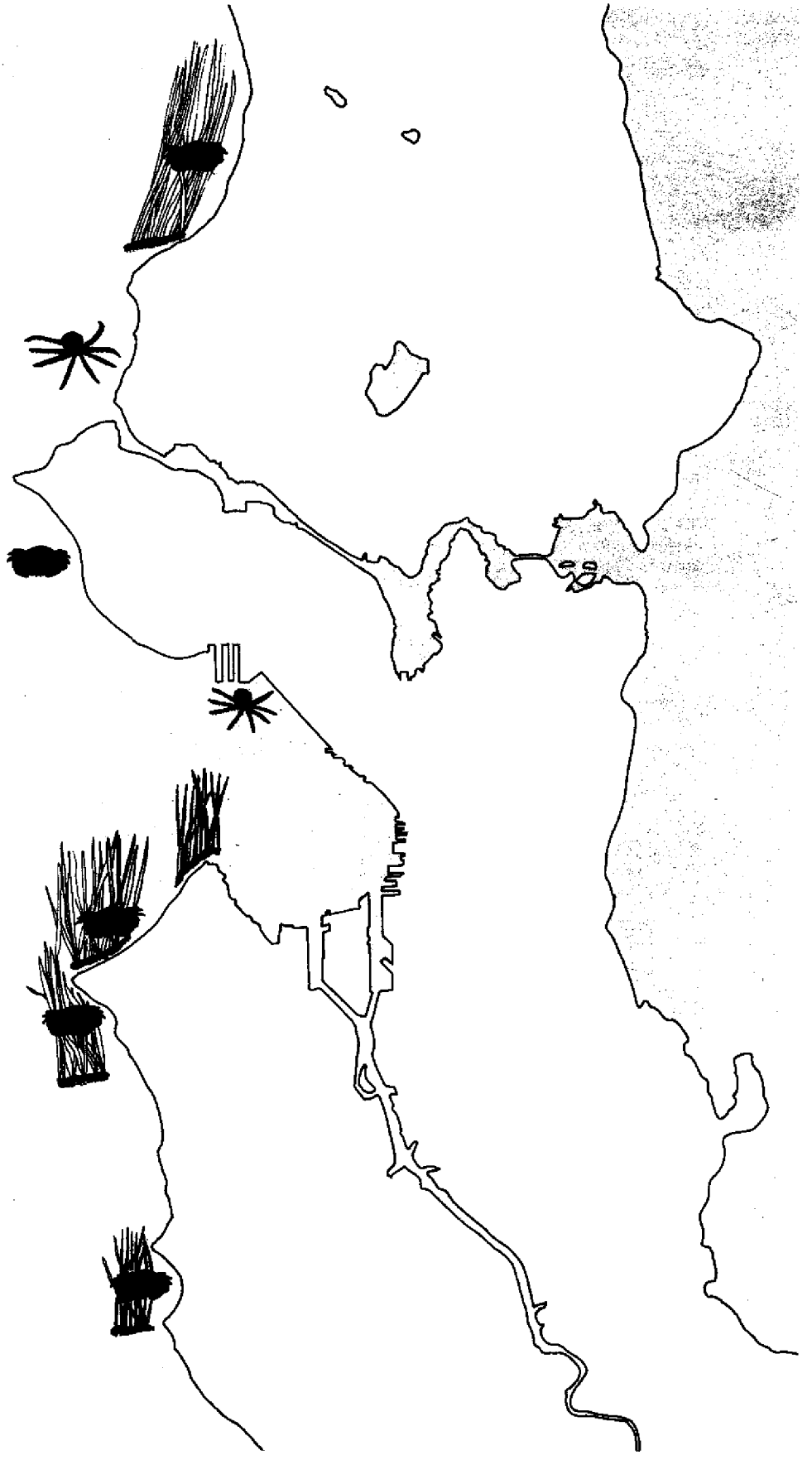
10. Octopus — Two species of octopus inhabit Seattle waters: the giant Pacific octopus and a smaller species. Both are very abundant in rocky reefs of shallow or deep water. They are eagerly sought by sport divers in the rocky shore areas and rock breakwater areas (e.g. Pier 89, Shilshole).

11. Squid — Two species of squid inhabit Seattle waters: the stubby squid and the opalescent squid. The stubby

Octopus Areas

Crab Areas

Eelgrass Beds



squid is known to burrow into muddy, shallow water (always subtidal). In contrast, the opalescent squid is an excellent free swimmer and is commonly found traveling in schools.

12. The following scattered shellfish populations can also be found in various environments within Seattle marine waters: Puget Sound pink scallop, mussell, rock louse, sand hoppers, coon-stripe shrimp, and side-stripe shrimp. Other shrimp-like forms are also found in local marine waters varying from microscopic plankton such as amphipods, copepods, and euphausids to tiny pelagic shrimp of non-commercial size.

B. Common Marine Organisms

1. *Sea Anemones* – These include the common pile anemone which inhabit piles and the rough anemone which inhabit floats and rocks.

2. *Jellyfish* – Only one of the many species of jellyfish in the Puget Sound area, the sea blubber, has stinging cells capable of penetrating human skin. The other common jellyfish are the moon jellyfish and aequoric jellyfish.

3. *Worms* – These are usually either segmented or ribbon.

4. *Hermit-crabs* – They have the well known habit of using empty snail shells for protection and are common inhabitants of gravel shores.

5. *Barnacles* – Rocks, pilings, floats, and boats throughout the intertidal zone are their common habitats. Species differences among barnacles are small, and they are identified primarily by the shapes of their cone-shaped shells. The acorn barnacle is the most common local species.

6. *Sea snails, sea slugs and chitons* – Sea snails have a single shell and may be predatory on clams or oysters. Sea slugs are shell-less snails and chitons have eight multiple shells. Sea snails, depending on the species, inhabit almost every type of shore: sand, mud, or rock. Sea slugs or nudibranchs, depending on the species, inhabit either rocky shores or eel grass beds. Chitons are common inhabitants of rocky shores.

7. *Sea urchins* – Four species of sea urchins inhabit Seattle shores: the heart urchin, green sea urchin, giant red urchin and purple urchin. Only the heart urchin inhabits sand or mud areas (of very deep depths) with the others inhabiting rocky shore areas. The rock dwelling sea urchins usually stay below the low tide line and live on kelp and seaweed.

8. *Starfish* – Approximately fifteen species of starfish inhabit the Seattle area with the sand star, leather sun star, mottled star, long-rayed star, sunflower star, and brittle star being abundant.

9. *Sea cucumber* – These are muscular, water-filled, sausage-like organisms; seven species of sea cucumbers are found in Seattle. The burrowing sea cucumber and the giant sea cucumber are the only two inhabiting sand or mud flats. The other five species of sea cucumbers – white cucumber, black cucumber, creeping pedal cucumber, salt and pepper cucumber and red cucumber inhabit rocky shores at various depths.

C. Freshwater Shellfish

1. *Crayfish* – These lobster-like animals will grow to over seven inches, the largest freshwater shellfish organism in Lake Union or Lake Washington. They are usually found in shallow rocky areas seldom below the five foot water depth. They are caught for commercial and recreational use.

2. *Seed Shrimp* – The nature of the substrate and the general type of environment seem to have little influence in the distribution of these extremely small shrimp-like organisms. However, most Lake Washington species are found in water depths of three feet or less.

3. *Opossum Shrimp* – They are usually marine; however, Lake Washington contains a species which has adapted to freshwater. Commonly called mysids, they superficially resemble minature crayfish. They exhibit a daily vertical migration, confining themselves to the bottom during the day and migrating to the surface at night.

4. *Fingernail Clam* – This is an extremely small freshwater clam. These animals live on the bottom substrate (sand or mud), concentrating in deeper depths of 120 feet and below. They behave in a typical bivalve fashion, in which they filter food and oxygen out of water.

5. Scuds, Copepods and other shelled animals also populate the freshwater areas of Seattle.

D. Common Freshwater Organisms

1. *Aquatic (segmented) Earthworms* – They have the same fundamental structure and function as the common terrestrial earthworm. They feed on bottom mud and mix sediments by excavating long and rather deep burrows, thus facilitating the circulation of water within the sediments.

2. *Roundworms* – Almost any collection of sand, mud, debris or vegetation from the bottom shallows of Lake Washington will contain small roundworms.

3. *Snails* – They are bottom dwelling animals found in almost any type of bottom substrate. They will creep about in water depths between one and six feet.

4. *Watermites* – They are especially abundant where there are substantial quantities of rooted vegetation. Superficially, watermites appear to be minute spiders; however, their clambering and swimming habits identify them unmistakably.

5. *Aquatic Insect – Larva, Pupa and Adult Forms* – From a biological standpoint, insects form the most successful group in the animal kingdom. One-third of the orders of insects contain species that are aquatic or semi-aquatic. The more common insect species found in Seattle freshwater areas include: (usually only with immature stages being aquatic) mayflies, caddis flies and midges.

Seattle's Typical Tidelands

Where the Puget Sound waters meet the land, several tideland environments are found. The presence and extent of biological life varies considerably and constantly as the ecological, chemical, geological, hydrological and physical systems vary.

The following schematic diagrams are an indication of the different local tideland environments and their representative biological communities.

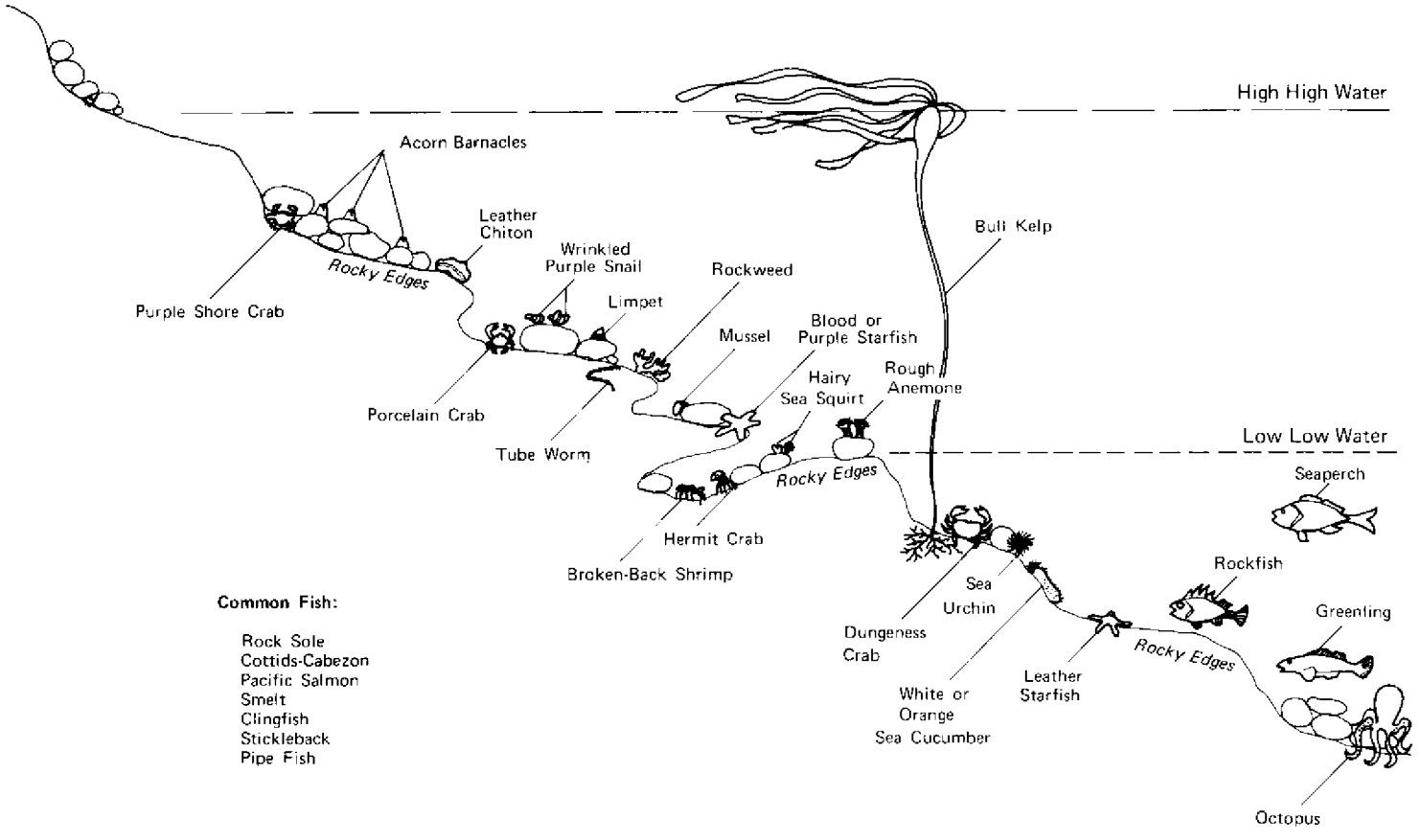
1) Rock and cobble tidelands – South Alki Beach

2) Sandy gravel tidelands – Golden Gardens

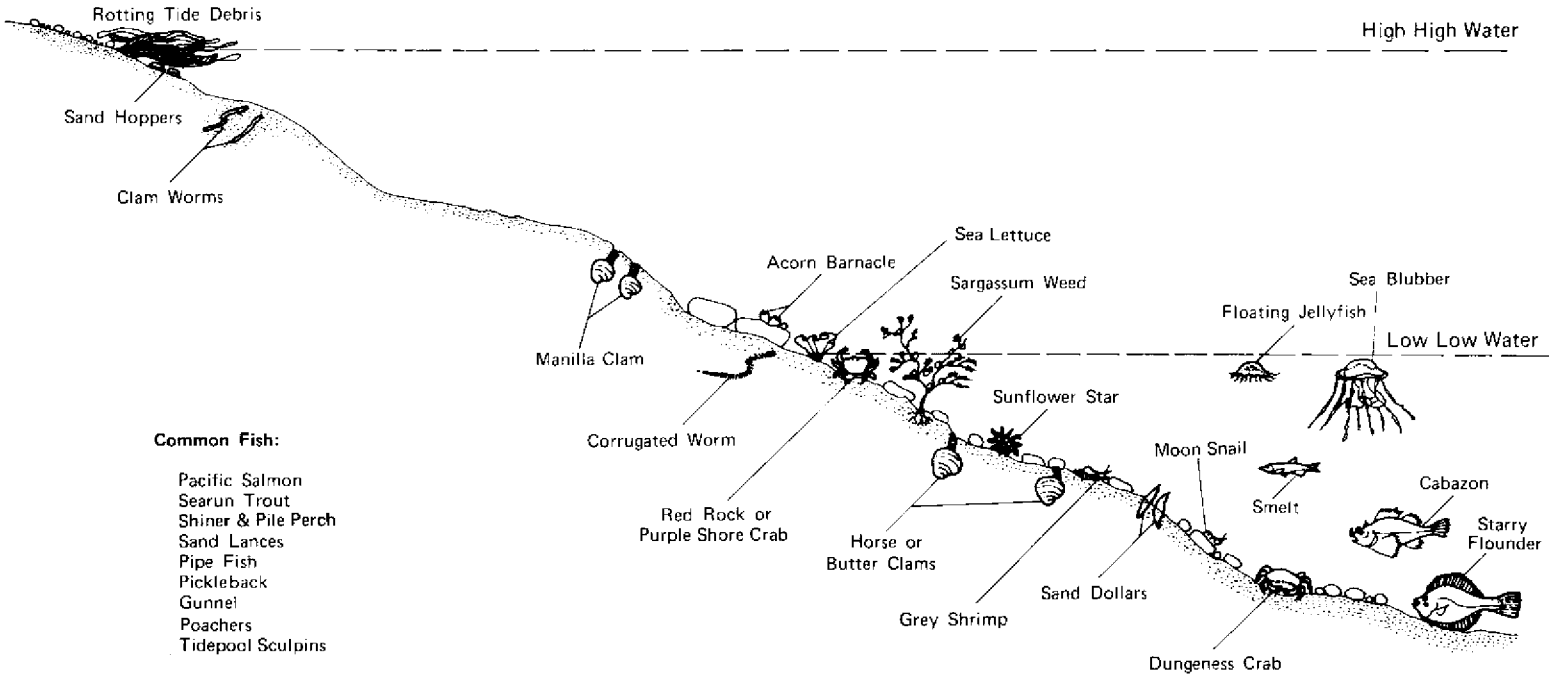
3) Muddy silt and sand tidelands – South Beach of Westpoint and Magnolia tidelands

Generally in the Seattle area the tideland environments are closely associated with each other, and often are intermixed. However, in each of the different tideland environments there are markedly representative biological communities that exist as follows:

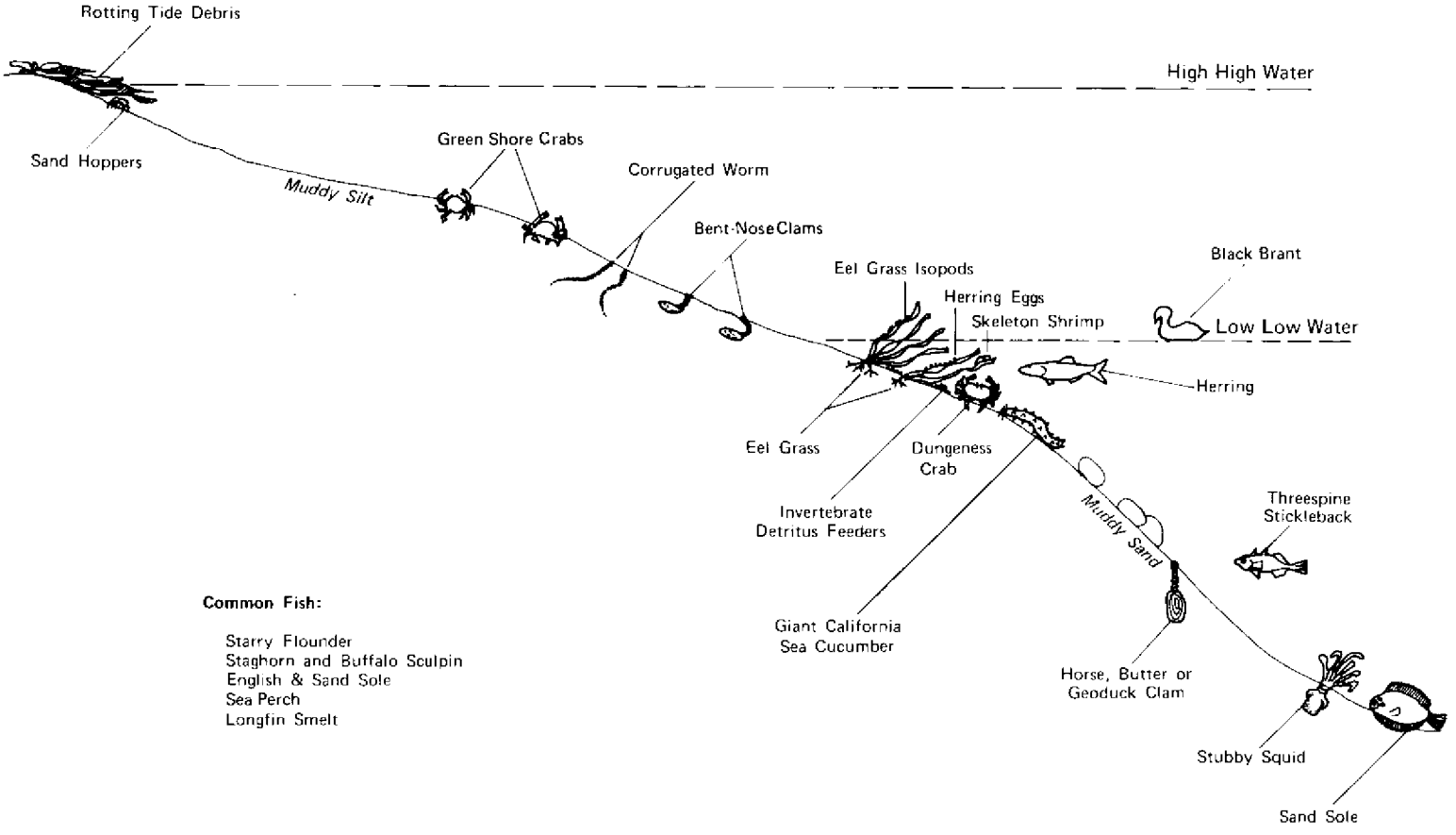
Rock and Cobble Tidelands



Sandy Gravel Tideland



Muddy Silt & Sand Tideland



Common Fish:

Starry Flounder
Staghorn and Buffalo Sculpin
English & Sand Sole
Sea Perch
Longfin Smelt

Commercial Harvesting

A. Commercial Salmon Fisheries

Commercial salmon purse seine and gill net fisheries generally operate in the areas indicated. The salmon landings (in number of pounds) for Seattle, as recorded by the Washington State Department of Fisheries, are as follows:

Average Annual Commercial Poundage for the years: 1961-1965

Chinook	3,587
Chum	261,332
Pink	3,425
Coho	200,385
Sockeye	3
Salmon Eggs	33

Average Annual Commercial Poundage for the years: 1966-1970

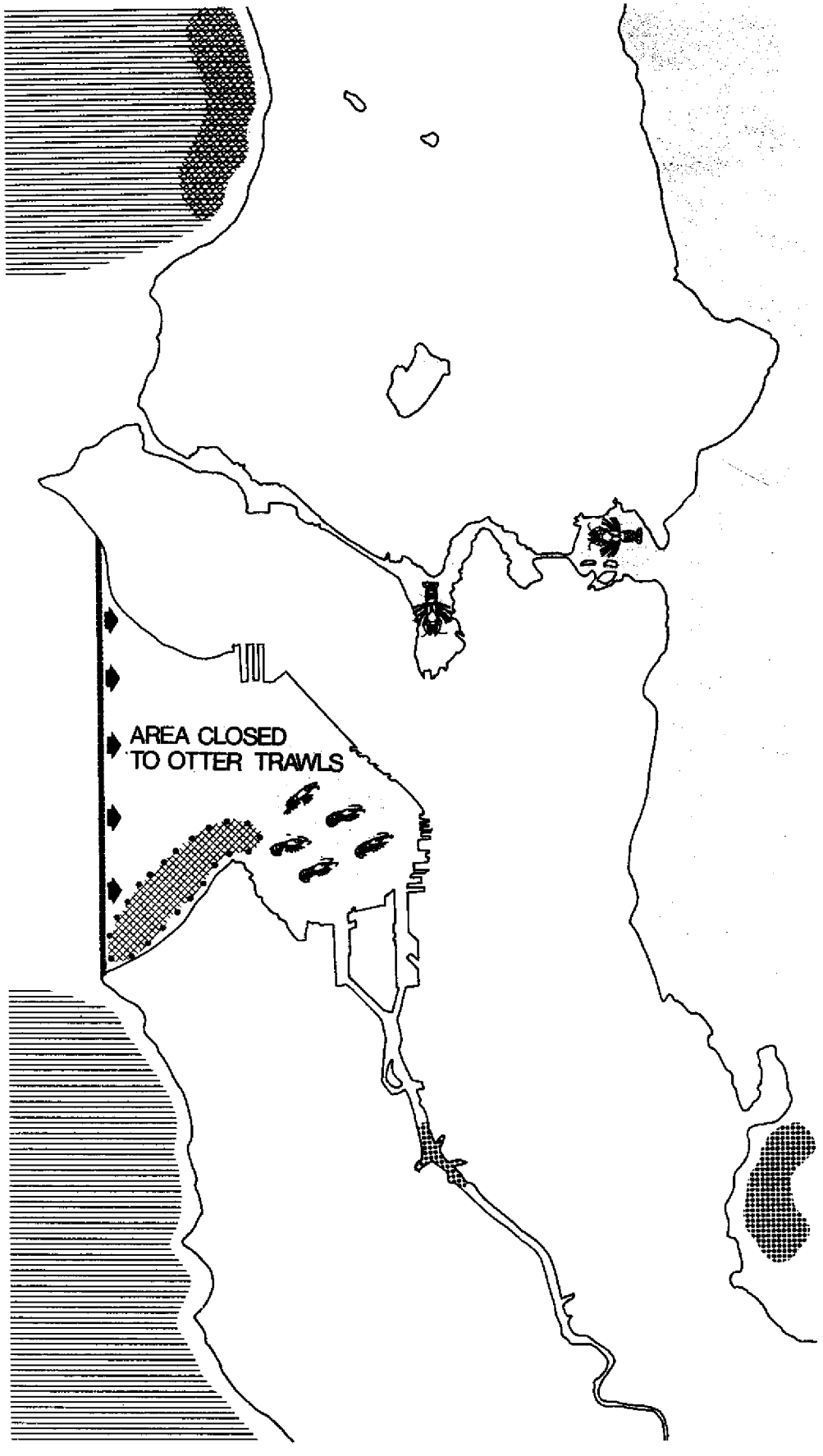
Chinook	132,596
Chum	431,770
Pink	1,217
Coho	599,952
Sockeye	30,529
Salmon Eggs	561

Commercial salmon landings and areas fluctuate with the season, conditions and type of migrating species being sought. However, commercial salmon fishermen are restricted from fishing in the designated salmon preserve areas established by the Washington State Department of Fisheries. The normal salmon preserve areas are as follows:

(1) The preserve area of Elliott Bay consists of the area east of a line from the Alki Point Lighthouse north to the Four Mile Rock. The entire Duwamish Waterway is a preserve area, although there is an Indian gill-net fishery on the Duwamish Waterway as indicated.

(2) The preserve area of Shilshole Bay consists of a three-mile radius outward from the Government Locks. This area includes Golden Gardens, West Point and the Four Mile Rock.

(3) A final preserve includes all of the drainage



basin of Lake Washington and its outflow passageways. However, in recent years there has been a "test" commercial gill-net fishery in Lake Washington which was part of a State Department of Fisheries research program, and also an Indian gill-net fishery.

B. Non-Salmon Commercial Fisheries

Over 20 fish and shellfish species are being commercially harvested in the Seattle area. The major commercial species are: herring, English sole, various other flounders, lingcod, white perch, blue perch, spot shrimp, and crayfish.

The herring fishery is located off Alki Beach and the catch is used primarily as bait fish for the local salmon sport fishery. Herring are caught by dip bag nets, round hauls, and beach seines. The average annual production in Seattle for the years 1961 to 1965 was 8,855 pounds, while the average annual production for the years 1966 to 1970 was 45,976 pounds.

English sole is the most important commercial flat fish, with the average annual production for the years 1966 to 1970 of 23,781 pounds. All the commercial flounders and sole (English, Dover, sand, and rock) are caught with otter trawls.

The Seattle area yields small amounts of lingcod, white sea perch, blue sea perch, and spot shrimp for the local commercial fisheries each year.

Ocassionally, true cod, rockfish, green sturgeon, skate, and silver smelt are commercially harvested.

The only commercial freshwater fishery is for crayfish, which are caught with pots in the shallow areas of Lake Union and Lake Washington. Most of the catch is exported to Europe where crayfish is a delicacy.

Sport Fisheries

Without a doubt, the most important and most intensive sport fishery in the Seattle area is based on the Pacific salmon.

The 1971 sport salmon catch (as recorded by the Washington State Department of Fisheries) for the Seattle area (defined as the Puget Sound waters south of a line true west from Richmond Beach and north of a line true west from Des Moines) was 35,225 salmon. The eight-year average for Seattle's marine salmon sport catch (1964-1971) was approximately 22,903 salmon. (This count only includes chinook, coho and pink salmon).

The 1971 sport salmon catches in the freshwater areas of the Duwamish and Lake Washington were 1,134 and 20,389 salmon, respectively. The eight-year average freshwater salmon sport catches (1964-1971) were 1,510 and 4,663 salmon, respectively.

A smaller but highly prized sport fishery is for the searun trout species. The Duwamish River and western end of the Lake Washington ship canal provide the main fishing areas, with Steelhead being the most sought after searun trout species.

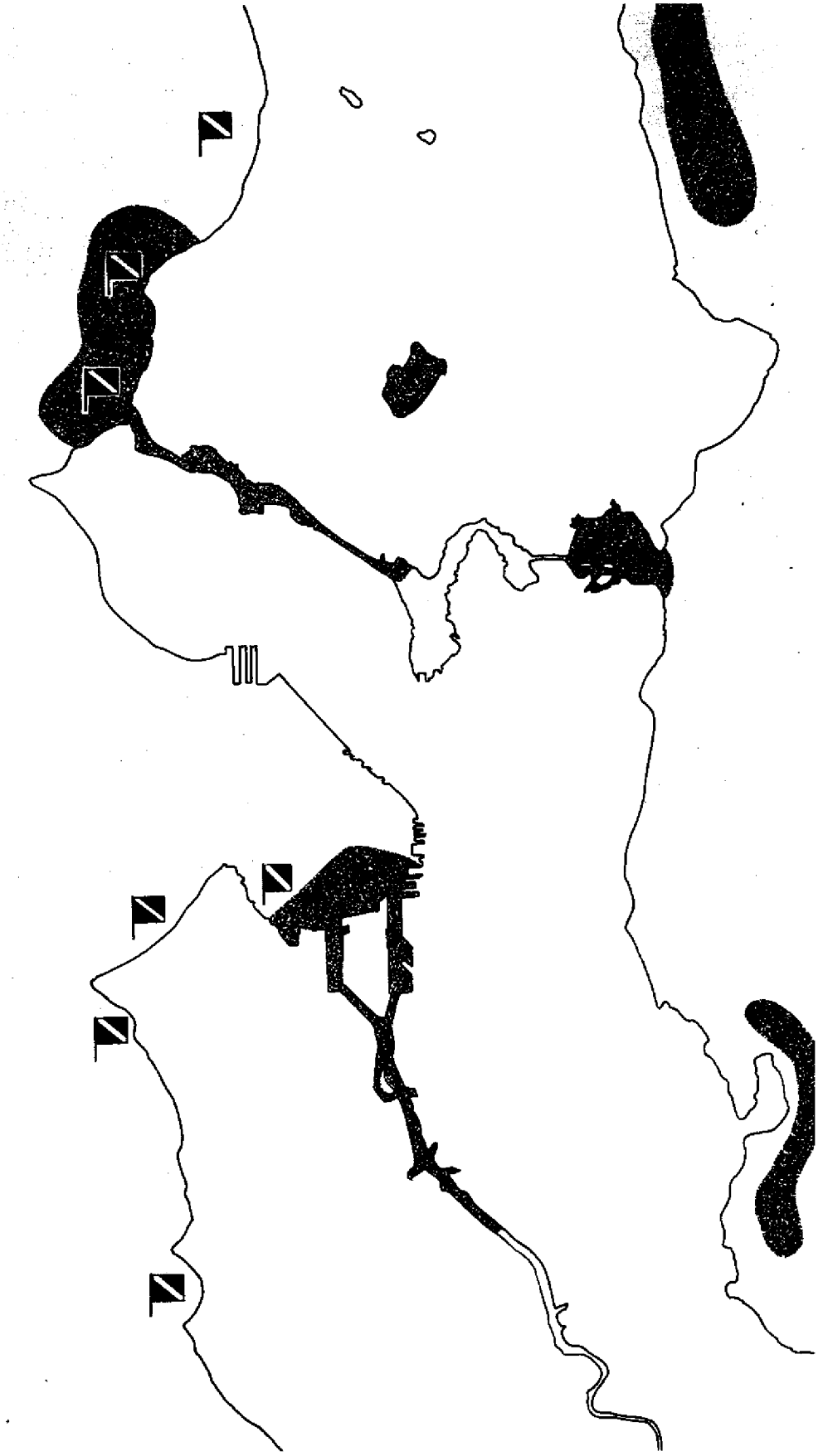
The saltwater and freshwater salmon and trout fisheries dominate so completely that most fishermen tend to ignore the existence of the sport fishing potential for other aquatic resources.

For instance, the bottomfish stocks of Elliott Bay are presently being utilized by relatively few sport anglers. However, rockfish, greenlings, English sole, sea perch, black cod, starry flounder and lingcod are being successfully caught by sport fishermen because of their abundance.

Surf perch and pile perch are used as a recreation resource by many shore and pier fishermen.

The shellfish populations of Seattle also support an active sport fishery with clams, crabs and crayfish being eagerly sought.

The largemouth bass, crappie, brown bullhead, kokanee, and rainbow trout are important sport species in Seattle's freshwater areas.



NORTH

Sport Fishing

Underwater Diving

Underwater Recreation Areas

Underwater recreation areas are sites utilized by scuba and free divers. They are of special interest because of the underwater biological life which exists in these localities. Collection, observation, exploration, photography and spearfishing are the attractions of the sport.

1. Alki Beach — includes many sunken wrecks placed by conservation-minded diving groups to create fish havens;

2. Golden Gardens Beach — provides easy access and a wide variety of biological life;

3. Shilshole Breakwater — is a haven for octopus, lingcod, cabezone, pink scallop and rockfish, which are eagerly sought by the underwater divers;

4. Carkeek Park and Lincoln Park areas — also promise easy access and a wide variety of marine life.

Wet-suit skin diving and scuba diving are popular in most rocky bottom areas supporting stands of kelp or eel grass, because of their rich biological life and their tendency toward clearer water.

Most divers swim out from shore; others use boats for access to the water. Free divers stay mainly within the 30 foot depth and scuba divers may work in depths up to 100 feet; but most of all diving in the Seattle area is done within the 60 foot depth.

Plant Life

Because of the immediate need for timber, early Seattleites depleted the great forest reserves which once covered our city.

Most of the natural vegetation in Seattle has been destroyed by man's activities. Nevertheless, many shoreline parks and undeveloped green belts still retain beautiful and important qualities of the original landscape.

Upland vegetation is of environmental and scenic value. The scenic green spaces of upland vegetation help purify and cool the air, absorb noise, and provide food, protection and habitat for wildlife.

The range of elevation, along with diverse topography, favorable climate, and abundant precipitation, causes a great variety in local vegetation.

The following list is representative of the native and naturalized trees and shrubs which may be found along the Seattle shoreline:

Western Hemlock
Western Red Cedar
Douglas Fir
Pacific Silver Fir
Sitka Spruce
Grand Fir
Pacific Yew
Quaking Aspen
Black Cottonwood
Salmon Berry
Monarch Birch
Sword Fern
Ocean Spray
Rose
Evergreen Huckleberries
Red Huckleberries
Blueberry
Western Spiraea
Bigleaf Maple
Red Alder
Scoulers Willow
Bitter Cherry
Pacific Madrone
Pacific Dogwood
Oregon White Oak
Western White Pine
Vine Maple
Cascara Buckthorn

Rhododendron
English Holly
Montpellier Maple
Red Horsechestnut
Norway Maple
English Hawthorn
London Flame
Katsura Tree
English Boxwood
Bracken Fern
Cotoneaster
Chinese Pieris
Camellia
Western Yew
Monkey Puzzle
Southern Magnolia
Western Hawthorne
White Poplar
Japanese Pagoda Tree
Tree-of-Heaven
Northern Red Oak
Sycamore
Low Oregon Grape
High Oregon Grape
Engelmann Spruce
Elderberry
Indian Plum
Blackberry
Serviceberry

The map (see page 31) indicates those areas where the above trees or shrubs may be most commonly found. The map includes all official City of Seattle green belts, all City of Seattle shoreline parks, and all vegetation growth areas of proximity to the water including those relatively untouched shoreline ravine sites.

In summary, the only natural forest of vital interest in the city is at Seward Park, although, many other important shoreline vegetation areas and clumps of water loving trees do thrive in many other parts of Seattle.

Other plants of interest and value growing either at the interface of water and land (emersed) or entirely in or on the water (submerged or floating) include:

Eel Grass - Eel grass plays an important role in the ecology of intertidal and subtidal marine waters. Optimum growing depths are 3 to 12 feet of water below mean low tide in muddy silt or muddy sand bottoms. Eel grass commonly grows in areas of little wave action and only if the currents of the area are under 3.5 knots, although eel grass cannot grow in completely stagnant waters. (See map on page 21.)

The primary contributing community role of eel grass is to:

(1) stabilize bottom sediments;

(2) provide a substance for bacteria and clinging organisms;

(3) provide decaying plant matter for a host of invertebrate detritus feeders;

(4) provide cover, food, shelter, and protection for various juvenile and adult marine organisms.

Thus, many organisms find their homes in, around, and upon eel grass while many others, such as fish and crabs, use the beds for feeding, resting and spawning activities. Also, the juvenile of many species of fish and crabs, and larval forms of various crustacea (shellfish), use the beds as rearing grounds. The perennial eel grass meadows provide a stable food web linkage between the primary producer and the herbivores and detritus feeders, a link which leads ultimately to the carnivorous fishes. Marine life in eel grass beds is varied and includes micro-organisms, larvae, herring eggs, and other valuable and interesting resources such as clams, flatfish, sea perch, and Dungeness crabs. Eel grass is also a basic source of food for the migrating black brant.

Algae and Seaweeds

Algae, which includes all seaweeds, vary greatly in size, habitat, and usage. Algae can be grouped according to their color, for algae pigments are good guides to various structural and bio-chemical relationships. Like all plants, algae are very sensitive to seasonal differences in light, water temperature and abundance of nutrients. The most common of the marine species found off Seattle beaches is the brown algae, of which the bulbous kelp, familiar to beach walkers and boaters, is one type. The most common of the freshwater types is the green algae, although the common Seattle marine algae, sea lettuce, is also a green algae. Generally, freshwater algae are less common and smaller in size than marine algae.

Freshwater Plants

Freshwater environments support many more emersed, submerged and floating species of higher plants than do saltwater areas. Some of the more common freshwater aquatic plants found in Seattle include:

Water Plantain — This plant grows in water 1/2 feet or less in depth. Mallard, green-wing teal, and American widgeon feed on the seeds of this plant.

Arrowhead or Wapato — This plant is an excellent food for waterfowl and usually grows in less than one or two feet of water.

American great and small-fruited bulrush — Bulrushes grow in various bottom materials particularly sand. They have strong, food-storing roots that can withstand heavy wave action. In dense stands the stems help to break the wave action against the shore and thus provide shore protection.

Broad-leaved cat-tail — Cat-tails offer good cover for waterfowl but only geese have been observed to feed on the vegetative parts of this plant. However, cat-tails are considered inferior to bulrushes in the amount of cover they provide.

Sedges — Sedges usually grow in water depths of 4 feet or less and provide shelter, food and spawning facilities for fish. Sedges provide little or no food for waterfowl but do provide excellent cover for waterfowl and usually support large insect populations.

Green's and simple-stemmed burreed — These plants provide no food for waterfowl but do provide excellent cover for waterfowl and wildlife.

Canadian waterweed — This plant has limited use as a food plant for waterfowl.

Duckweed Fern — This plant has limited use as a food plant for waterfowl.

Coon-tail — These plants have no roots and therefore are not influenced by the character of the bottom. They grow entirely submersed in quiet bays at depths of 2 to 14 feet. Coon-tail are eaten by waterfowl but may crowd out other valuable plants. The plants provide shelter for juvenile fish and support insect life.

Yellow Pond-Lily — These plants usually grow in water depths of 10 feet or less. They require silt, muck, or rich organic soil in very quiet or

slow-moving waters. They have strong, large tubers and root systems that hold the bottom extremely well. Pond lilies offer some shelter and shade to juvenile and adult bass, sunfish, and other fish. Pond lilies provide only limited amounts of food for waterfowl but their leaves provide a place where aquatic insects can deposit their eggs.

Greater Duckweed and Lesser Duckweed – These are small plants which float on the surface and therefore are not dependent on the character of the bottom. Duckweed requires still, undisturbed water, and prefers shallow, shady places. Duckweed is excellent food for waterfowl but is not regarded as desirable for fish life since, in dense stands, they shut out light to other vegetation and animal life below, and have little value as aerators of the water.

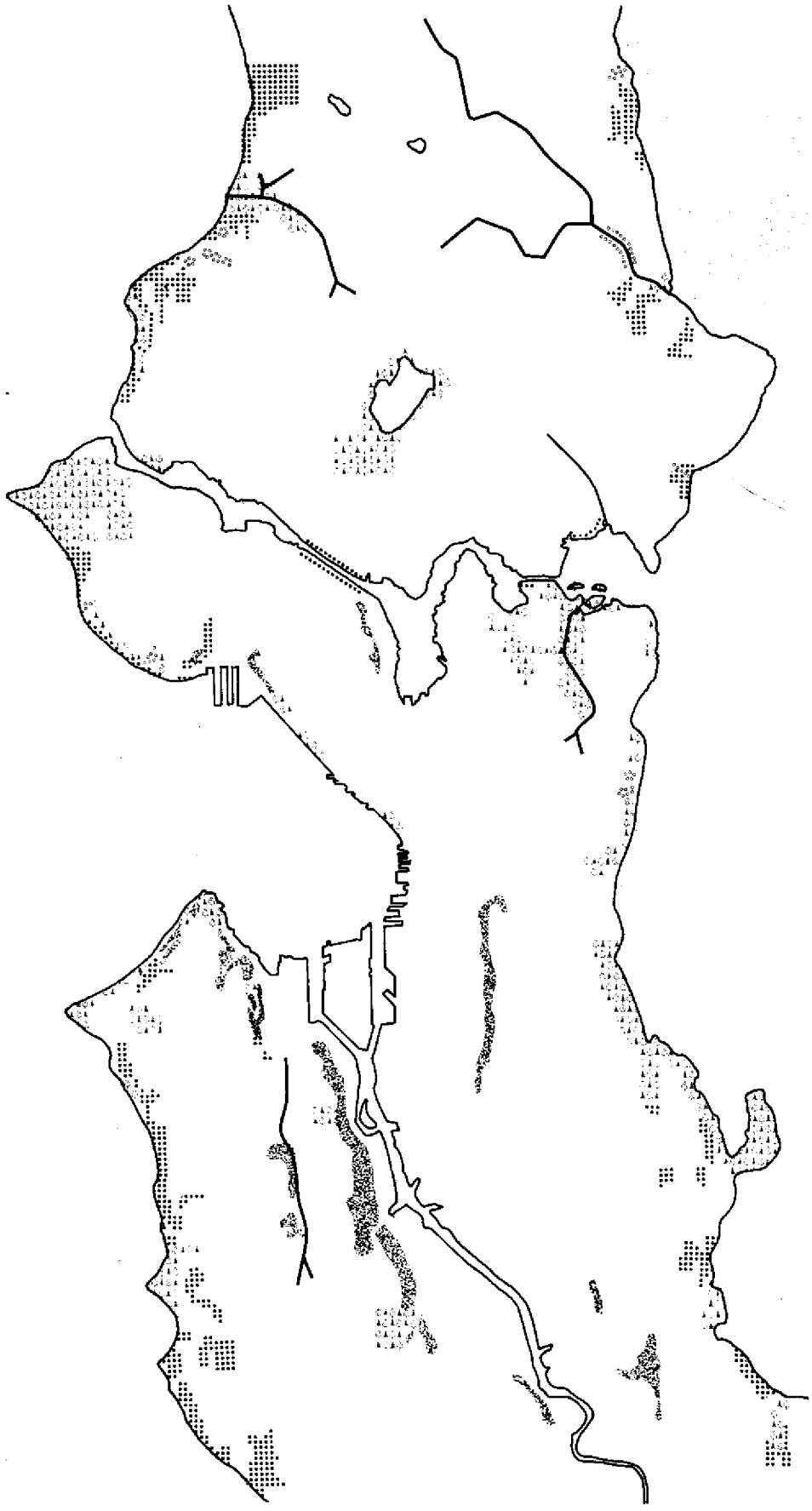
Pondweeds –

a) Slender Najas or Bushy Pondweed – This is a submerged plant with flowers which grows in various bottom substrates. It will effectively shelter young fish, such as sunfish, and is heavily used as waterfowl food.

b) Nuttail's Pondweed, Small pondweed, Sago pondweed, and Richardson's Pondweed – These are all submerged plants utilized by waterfowl for food and by juvenile fish for shelter.

In general, the pondweed group usually dominates the zone of submerged vegetation and are commonly found in water depths of 5 to 16 feet on the slope just below the shoal. Pondweeds utilize a variety of soils but favor those with moderately rich bottoms. They can withstand fairly heavy wave action. They also offer excellent shelter for young fish and, in some cases, may even attract adult fish. Pondweeds support large insect populations and are frequented often by foraging fish. In summary, pondweeds are important plants for fish and waterfowl production.

The above freshwater plants can be found at almost any relatively natural shore. The aquatic plants are not only biologically important but may also protect the shore against erosion.



The most abundant plant stands are located at Thornton Creek, Union Bay Marsh, Portage Bay Marsh, and other freshwater marshlands (see map on page 33). Fortunately, these plants are also common around human alterations of the natural shoreline. Numerous undeveloped shoreline lots (street ends, waterways, vacant lots) and natural plant growth areas adjacent to private shoreline residences are additional resources that provide essential food and cover for fish, waterfowl and wildlife.

Unfortunately, the littoral zones available for freshwater plants in Lake Washington is limited. The water of Lake Washington is of relatively poor transparency and only 9% of the surface area is shallower than 5 meters. Thus, Lake Washington has a fragile and limited littoral primary production zone.

Marshlands

Marshlands are areas of shallow water that are gradually being filled through nature's processes of sedimentation and the decay of shallow water vegetation. These areas are extremely important to plant and animal life and are highly susceptible to irreversible damage from human activities. These marshes support a wide variety of life: vertebrate and invertebrate, reptile, amphibian, fish and mammal.

Seattle's Marshlands

1. Union Bay
2. Portage Bay
3. Westmore Slough
4. Lakewood Bay
5. South Andrew Bay
6. North Brighton Beach
7. Atlantic City Park
8. Kellogg Island

Wildlife

Rapid expansion of urban and suburban development has had serious implications for the local animal populations.

Initially, early Seattleites saw wildlife as an economic asset. Today, the emphasis is more on its recreational, educational and aesthetic values.

In Seattle, the animal populations are in scattered areas where diverse and relatively stable, though restricted, wildlife communities are part of man's total environment.

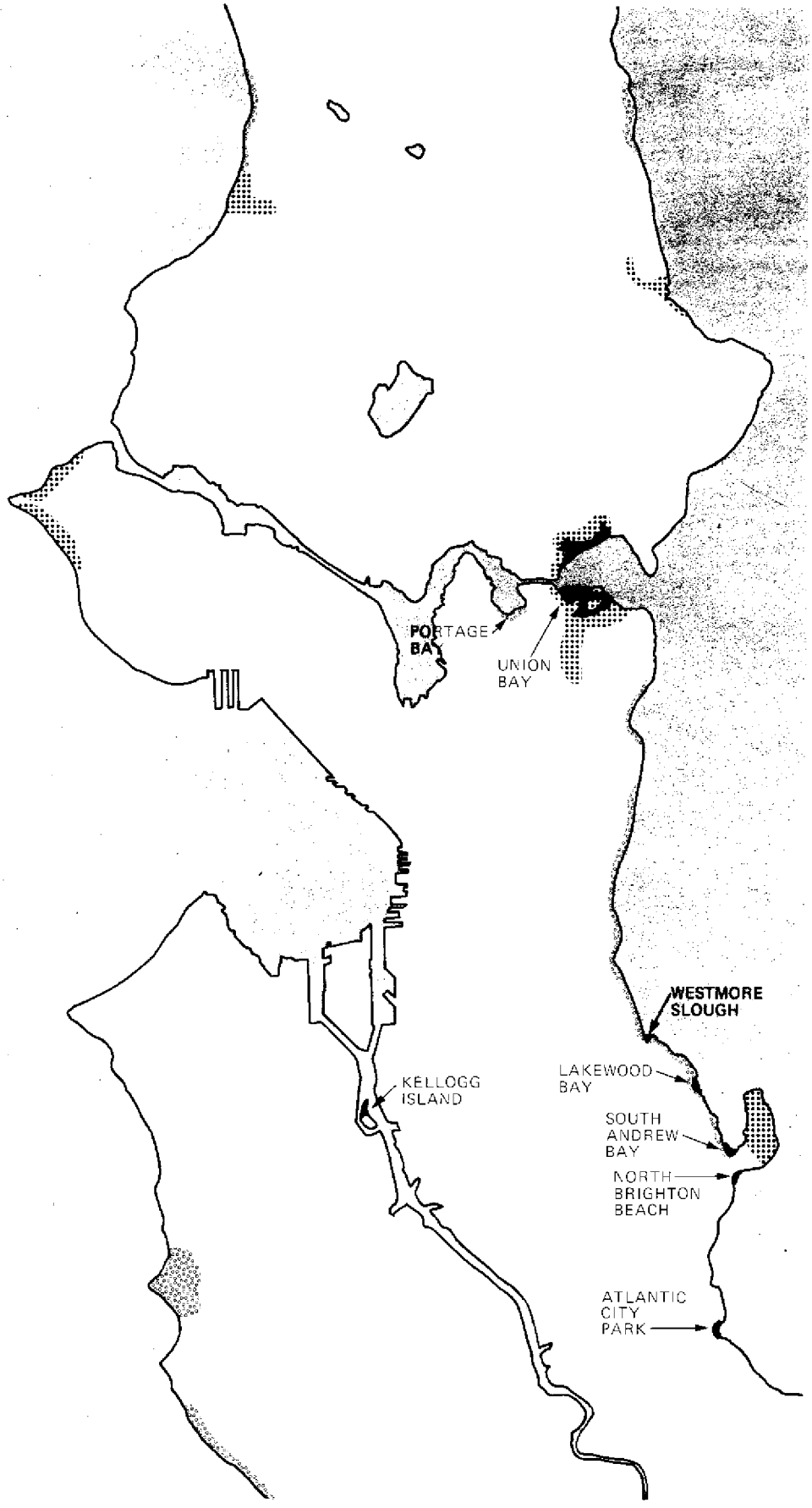
It is vitally important to understand the part wildlife plays in the balance of nature in an urban environment, and to establish management values that lead to the preservation of this wildlife.

The critical element for wildlife is vegetational abundance and diversity. As marshland or upland vegetation is reduced, a correlated reduction of wildlife will occur.

Fortunately, diverse and abundant wildlife populations are still found in areas of substantial vegetation, such as Seward Park and Carkeek Park.

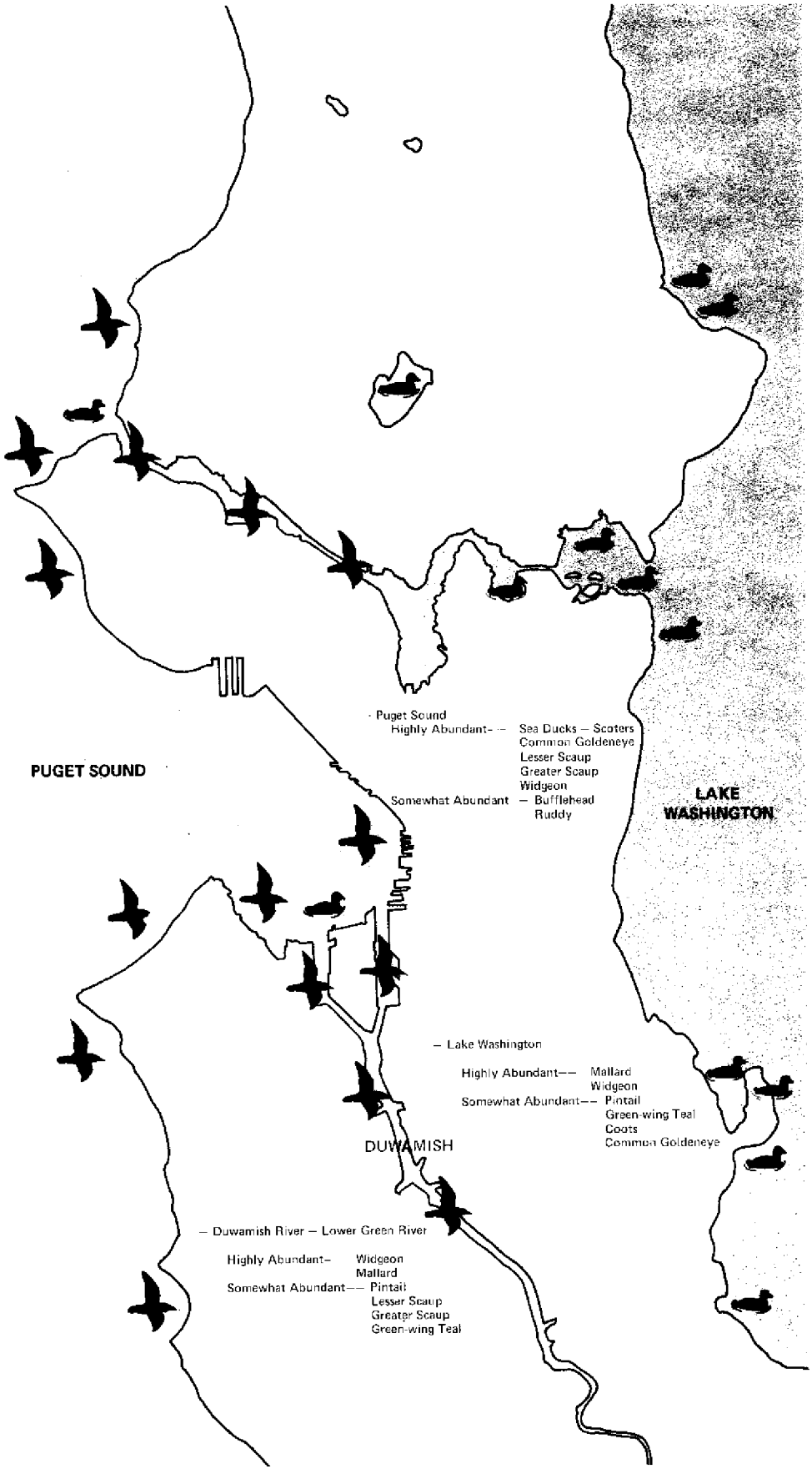
Meanwhile, less diverse and less abundant wildlife exists in areas of modified landscapes of less vegetational density. Much of the suburban areas surrounding Seattle consist of large undeveloped residential lots, vacant lots, neighborhood parks, and undeveloped ravines, all of which provide necessary vegetation for scattered populations of wildlife.

Deer, elk, and other large species of wildlife are no longer within the city limits. However, some smaller animals have adapted well to human pressures, such as the raccoons, and long-tail weasels. Shrews, moles and mice are commonly found where soil characteristics allow burrowing. Rabbits and squirrels are forms common throughout the city. The remarkable ability of wild animals to adapt to urban influence is further indicated by the presence of coyotes in Seward Park.



Waterfowl and Water-Associated Bird Life

The Seattle area is principally a wintering feeding and resting ground for waterfowl which use the Pacific flyway during their fall migration south, and then again during their spring migration north. Development for industry, residences and recreation have altered much of the shore and intertidal habitat to such an extent that almost no shore birds inhabit the Seattle area anymore. Nevertheless, Seattle still retains some measure of diversified habitats (from saltwater to freshwater) for waterfowl and water-associated birds. Many birds and waterfowl stay exclusively on saltwater, (eg. surf scoters). Some of the waterfowl species in Puget Sound rest in the open saltwater areas. Other waterfowl feed in or near the marine tidal zones; for instance, the migrant black brant will feed extensively on submerged eelgrass. However, most waterfowl species in this area will utilize either the saltwater areas of the Sound or the freshwater areas of Lake Washington and of the Duwamish River. A few water-associated birds or waterfowl will exclusively inhabit the freshwater areas. (e.g. Hooded Mergansers). The Seattle area has a large number of year-round resident population of waterfowl and water-associated birds inhabiting freshwater marshes (e.g. mallards) or marine shorelines (e.g. gulls). Generally, most waterfowl or water-associated birds can be found in protected habitats (coves and inlets) of minimal human harassment and minimal pollution. Exceptions are the semi-domesticated birds such as the mallards, which will live any place human hand-outs are available. Theoretically, any bird species known to live or visit within the city limits could be found near the shore, however, the following list only includes the waterfowl and water-associated birds commonly found on Seattle shorelines.



WATERBIRD ABUNDANCE IN WINTER (not including species which are only migrants)

Species	Freshwater	Saltwater
Common Loon	○	●
Arctic Loon		○
Red-throated Loon		○
Red-necked Grebe		●
Horned Grebe	●	●
Eared Grebe	○	○
Western Grebe	●	●
Pied-billed Grebe	●	
Double-crested Cormorant	○	●
Brandt's Cormorant		○
Peleagic Cormorant		○
Great Blue Heron	○	○
Canada Goose	●	
Mallard *	●	●
Gadwall *	○	
Pintail *	●	
Green-winged Teal *	○	
American Widgeon *	●	●
Shoveler *	●	
Redhead *	○	
Greater Scaup +	○	●
Lesser Scaup +	●	○
Common Goldeneye +	●	●
Barrow's Goldeneye +		○
Bufflehead +	●	●
White-winged Scoter +		●
Surf Scoter +		●
Common Scoter +		○
Ruddy Duck +	●	○
Hooded Merganser †	○	
Common Merganser †	○	
Red-breasted Merganser †		●
American Coot	●	●
Killdeer	○	○
Black Turnstone		○
Sanderling		○
Glaucous-winged Gull	●	●
Herring Gull	○	○
Thayer's Gull	○	○
Mew Gull	●	●
Common Murre		○
Pigeon Guillemot		○
Marbled Murrelet		○
Rhinoceros Auklet		○

WATERBIRD ABUNDANCE OF MIGRANTS (spring and/or fall only)

	Freshwater	Saltwater
Ring-neck Duck +	○	
Canvasback Duck +	○	○
California Gull	○	○
Ring-billed Gull	○	○
Bonaparte's Gull	○	○
Snow Goose		○
Black Brant		○

NORTHWEST WATERFOWL AND THEIR FOOD PLANTS	Aquatic Plants									Marsh Plants			
	Pondweeds	Wild Celery	Widgeon Grass	Eel Grass	Yellow Water Lily	Musk Grasses	Duckweeds	Coontail		Wild Rice	Wapato	Chufa	Wild Millet
DIVING DUCKS +													
Greater Scaup	●	●	●	●		●	●	●		●	●		
Lesser Scaup	●	●	●	●	●	●	●	●		●	●		●
Ruddy Duck	●	●	●			●		●		●	●		
Bufflehead	●	●	●	●		●	●	●		●			
Common Goldeneye	●	●	●	●		●		●					
White-winged Scoter	●	●		●				●					
Surf Scoter	●	●	●	●									
SURFACE-FEEDING DUCKS *													
Mallard	●	●	●	●	●	●	●	●		●	●	●	●
Pintail	●	●	●	●	●	●	●	●		●	●		●
American Widgeon	●	●	●	●		●	●	●		●	●		●
Green-winged Teal	●	●	●			●	●	●		●	●		●
Gadwall	●	●	●			●	●	●			●		●
Shoveler	●		●		●	●	●	●			●		●
GEESE													
Canada Goose		●		●						●	●	●	●
MIGRANTS													
Snow Goose		●								●			●
Black Brant			●	●									
Ring-neck Duck (diving duck)	●	●	●		●	●	●	●		●			●
Canvasback Duck (diving duck)	●	●	●	●	●	●	●	●		●	●	●	●

Duck Classification

* A) Surface-feeding ducks — These ducks are also called dabbling ducks (eg. mallard, widgeon) and they will concentrate in the shallow fresh water or intertidal marine water.

\+ B) Diving Ducks — These ducks (eg. scaup, scoter) do not rely heavily on shallow water plants and thus they are found farther out in open water areas.

† C) Fish Ducks — These ducks (eg. common merganser) primarily feed on small adult or small juvenile fish. They are found in shallow water areas.

● Common

○ Less Common

Geology

The geological materials as well as topography of Seattle shoreline areas, were primarily the result of glaciation.

The most recent of the great ice sheets advanced into the Puget Sound lowland approximately 15,000 years ago. As the glacier moved into the Puget Sound lowland, a large freshwater lake was formed around the Seattle area. This lake was located in front of the advancing ice because drainage out of the Puget Sound lowland was blocked by the northerly position of the glacier. Silt and clay particles settled to the bottom in the less turbulent parts of the lake producing a sediment layer known as Lawton Clay. Deposits which immediately predate the last glaciation are found stratigraphically beneath the Lawton Clay formation.

As the glacier continued southward, sand particles were deposited on top of the lake-fill. The thick layer of sand, known as Esperence Sand was deposited by the meltwater streams before the glacier advanced over Seattle.

When the glacier neared the Seattle area, a coarser and more pebbly-type of sediment was deposited. This coarser sand and pebble-sized gravel, known as Vashon advance outwash was deposited by meltwater streams. The southward advancing Puget lobe of the last glacier continued cutting troughs and sculpturing hills 15 miles beyond Olympia. Finally, as the glacier began to melt about 13,500 years ago, a less compact layer of Vashon till was deposited by the now retreating glacier. Stratigraphically, the glacial deposits can be found with Esperance Sand overlying the Lawton Clay and underlying the Vashon outwash and Vashon till. The boundary between the sand and the clay will later be referred to as a contact which is an impermeable boundary to the downward seepage of water. (see hazardous landslide zones, page 38).

Thus, the topography and underlying material of Seattle, Puget Sound, and Lake Washington are primarily the result of glacier deposition and excavation that deposited diverse material and cut out deep, water-filled troughs.

The sediments of uplands are well known. The submerged sediments of Puget Sound and Lake Washington, however, are not so well known.

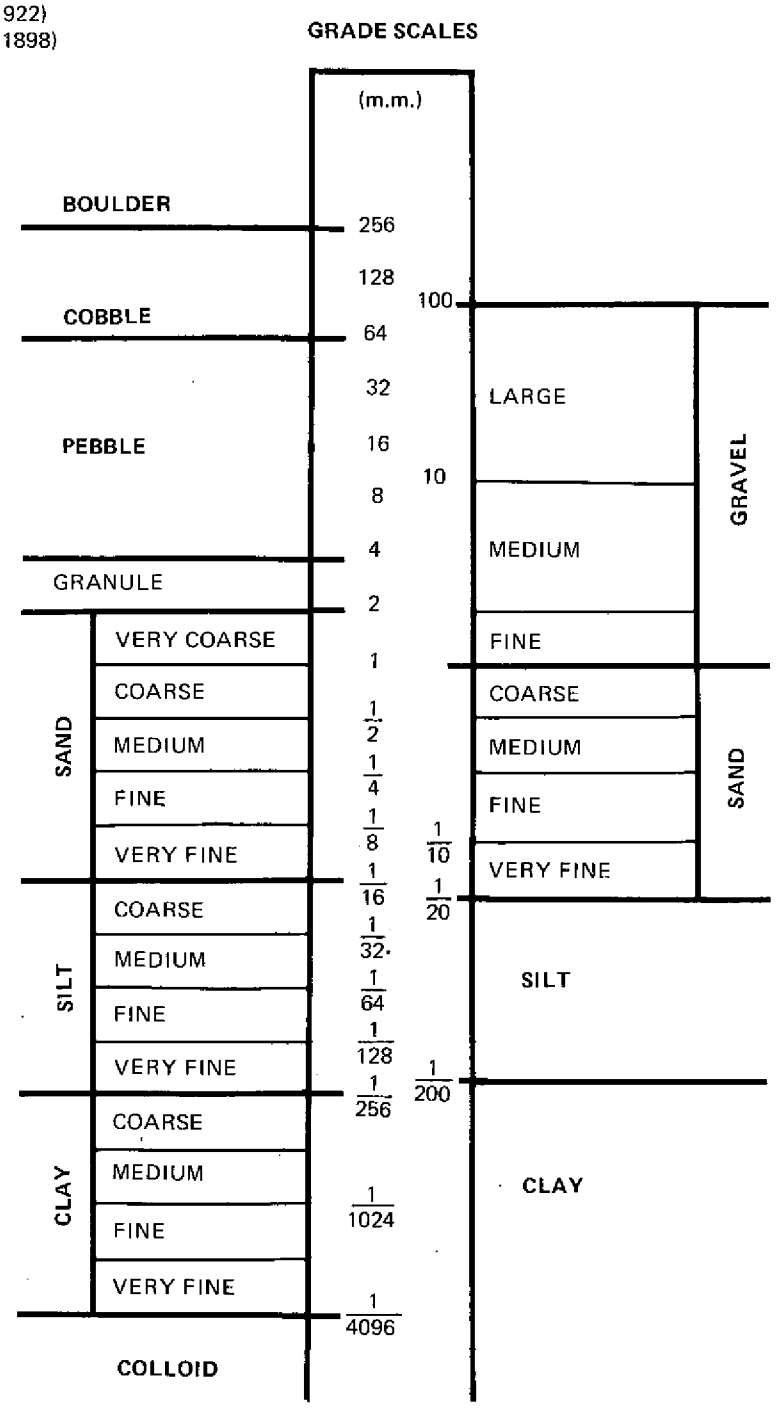
Unfortunately, comprehensive bottom sediment studies of submerged lands are not available, although scattered core sampling and dredging data is available. Knowledge of the sediment types and stratification for submerged lands will not be realized until extensive surveys are conducted.

Resorting and redepositing of sediment is well documented by up to date surveys for upland areas. However, what effect man's activities has had on submerged sediments is not known. Man has changed river transport, aggravated shore erosion, dredged, erected shore protection structures and probably caused numerous unknown changes in submerged sedimentation. Therefore, the sediment characteristics of Seattle's submerged shorelines is still quite unknown.

Grain Size for Sediments

Taken from Wentworth(1922) after Udden (1898)

U.S. BUREAU OF SOILS



NORTH

Vashon Till

Esperance Sand

Alluvium

Lawton Clay

Fill or Modified Land

Other

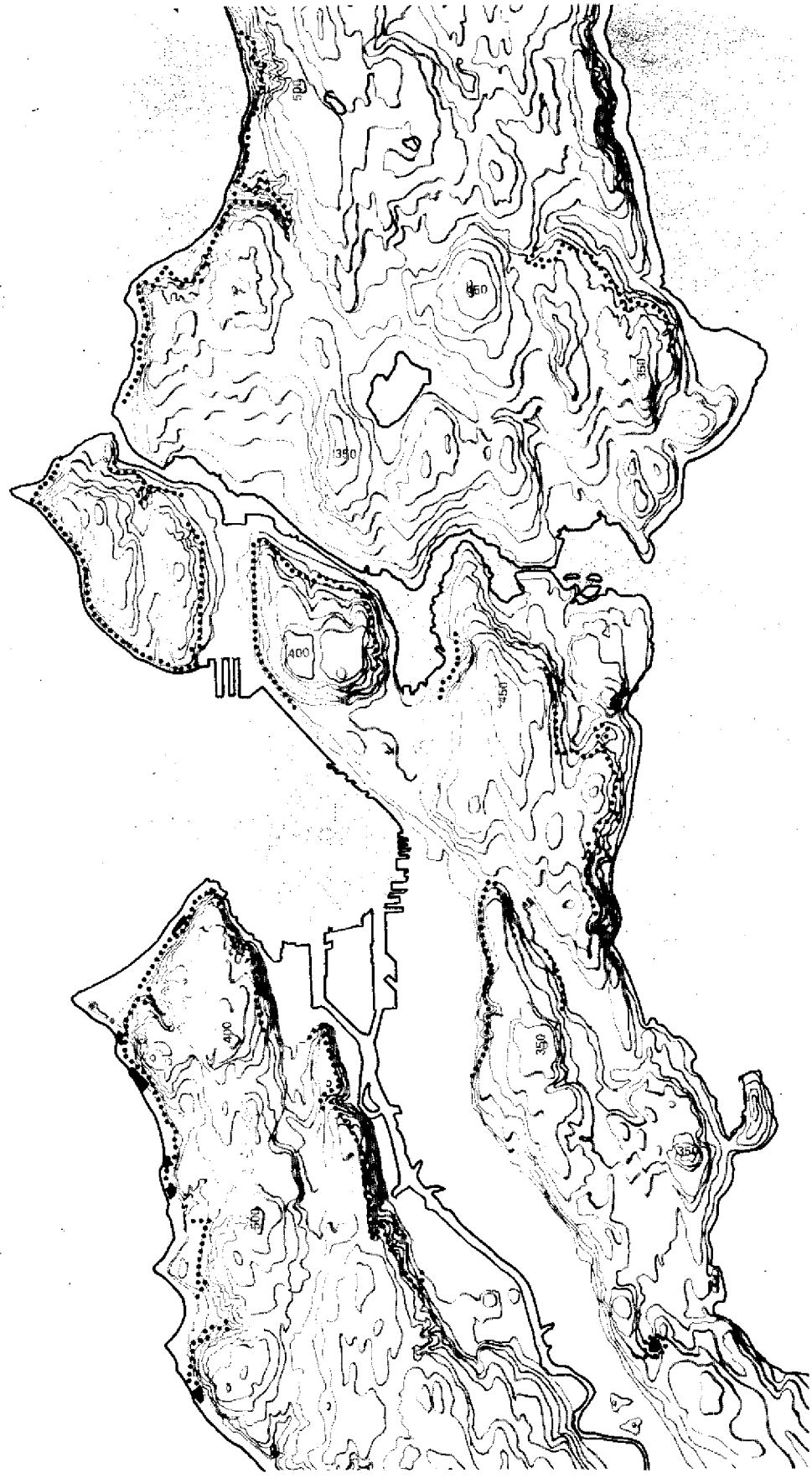
Hazardous Landslide Zones

The most hazardous landslide zones are largely those areas that follow the "contact" between the overlaying Esperance Sand and either the underlying Lawton Clay or pre-Lawton sediments. Groundwater can easily move downward through the permeable sand but is stopped when it reaches the underlying impermeable clay sediments. The ground water then moves laterally along the top of these clay deposits until it reaches the hillside as groundwater seepage. Hillsides of this kind, depending on the slope, are particularly sensitive to changes in groundwater conditions caused by heavy rainfalls and to the diversion of additional drainage water onto the hillside, usually from roofs or paved roads. The permeable sand deposits are readily saturated by the groundwater, because the groundwater cannot readily seep into the impermeable clay deposits. When the sand deposits become super-saturated with groundwater, the seepage of the water reduces the hillside stability and a landslide may be triggered.

Therefore, due to groundwater seepage, the major hazardous landslide zones within the Seattle area are along the contact between Esperance Sand and Lawton Clay.

Other hazardous landslide areas include past landslide deposits. Such material is often unstable and is easily saturated with groundwater; it is quite susceptible to slides.

Another type of hazardous landslide zone is found where waves cut away at the base of cliffs, so that the slope becomes too steep and the undercut material slides down to the beach, later to be removed by waves and currents. Under this combination of wave and tidal action, the sea cliffs are slowly retreating. The sea-bluffs south of West Point are typical of this process.



NORTH

Unstable Contact Line

Landslide Deposit

Scientific - Educational Areas

The many diverse environments characteristic of Seattle provide many areas of scientific or educational interest.

Bluffs — North and south uplands of Westpoint

Tidelands — North and south beaches of Westpoint

Freshwater Creeks — Thornton Creek and Piper Creek

Marshlands — North and south shores of Union Bay

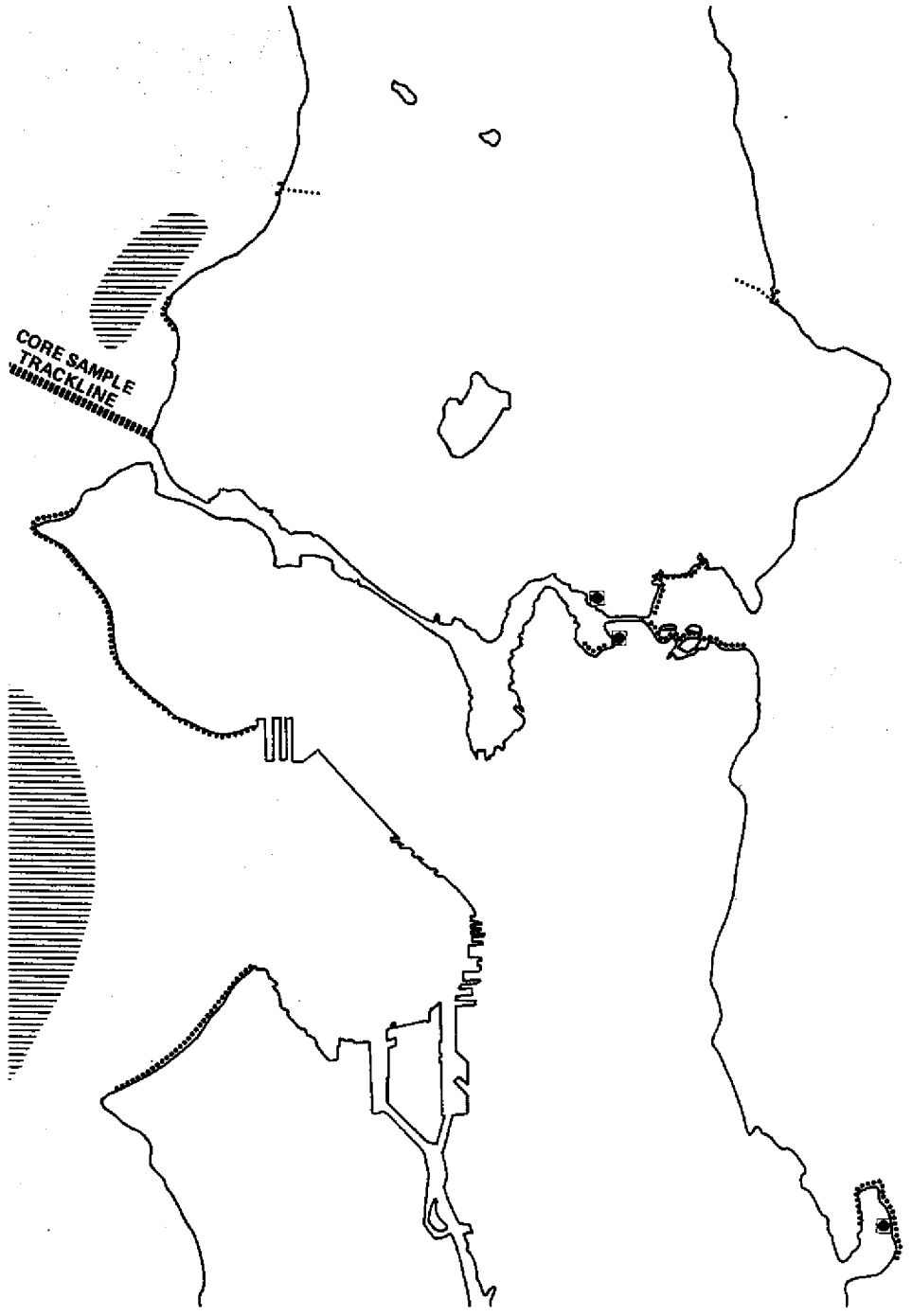
Natural Beaches — Alki Beach and Golden Gardens

Virgin Forest — Seward Park

The local scientific communities also utilize submerged lands:

1) Geological core sample trackline

2) Benthic research sites



NORTH

Fish Hatchery

Benthic Research

Scientific or Educational Areas

Biology
Botany
Fisheries
Wildlife Sciences
Zoology

Geology
Mineral Resources
Rock Stratification
Near-Shore Processes

Flora & Fauna Ecology

Physical Oceanography
Tides
Waves—Inshore & Offshore
Water Circulation
Water Temperature

Benthic Life Research

Geological Oceanography
Core Samples
Minerals

Sea Chemistry
Nutrients
Water Quality
Radioactive Isotopes
PO_4, NO_3, NO_2, O_2

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