SOILS OF THE TOFINO-UCLUELET LOWLAND OF BRITISH COLUMBIA

Report No. 11
British Columbia Soil Survey

RESEARCH BRANCH
Canada Department of Agriculture
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CONTENTS

Soil map of the Tofino-Ucluelet lowland is bound in at the end of the report.

PREFACE

This report and the accompanying map present the results of a soil survey of the Tofino–Ucluelet lowland on the west coast of Vancouver Island carried out at the request of B.C. Forest Products Ltd., via the British Columbia Forest Service. The object of the survey was to classify and map the distribution of the various types of soils, to provide some basic analytical data for an area where commercial trees were showing poor growth, and, if possible, to make recommendations for amendments that would improve that growth. This study was carried out to help answer a particular problem and does not purport to be an exhaustive soil survey of the whole area.

Approximately 36,000 acres were surveyed between Ucluelet, Kennedy Lake, and the Tofino airport. The field work consisted of two trips to the area in September and October 1966.

A total of 6 days was spent in field mapping and soil sampling. Subsequent mapping was completed by using air photos at a scale of 4 inches to 1 mile taken by Lockwood Survey Corporation.

SUMMARY

Two terrain systems were defined within the Tofino–Ucluelet lowland on the basis of topography, surface materials, and drainage. Within each of these a soil catena containing three soil series has been described. The clay soils of the Tofino terrain system (Kennedy Lake catena) range from a moderately well drained Orthic Dystric Brunisol (Kennedy Lake series) through an imperfectly drained Gleyed Orthic Dystric Brunisol (Kootowis series) to a very poorly drained Rego Humic Gleysol (Tofino series). The sandy soils of the Ucluelet terrain system (Ucluelet catena) range from a moderately well drained Orthic Ferro-Humic Podzol (Ucluelet series) through an imperfectly drained Gleyed Orthic Ferro-Humic Podzol (Sandhill series) to a very poorly drained Placic Humic Podzol (Wreck Bay series).

GENERAL DESCRIPTION OF THE AREA

Location, Settlement, and Land Use

The Tofino–Ucluelet lowland is part of the coastal plain on the west coast of Vancouver Island (Fig. 1). The lowland is a peninsula trending northwest–southeast between Barkley Sound, the Pacific Ocean, Tofino Inlet, Kennedy River, and Kennedy Lake.

The principal settlements are Tofino and Ucluelet, which serve as supply centers for neighboring Clayoquot, Ahousat, Hesquiot, and Estevan Point. Fishing and logging are the main occupations. There is an all-weather road from Ucluelet to Tofino and access to the lowland is afforded by the road across the drainage divide from Port Alberni.

There is very little settlement in this part of the island and the land is used principally for logging, except for the tourist facilities on the west coast beaches. The numerous logging roads give satisfactory access.

Climate

The principal features of the climate are mild winters, cool summers, and abundant precipitation especially in the winter; only a little of this is in the form of snow.

Temperatures are controlled by the proximity to the ocean rather than by direct insolation. Consequently, the figures for Tofino airport and Ucluelet show a small annual range (less than 20 F) about a moderate mean annual temperature of 49 F. The growing season is long; Clayoquot with 341 days has one of the longest seasons in Canada, and the number of growing degree-days (above 42 F) is correspondingly high.

The pattern of the precipitation follows a marine west coast regime. The annual total precipitation is high, Tofino airport receives over 120 inches and Ucluelet over 100 (Table 1). Moreover, the amount of precipitation increases inland; Kennedy Lake has over 173 inches each year. Winter snowfall is limited. During autumn and winter the land is cool and the moist air is subject to greater instability than in summer. Therefore more precipitation falls at this time than in spring and summer. The annual variation in precipitation is small. The relative humidity is high all year; sea fogs and haze are common, especially during winter.

Data from Estevan Point and Pachena Point show that the predominant winds are from the southeast during October to April and from the northwest during the rest of the year. Storms with winds of more than 32 mph are common during the winter, but in the summer, with less cyclonic activity, the winds are light and variable.

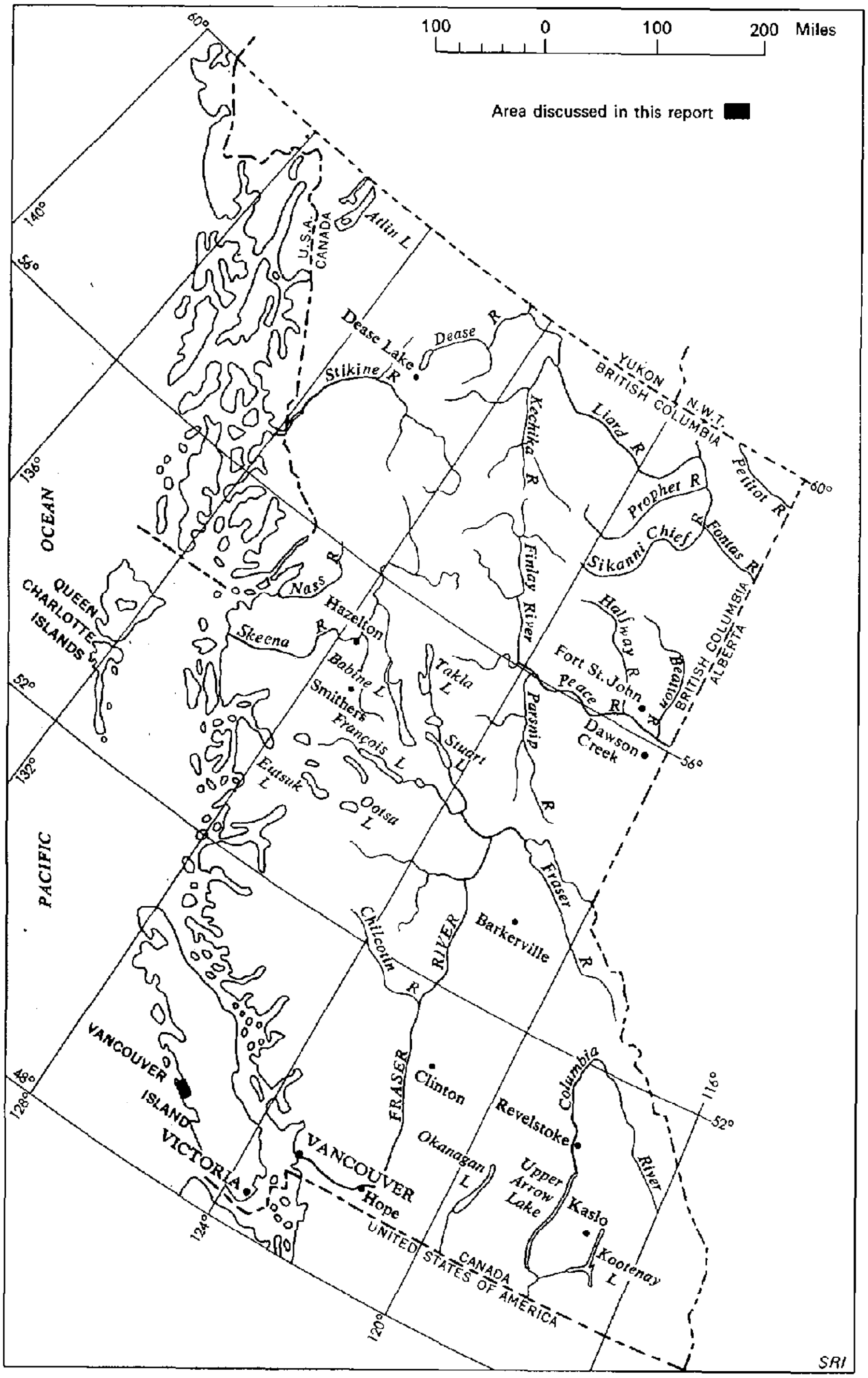

Fig.1. General location map of the Tofino-Ucluelet lowland.

Table 1. Meteorological Data for the Tofino-Ucluelet Lowland

Source	Station	No. of years	J	F	M	A	M	J	J	A	S	O	N	D	Mean	
								Temperature, F								
(1)	Tofino airport	(10)	41	42	42	45	50	55	58	58	56	51	44	42	49	
(2)	Clayoquot	(58)	41	42	44	47	51	55	58	59	56	51	45	42	49	
(2)	Ucluelet	(34)	39	40	43	46	50	55	59	58	55	51	46	42	48	
								Precipitation, inches								Winter snowfall
(1)	Tofino airport	(11)	16.9	14.2	12.4	10.9	4.3	3.2	3.3	3.3	5.2	14.0	16.6	16.8	121.1	9.5
(2)	Kennedy Lake	(13)	25.6	19.0	15.8	10.0	7.8	5.7	5.0	4.6	9.6	22.8	19.2	28.3	173.4	2.6
(2)	Ucluelet	(34)	14.3	11.1	10.6	8.0	4.8	3.6	2.6	2.4	5.5	11.9	12.9	15.9	103.6	7.3
								Growing season (42 F)								
		Average first date				Average last date			Length of period					Degree-days		
(3)	Tofino airport	March 19				December 12			268 days					2,615		
(3)	Clayoquot	January 19				December 26			341 days					2,715		
(3)	Ucluelet	March 30				December 10			255 days					2,536		
				Potential evapotranspiration				Moisture surplus				Moisture deficit				
(3)	Tofino airport			24.5 inches				96.8 inches				0.2 inch				
(3)	Ucluelet			24.4 inches				79.5 inches				0.3 inch				

Sources: (1) Climate of British Columbia, 1966 - Department of Agriculture, Province of British Columbia
(2) Climate of British Columbia, 1962 - Department of Agriculture, Province of British Columbia, Inactive Station Data
(3) Farley, A. L., unpublished data for ARDA agro-climatology maps, Department of Geography, University of British Columbia, Vancouver, B. C.

Length of individual station records

Tofino airport	1958-67 (also 1942-46)
Clayoquot	1900-58
Ucluelet	1914-48
Kennedy Lake	1924-36

The general picture is one of a very long growing season without extremely high summer temperatures and with excessive rainfall. The mild winters result in potential evapotranspiration values among the highest in Canada; at Tofino airport the value is 24.5 inches and at Ucluelet 24.4 inches. However, the moisture deficit figures for these stations are negligible, 0.2 and 0.3 inch respectively, showing that actual evapotranspiration values match the potential and that plants do not suffer from any lack of water. In fact, the opposite obtains. The main problem for vegetation is to adjust to a moisture surplus of 96.8 inches at Tofino airport and 79.5 inches at Ucluelet. This is the most important single feature of the climate to be reckoned with when the interrelationships of climate, soil, and vegetation growth are considered.

Physiography

The Tofino-Ucluelet lowland lies between 100 and 200 ft above sea level and is dotted with isolated hills. The basement geology is complex. It includes Permian altered volcanics and sediments, basic and ultrabasic intrusives, and Tertiary granitic rocks. Bedrock exposures are confined to the hills. During the last glaciation the Vancouver Island mountains were a center of ice accumulation. The land surface was depressed 150-200 ft below sea level and most of the surveyed area was submerged. The isolated hills formed islands. The ice moved generally southwestwards and deposited marine drift in the shallow waters. Postglacial uplift resulted in a coastal plain formed of these littoral deposits and was accompanied by accelerated terrestrial erosion. Outwash sands and gravels were deposited over the emerging clay plain by a river complex emanating from east of the present Kennedy Lake. Reworking of these materials by marine and aeolian action has produced wide sandy beaches backed by sand ridges along Wickaninnish Bay and high cliffs around Florencia Bay.

The regional physiography is described as two terrain systems (Fig. 2). A terrain system is defined as an area of land having a recurring pattern of surface materials, morphology, and drainage. It can be mapped at a scale of 1:250,000. The two terrain systems are used as a basis for the soil map legend because slope and underlying materials were very significant in differentiating the soils.

Tofino Terrain System

The Tofino terrain system is that part of the plain formed from the marine drift. This bluish gray stony clay containing occasional sand lenses, small marine shells, and angular gravel is similar to the Newton stony clay mapped in the Vancouver area (Armstrong, 1956). The surface of the plain is pitted with numerous enclosed depressions and although a number of small streams cross it in shallow valleys, drainage is generally poorly adjusted to the topography. Moreover, normal seaward runoff is also restricted by a low narrow ridge immediately inland from the coast. Thus the topography, high rainfall, and low permeability of the surface materials all contribute to a very moist land surface where soil water content is high all year.

Most of the isolated hills occur within this terrain system and range in height from 500 to over 1,000 ft. They rise sharply from the general level of the plain and usually have only a thin cover of drift material; outcrops of bedrock are common. On the northeastern side near Tofino Inlet and Kennedy River, the rocks are highly faulted basic and ultrabasic intrusives and a metamorphic complex of gneiss and schist. Other hills through the center of the area and toward the south and west are composed of granitics and altered volcanics and sediments.

Ucluelet Terrain System

The Ucluelet terrain system is topographically similar to the Tofino system apart from its lack of hill remnants. It has a gently undulating surface and is crossed by small streams in shallow open valleys. There are a number of depressions that contain either shallow lakes or marshland. The surface materials, however, consist of coarse sands and gravels rather than stony clays. The top 12 inches is usually of finer texture, sandy loam to sandy clay loam. These coarse-textured deposits are 10 ft thick and overlie the stony clay on the high cliffs behind Florencia Bay (Wreck Bay), but inland they are at least 40 ft thick in gravel pits on the Ucluelet–Alberni road (Fig. 3). However, the higher

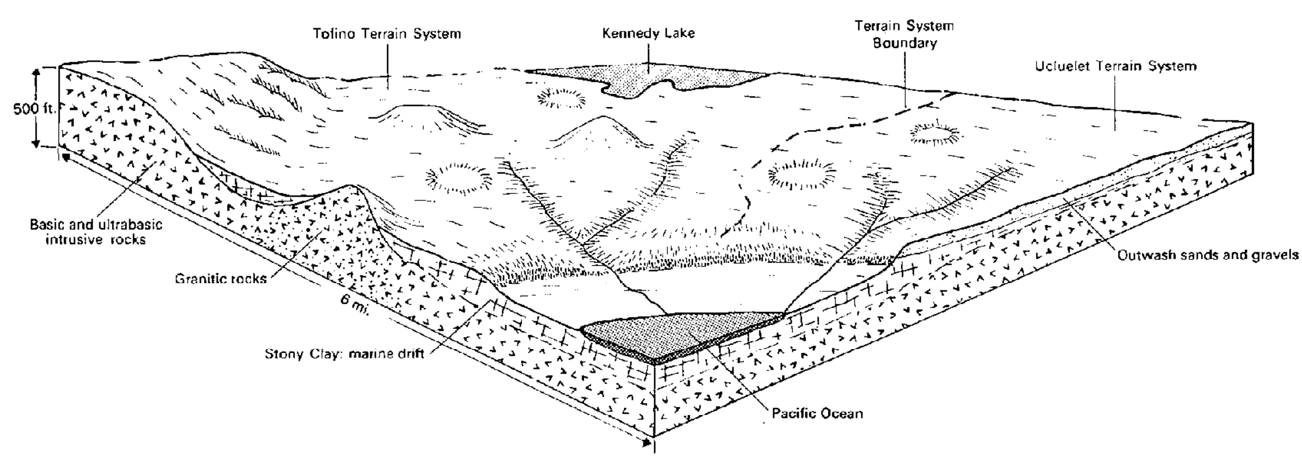

Fig. 2. Terrain systems of the Tofino–Ucluelet lowland.

Fig. 3. Outwash gravels of the Ucluelet terrain system: gravel pit near Port Alberni - Ucluelet road.

permeability of these surface materials does not compensate for the high rainfall and limited surface runoff; the land generally has the same range of drainage characteristics as the Tofino terrain system.

The only highland is found in the extreme southeast where granitics and basaltic volcanics form the boundary of the surveyed area.

Vegetation

Previous work has placed the map area in the Coastal Western Hemlock zone of the Pacific Coastal Mesothermal Forest (Krajina, 1965), or in the Southern Pacific Coast Section of the Coast Forest Region (Rowe, 1959).

The main portion of both terrain systems in the Tofino–Ucluelet lowland is a gently undulating plain. Within this plain the vegetation types are closely allied to topography and drainage. Moreover, each terrain system has similar drainage conditions in similar topographic positions irrespective of the texture of its surface materials. Therefore, both terrain systems have the same range of vegetation types. Sphagnum bog vegetation occurs in the enclosed depressions. A climax forest type occurs on the broad rises of the plain, on the gentle valley slopes, and on the lower slopes of the hills that rise from the plain farther inland. Between these two vegetation types is a transitional bog forest (Wade, 1965). There is also a strip of Sitka spruce on a low narrow ridge that fronts the ocean. This vegetation type consists of a pure Sitka spruce* forest and a dense shrub layer of salal. It is only a few hundred feet wide and is found immediately adjacent to the open ocean. It is therefore of little importance.

The surface of the bogs in poorly drained depressions is covered with sphagnum mosses (principally *Sphagnum papillosum, S. recurvum,* and *S. mendocinum*), rushes (*Juncus* spp.), and sedges (*Carex* spp. and *Scirpus* spp.). There are also occasional shrubs such as Labrador tea, black crowberry, bog laurel, and small cranberry. Scattered throughout the bogs are dwarf lodgepole pine and yellow cedar, which grows as a prostrate shrub (Fig. 4).

The dominant trees in the climax forest are western hemlock, amabilis fir, and western red cedar (Fig. 5). Many of these trees are large, up to 150 ft high, and much of the area is being logged. The undergrowth can be very dense and extremely difficult to penetrate especially where a crisscross pattern of fallen trees occurs. Salal, red huckleberry, copper bush, and deer fern are the principal plants in the shrub layer. Although this forest is usually found on the better-drained sites, the surface is still very moist and supports a thick cover of herbs and mosses among which bunchberry, *Mnium punctatum*, and *Rhytidiadelphus* sp. predominate.

Between the bogs and this climax forest occurs a transitional vegetation type called a bog forest (Wade, 1956), because it exhibits some characteristics of both the other two vegetation types. The most common trees are stunted lodgepole pine with peculiar flat tops, yellow cedar, and western hemlock with an occasional western red cedar. Very few of these trees are of commercial value because of their small size. The bog vegetation is represented predominantly by sphagnum mosses and Labrador tea. Salal, bunchberry, and sedges also occur.

DESCRIPTIONS OF THE SOILS

The factors influencing the development of the soils are outlined below, and the characteristics of the individual soils subsequently described. Table 2 is a key to soils. The soils have been classified according to *The System of Soil Classification for Canada.*

Soil Development and Morphology

The principal factors influencing soil development on this part of the west coast of Vancouver Island are copious rainfall, moderate temperatures with a narrow annual range, a dense vegetation, and a relatively flat plain where the drainage network is not sufficiently integrated to carry off the excess water efficiently.

Following the emergence of the plain from beneath the sea the action of the above factors over time produced a sequence of soil developments. The present soils of the area illustrate some of the stages in this sequence. After the organic matter began to accumulate on and in the surface soil, soluble salts were leached from the solum of the Regosolic soils. As leaching continued the basic cations were replaced by Al, particularly in the surface horizons, creating a pH gradient between the A and B horizons. Fe and Al were liberated and the oxides largely retained in the surface horizons. These oxides, as suggested by Clark (1964), serve to inactivate the organic- and inorganic-exchange sites resulting in an apparent low base status. This is the stage that the Brunisolic soils on the marine drift have reached.

*A complete list of vegetation is included as Appendix 1.

.Fig. 4. Vegetation on the Tofino series.

Fig. 5. Dense commercial stands on the Kennedy Lake series.

The sandy and gravelly outwash sediments allow a great degree of leaching, and the translocation of Fe, Al, and humus from the Ae into the B horizon is evident. Percolating humus solutions, with some clay, are immobilized as amorphous coatings around sand grains resulting in a marked segregation of humus (Table 3). This layer becomes the Bh horizon of an Orthic Ferro-Humic Podzol: Ucluelet series. With further development the Fe, Al, and humus are precipitated as a thin band or series of bands (Placic horizon). These iron–humus pans may become an impediment to free water movement. Waterlogging develops and the B horizon appears to develop from the bottom upward eventually completely masking the Ae horizon. Thick peaty horizons, mainly sphagnum moss, form on the surface of these very poorly drained areas. The Wreck Bay soils, Placic Humic Podzols, represent this advanced stage of development.

Very poorly drained soils are also found in the depressions of the clay plain. The A horizons are usually drained and aerated during the relative drought of the summer and show only patches of mottling. The waterlogged horizons are bluish gray in color, presumably owing to the reduction of Fe under anaerobic conditions. The Tofino soils, Rego Humic Gleysols, are characteristic of this early stage of development.

One feature common to all soils of the lowland is the high organic matter content of their surface layers. The dense vegetation coupled with the narrow annual range of moderate temperatures, allowing chemical and biological activity to continue throughout most of the year, forms a constant source of raw humic material. It is possible that most plant nutrients are derived from this organic matter in the surface litter and the upper mineral horizons rather than from the mineral soil as a whole. Moreover, the organic matter not only supplies plant nutrients to the soil, but increases the cation-exchange capacity thus enabling the soil to retain some of these nutrients in a form more available to plants. It was noticeable in many soil pits even under dense tree growth that most of the plants were shallow rooted.

Table 2. Soils of the Tofino-Ucluelet Lowland

Soil parent materials	Soil catena	Soil series	Classification*	Drainage class	Area Acres	Area %
		Soils of the Tofino terrain system				
Marine drift: stony clay with sand lenses	Kennedy Lake	Kennedy Lake	Orthic Dystric Brunisol	Moderately well drained	7,776	21.7
		Kootowis	Gleyed Orthic Dystric Brunisol	Imperfectly drained	13,660	38.0
		Tofino	Rego Humic Gleysol	Very poorly drained	1,164	3.2
		Soils of the Ucluelet terrain system				
Outwash: sands and gravels	Ucluelet	Ucluelet	Orthic Ferro-Humic Podzol	Moderately well drained	2,396	6.7
		Sandhill	Gleyed Orthic Ferro-Humic Podzol	Imperfectly drained	4,736	13.2
		Wreck Bay	Placic Humic Podzol	Very poorly drained	294	0.8
		Miscellaneous soils common to both terrain systems				
Exposed bedrock and shallow drift		Hill soils	Thin soils and bare rock	Rapidly to well drained	5,872	16.4

*Tentative.

Soils of the Tofino Terrain System

The clay soils of the Tofino terrain system form the Kennedy Lake catena, which is composed of three soil series: Kennedy Lake, Kootowis, and Tofino. The relative topographic positions and the main profile characteristics of the individual soils are shown in Fig. 6.

There is an increase in the thickness of organic surface layers and in soil water content downslope. The organic matter content of the upper mineral soils increases in the same direction as does the amount of gleying. The depth of the solum decreases and the structure weakens.

Kennedy Lake Series

The Kennedy Lake soils are found on the broad rises of the plain and the sides of the shallow stream valleys where the gently and moderately sloping topography allows lateral drainage either as runoff or subsurface percolation. The soils have tentatively been classified as Orthic Dystric Brunisols of which physical and chemical analyses are given in Table 3. In some areas there is a gradation to an Orthic Humo-Ferric Podzol; a thin Ae horizon occurs at the mineral soil surface. Permeability appears to be adequate to cope with the high rainfall because no mottling was found in the solum. The clay and silt contents of each horizon are high and the total porosity is also quite high although the individual pore spaces are small. Moreover, there is no clay accumulation at depth and the structure, although weak, is maintained into the C horizon. In places there are also lenses of sand, which add considerably to soil permeability.

The soil supports a dense western hemlock - salal - moss vegetation association with good commercial tree growth (Fig. 5). Much of this growth appears to be sustained by the organic surface, especially the H horizon. The mineral solum is strongly acid and low in basic cations, total N, and available P. The H horizon, containing over 90% organic matter, is adequately endowed with basic cations although total N and available P are low. The mineral soil horizons are not only low in N and P but also in the basic cations.

The following description is of a soil on the Grice Bay logging road near Staghorn Creek at 49° 05′N, 125° 38′W.

Horizon	*Depth inches*	
L–F	4 - 2	Litter of needles, leaves, and living moss roots; wet.
H	2 - 0	Well-decomposed organic materials; abundant roots.
Bm1	0 - 8	Yellowish brown (10YR 5/8, m) clay; weak, fine subangular blocky; firm; coarse, medium, and fine roots are plentiful; clear, smooth boundary; 5 to 10 inches thick; pH 3.7.
Bm2	8 - 24	Light olive brown (2.5Y 5/4, m) clay; weak, fine subangular blocky; firm; few roots; clear, wavy boundary; 13 to 21 inches thick; pH 3.9.
BC1	24 - 38	Light olive brown (2.5Y 5/4, m) clay; moderate, fine subangular blocky; very firm; few, fine roots; clear, wavy boundary; 12 to 18 inches thick; pH 3.9.
BC2	38 +	Dark yellowish brown (10YR 4/4, m) clay; weak, fine pseudoblocky; firm; very few, fine roots; pH 4.0.

Kootowis Series

The Kootowis soils are tentatively classified as imperfectly drained Gleyed Orthic Dystric Brunisols. They are found on the level and very gently sloping topography where lateral drainage is limited or on the moderately sloping seepage areas at the foot of the hill remnants. The whole solum is wet, and mottling appears in the B horizon. There is occasionally a thin Ae horizon at the surface of the mineral soil.

Like the Kennedy Lake soils, the Kootowis soils support a western hemlock - salal - moss association, but the

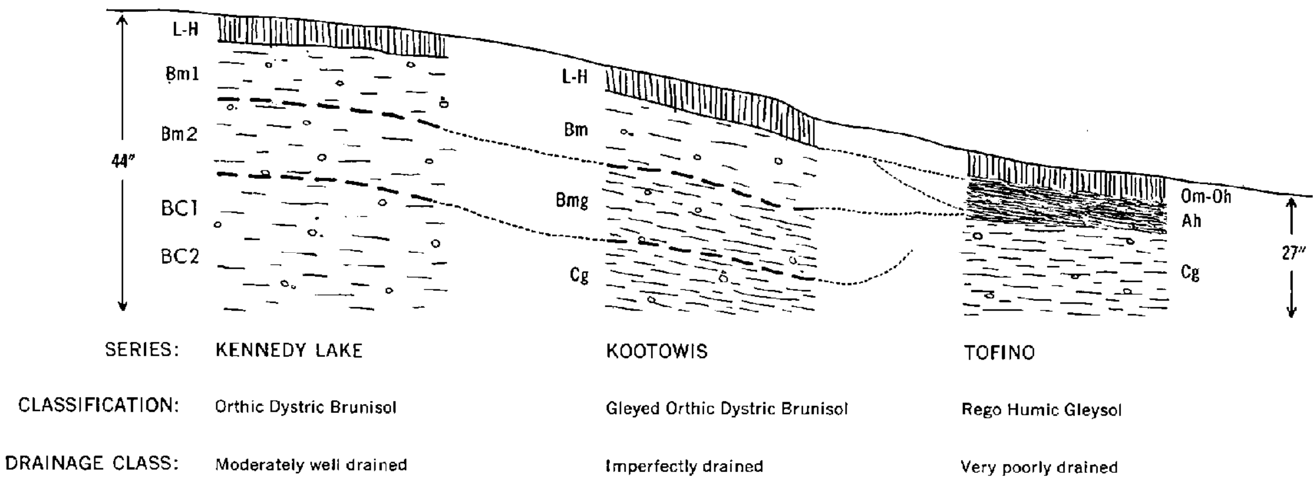

Fig. 6. Soils of the Tofino terrain system (Kennedy Lake catena).

forest is more open and hygrophytic vegetation is becoming more common. Poor drainage, lack of aeration, and restricted rooting depth are the principal limitations to adequate growth rather than any nutrient deficiency in the soil. This can be inferred from the soil analyses for the very poorly drained Tofino soils, which show that they contain more bases, and a similar amount of P and total N compared to the moderately well drained Kennedy Lake soils.

The following is a description of a Kootowis soil.

Horizon	*Depth inches*	
L-F	8 - 3	Layer of partially decomposed needles, leaves, and mosses.
H	3 - 0	Black (10YR 2/1, w), well-decomposed, amorphous organic materials; abundant roots.
Bm	0 - 6	Yellowish brown (10YR 5/6, m) clay; weak, fine subangular blocky; firm; plentiful, medium and fine roots; clear, smooth boundary; 3 to 8 inches thick.
Bmg	6 - 18	Light olive brown (2.5Y 5/6, m) clay; common, medium, distinct, yellowish brown (10YR 5/8) mottles; weak, fine subangular blocky; firm; plentiful, medium and fine roots; gradual, irregular boundary; 8 to 14 inches thick.
Cg	18 - 30	Light olive brown (2.5Y 5/4, w) clay; common, prominent, greenish gray (5BG 5/1) gleying and few, medium, distinct, yellowish brown (10YR 5/8) mottles; amorphous; slightly plastic, slightly sticky; few, fine roots.

Tofino Series

The Tofino soils are found in the shallow enclosed depressions or on the adjacent level topography of the Tofino terrain system. They are very poorly drained Rego Humic Gleysols. The mineral soil is covered with about 10 inches of organic matter in various stages of decomposition. The water table was 2 inches below the mineral soil surface in September and the vegetation was dominated by mosses, Labrador tea, and stunted lodgepole pine.

Table 3. Physical and Chemical Analyses

Horizon	Depth inches	pH ($CaCl_2$)	pH + (H_2O_2)	Organic matter %	Total N %	Organic C %	C:N	Exchangeable cations meq/100 g soil Ca	Mg	K	Available P ppm	Gravel %	Sand %	Silt %	Clay %	Texture*	Bulk density g/cc	Porosity %	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
Kennedy Lake Series, Orthic Dystric Brunisol**																						
L-F	4 - 2	3.5	3.7																			
H	2 - 0	3.1	3.1	96.44	.37	55.94	152.4	11.7	7.3	.2	2.40											
Bm1	0 - 8	3.7	3.7	4.63	.11	2.68	25.5	2.8	1.1	.1	0.64	-	3.0	27.9	69.1	C	1.45	45.3	2.77	1.32	4.56	1.64
Bm2	8 -24	3.9	3.9	1.25	.10	0.72	7.1	2.7	1.0	.1	1.15	-	1.7	35.4	62.9	C	1.30	50.9	1.25	1.12	2.57	1.45
BC1	24 -38	3.9	3.9	1.26	.05	0.72	7.1	2.6	0.9	.1	1.24	-	2.1	29.7	68.2	C	1.41	46.8	1.60	1.18	2.36	1.17
BC2	38 +	4.0	4.0	1.85	.07	1.07	16.0	2.7	0.8	.2	1.19	-	8.1	31.3	60.6	C	1.30	50.9	2.71	1.23	4.43	1.50
Tofino Series, Rego Humic Gleysol																						
Om	9 - 2	4.0	2.3	84.96		49.28																
Oh	2 - 0	4.6	2.6	70.63	1.03	40.96	39.8	12.6	5.3	.1	0.70								2.70	1.23	3.12	0.78
Ah	0 - 4	5.0	2.7	27.85	0.55	15.87	28.9	8.9	2.9	.1	0.64	-	14.4	37.5	48.1	C	1.36	48.7	1.30	1.20	1.19	0.46
Cg	4 -18	5.2	3.7	0.78	0.03	0.45	13.2	10.6	5.0	.3	1.24	-	11.0	35.0	54.0	C	1.56	41.1	1.15	1.17	0.93	0.14
Ucluelet Series, Orthic Ferro-Humic Podzol																						
L-F	6 - 3	3.7	3.8	91.04		52.80																
H	3 - 0	3.1	3.2	90.34	.83	52.40	62.9	20.2	14.1	0.44	3.05											
Ae	0 - 0.5																					
Bh	0.5- 2	3.6	3.6	18.61	.36	10.79	30.0	3.5	0.2	<0.1	2.00	36.9	61.5	19.3	19.2	GSL			0.81	1.58	2.20	2.01
Bhf	2 - 7.5	4.4	4.3	10.94	.19	6.34	33.7	2.3	<0.1	<0.1	2.05	41.0	65.9	13.9	20.2	GSCL	1.02	61.5	1.22	3.45	4.03	4.03
Bfh1	7.5-16	5.0	5.0	6.21	.11	3.60	32.1	2.2	<0.1	<0.1	4.41	44.2	62.1	15.7	22.2	GSCL	1.25	52.8	0.93	4.18	4.52	3.99
Bfh2	16 -24	4.9	4.9	7.19	.11	4.17	39.3	1.7	<0.1	<0.1	6.10	63.4	82.0	6.4	11.6	GLS			0.73	3.98	2.58	4.19
Bfh3	24 -35	5.0	4.9	6.96	.11	4.04	38.1	1.6	<0.1	<0.1	4.84	61.3	79.4	3.4	17.2	GSL			0.58	3.33	2.40	4.53
BC	35 -48	5.4	5.4	1.15	.02	0.67	33.5	1.0	<0.1	<0.1	40.00	57.9	92.2	-	7.8	GS			0.43	3.12	2.06	1.83
Wreck Bay Series, Placic Humic Podzol																						
Of-Om	6.5- 1	3.1	2.9																			
Oh	1 - 0	3.1	2.9	49.1	.80	28.49	35.33	4.9	1.0	.3	3.48											
Bh1	0 - 3	3.1	3.0	15.3	.36	8.85	24.31	3.4	0.9	.1	1.40	-	54.8	25.4	19.8	SL			0.06	.52	0.14	0.58
Bh2	3 - 3.5	3.4	3.2	20.0	.40	11.60	29.07	3.3	0.7	.1	1.54	-	73.9	15.9	10.2	SL			0.34	2.20	0.85	2.82
Bfhc	4 - 4.1			5.9	.07	3.40	48.6	1.7	0.2	.1									8.80	1.36	15.99	2.41
Bfc	4.1- 7	3.7	3.6	2.1	.04	1.20	28.5	0.6	0.1	.1	4.00	12.2	81.5	7.2	11.3	LS	1.78	32.8	1.98	2.06	2.53	1.78
IIBf	7 -18	5.1	4.8	2.1	.02	1.20	60.0	0.8	0.1	.1	38.00	29.0	88.0	1.8	10.2	LS			0.96	4.00	1.31	1.81

*Symbols for texture: C clay, G gravelly, L loam or loamy, S sand or sandy.

**Tentative classification.

The physical and chemical analyses of these soils are given in Table 3.

Total N and available P are low in most horizons, but the soil contains more basic cations than the Kennedy Lake series. This may be largely caused by the gain of these constituents from the groundwater moving laterally into the depressions. The C:N ratio is wide in the Oh and Ah horizons, which support tree growth. However, it is the physical rather than the chemical soil characteristics that lead to poor growth. The high clay content and low porosity in addition to the depressional topography cause a high water table and lack of soil aeration throughout most of the year. A potential problem, if the soil were ever drained, might be the reaction of acid polysulfides, "the cat-clay effect." All soil horizons were strongly or very strongly acid, but when oxidized by H_2O_2 the pH dropped at least one unit and in the case of the Ah it decreased from 5.0 to 2.7. This is a feature of soils developed from saline or brackish deposits containing sulfates (Edelman and van Staveren, 1958). The soil described was near the coast, and a similar soil farther inland near Kennedy Lake did not show this "cat-clay effect." It may be that only some of the poorly drained soils near the present coast have this quality.

A soil sampled at a site approximately 0.25 mile inland from Wickaninnish Bay is described as follows:

Horizon	*Depth inches*	
Of	11 - 9	Living sphagnum moss and litter of sedges and herbs; wet.
Om	9 - 2	Partially decomposed mosses, sedges, and herbs; wet; pH 4.0.
Oh	2 - 0	Very dark gray (10YR 3/1, m), well-decomposed organic material; wet; clear, smooth boundary; pH 4.6.
Ah	0 - 4	Dark gray (5Y 4/1, m) clay; amorphous; slightly plastic, slightly sticky; abundant, medium and fine roots; clear, wavy boundary; 3 to 6 inches thick; pH 5.0.
Cg	4 - 18	Yellowish brown (10YR 5/6, m) clay; many, prominent, greenish gray (5BG 5/1, m) mottles; amorphous; slightly plastic, slightly sticky; plentiful, medium and fine roots; pH 5.2.

Soils of the Ucluelet Terrain System

The soils derived from the coarse-textured parent materials of the Ucluelet terrain system form the Ucluelet catena. This catena has three soil series with the same drainage qualities as those of the Kennedy Lake catena: Ucluelet series, Sandhill series, and Wreck Bay series. The relative positions and profile characteristics of each soil are shown in Fig. 7.

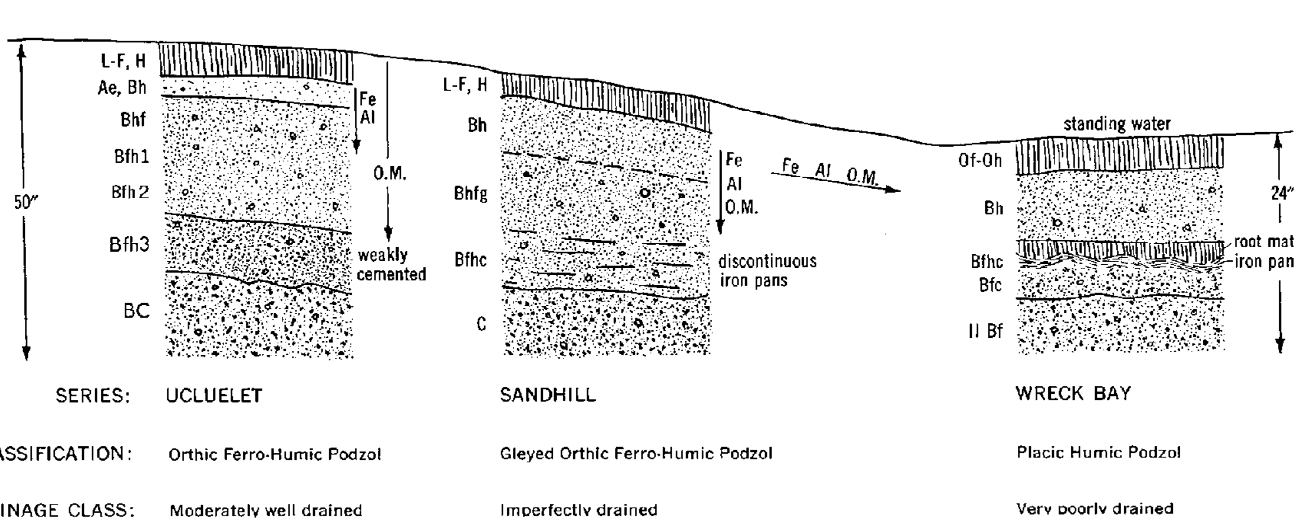

Fig. 7. Soils of the Ucluelet terrain system (Ucluelet catena).

Under conditions of high leaching in the moderately well drained Ucluelet soils, bases have been eluviated and organic matter illuviated to a depth of almost 3 ft. This organic accumulation has masked the Ae horizon of the upper 2 inches. Fe and Al are being translocated from this horizon to the Bhf immediately below. At depth there is a slightly indurated horizon with Fe staining on the gravel. The Sandhill soils are intermediate with thin discontinuous pans, but their transitional qualities are somewhat conjectural because they were not sampled.

Ucluelet Series

The Ucluelet soils are moderately well drained Orthic Ferro-Humic Podzols, which have developed on gently sloping topography. The upper portions of the mineral soil have sandy loam to sandy clay loam textures, but the main body of the soil parent material is stratified outwash material, ranging from large rounded gravels to coarse sand (Fig. 3). Thus variations in the chemical and more especially the physical characteristics of the soil may be due to initial sedimentation rather than soil genesis.

The Ucluelet soils support a good commercial growth of western hemlock and western red cedar, with a dense undergrowth of salal and deer fern.

The physical and chemical analyses of these soils are given in Table 3.

The few bulk density measurements that were made suggest a high porosity. Leaching is very prevalent and causes a loss of basic cations. This is indicated by the very low Ca, Mg, and K contents of the mineral portion of the soil and the generally acid solum. In such a porous medium, organic matter has been deeply illuviated into the soil and the removal of Fe and Al from the Bh horizon is indicated. Lower in the profile a slightly indurated horizon (Bfh3, 24–35 inches) is sufficiently impermeable to impede water percolation and to hinder the penetration of roots.

Like the Kennedy Lake clay, most of the soil nutrients are concentrated in the surface H and Bh horizons, which contain abundant roots. Total N is low in relation to organic C in the lower horizons. An unusual feature of this soil is the high Al content (oxalate and dithionite extractable) in the solum. The following description is of a soil bordering Lost Shoe Creek south of the Tofino–Ucluelet road at 49° 00′N, 125° 37′W.

Horizon	*Depth inches*	
L–F	6 - 3	Undecomposed and partially decomposed needles, leaves, and mosses; pH 3.7.
H	3 - 0	Very dark gray (10YR 3/1, d), decomposed organic material; pH 3.1.
Ae	0 - 0.5	Light gray (10YR 7/2, d) silt loam; amorphous; loose; fine roots.
Bh	0.5 - 2	Dark grayish brown (10YR 4/2, m) gravelly sandy loam; weak, fine subangular blocky; friable; fine roots; clear, wavy boundary; 1 to 3 inches thick; pH 3.6.
Bhf	2 - 7.5	Dark brown (10YR 4/3, m) gravelly sandy clay loam; weak, fine subangular blocky; firm; fine roots; clear, wavy boundary; 3 to 7 inches thick; pH 4.4.
Bfh1	7.5 - 16	Yellowish brown (10YR 5/8, m), gravelly sandy clay loam; weak, fine subangular blocky; firm; few, fine roots; gradual, irregular boundary; 6 to 11 inches thick; pH 5.0.
Bfh2	16 - 24	Dark brown (10YR 4/3, m), gravelly loamy sand; single grain; common, fine, yellowish brown (10YR 5/6, m) distinct mottles; nonplastic, nonsticky; few, fine roots; clear, wavy boundary; 6 to 12 inches thick; pH 5.0.
Bfh3	24 - 35	Dark brown (10YR 4/3, m), gravelly loamy sand; single grain; common, fine, distinct yellowish brown (10YR 5/6, m) mottles; nonplastic, nonsticky; thin iron coatings on sand and gravel particles; weakly cemented; few, fine roots in clay pockets; abrupt, smooth boundary; 7 to 15 inches thick; pH 5.0.
BC	35 - 48	Olive (5Y 4/4, m) gravelly sand; single grain; nonplastic, nonsticky; no roots; pH 5.4.

Sandhill Series

The Sandhill soils are imperfectly drained Gleyed Orthic Ferro-Humic Podzols. They occur on the level and very gently sloping topography of the Ucluelet terrain system. Their occurrence is not easily predictable, but they seem to occur where the thin discontinuous pans of the lower B horizon seriously impede soil drainage in the stratified sands and gravels. The upper 12 inches of the mineral soil varies in texture from sandy loam to sandy clay loam. Mottling is common in the upper profile and much of the soil is wet above the discontinuous pans.

Like the vegetation on the imperfectly drained Kootowis soils, the forest on the Sandhill soils has an open appearance. The western hemlock and western red cedar trees are shorter than on the Ucluelet soils and yellow cedar begins to appear. Labrador tea also occurs.

The following is a description of a Sandhill soil.

Horizon	*Depth inches*	
L-F	6 - 3	Undecomposed and partially decomposed needles, leaves, and mosses.
H	3 - 0	Black (10YR 2/1, m) decomposed amorphous organic material.
Bh	0 - 3	Very dark grayish brown (10YR 3/2, m) sandy loam; weak, fine subangular blocky; firm; plentiful, medium and fine roots; some gravel; gradual irregular boundary with some tongues into underlying horizon; 1 to 4 inches thick.
Bhfg	3 - 12	Dark grayish brown (10YR 4/2, w) sandy clay loam; common, medium, distinct yellowish brown (10YR 5/6) mottles; amorphous; firm; few, medium and fine roots; some gravel; clear, smooth boundary; 6 to 11 inches thick.
Bfch	12 - 19	Dark brown (10YR 4/3, m) loamy sand with thin wavy dark brown (7.5YR 3/2, m) discontinuous horizontal pans; single grain; firm; very few, fine roots; some gravel; clear, smooth boundary; 6 to 10 inches thick.
BC	19 - 30	Olive (5Y 4/4, m) coarse sand; single grain; nonplastic, nonsticky; no roots; some gravel.

Wreck Bay Series

The Wreck Bay soils occur in the depressions and on the level topography of the Ucluelet terrain system. They are very poorly drained Placic Humic Podzols, formed on stratified outwash sand. They commonly have a somewhat fine surface texture, usually sandy loam. The vegetation is dominated by sphagnum mosses, sedges, Labrador tea, and a few stunted lodgepole pine and yellow cedar trees.

The physical and chemical analyses of these soils are given in Table 3.

The high water table severely limits the depth to which the soil can be described or sampled. The Bh1 horizon is black when wet, but gray when dry. The oxalate-extractable Fe and Al of this horizon are low and it may have been a previous Ae horizon that has been masked by the accumulation of organic matter. Below the Bh2 horizon is a mat of fine and medium roots that have been unable to penetrate the very thin but very impervious iron pan. This iron pan (the Bfhc horizon) is a thin undulating horizon, which occurs at varying depth. It occasionally bifurcates to form a number of irregular pans and appears impermeable enough to prevent the passage of water and roots. It occurs between the Bh2 and Bfc horizons, which show significant differences in their particle size analyses. The Bfc horizon contains more gravel and sand than the Bh. The lower horizons, Bfc and IIBf, are dominantly gravels and sands; these are single grained at depth, but show some cementation immediately under the main pan.

The soil is strongly acid in the upper horizons and moderately so in the IIBf. The basic cation content is low, especially in the lower horizons, as is base saturation judging from the low pH values. Total N is low and the C:N ratio is therefore wide. Available P fluctuates. The Fe and Al contents of each horizon are similar apart from the Bfhc (the iron pan). Here the Fe content is much greater than the Al, a fact reported in Newfoundland (McKeague et al., 1967). The formation of these pans has been ascribed to the mobilization of Fe under reducing conditions and its precipitation as a complex with organic matter under oxidizing conditions lower down the profile (Damman, 1965; Crampton, 1963). Al or Mn may be associated with this complex. Work in Newfoundland (McKeague et al., 1967) has cast doubts on this theory as such complexes with ratios of Fe plus Al to organic matter of over three are insoluble. Moreover, it is difficult to envisage anaerobic conditions overlying aerobic. The Fe, Al, and organic matter contents of the Wreck Bay series are similar to those of the Newfoundland profile. But unlike the Newfoundland soils the horizons immediately below the pan have much coarser textures than the horizons above. Downward-percolating water could be held at the junction thus providing a sharp boundary between materials of very different water contents as required by the first theory. Moreover, the pan is saucer shaped under the bog and the source of its constituent materials may be water moving laterally into the depressions as well as simple downward leaching.

The following description is of a soil on the corduroy road south of the Tofino-Ucluelet road at 49° 0.1′N, 125° 37′W.

Horizon	*Depth inches*	
Of-Om	6.5 - 1	Dark brown (7.5YR 3/2, w) semidecomposed mosses, leaves, and needles; fibrous, abundant, fine, medium, and coarse roots; abrupt, smooth boundary; 5 to 8 inches thick; pH 3.1.
Oh	1 - 0	Black (10YR 2/1, w) or very dark gray (10YR 3/1, d), decomposed organic matter; slightly sticky; abundant, fine, medium, and coarse roots; abrupt, smooth boundary; 0.5 to 2 inches thick; pH 3.2.
Bh1	0 - 3	Black (10YR 2/1, w), very dark gray (10YR 3/1, m), or gray (10YR 5/1, d) sandy loam; weak, fine subangular blocky; nonplastic, nonsticky; abundant, fine and medium roots; occasional fine to medium concretions; abrupt, smooth boundary; 2 to 5 inches thick; pH 3.1.
Bh2	3 - 3.5	Very dark brown (10YR 2/2, w) or dark gray (10YR 4/1, d) sandy loam; weak, fine subangular blocky; nonplastic, nonsticky; abundant, fine and medium roots; abrupt, smooth boundary; 0.5 to 1.5 inches thick; pH 3.4.
Root mat	3.5 - 4	Very dark brown (10YR 2/2, w) mat of living roots and single loose sand grains; fibrous; very abrupt boundary with iron pan below; 0.5 inch thick.
Bfhc	4 - 4.1	Black (10YR 2/1, w) or dark brown (7.5YR 3/2, d) amorphous material forming an undulating pan that cements the sand grains and fine gravel. The pan varies in depth from 4 to 8 inches and occasionally bifurcates. It is completely impervious to roots.
Bfc	4.1 - 7	Very dark grayish brown (10YR 3/2, w) or brown (10YR 5/3, d) loamy sand; strongly cemented with iron coatings on individual grains; nonplastic, nonsticky; no roots; clear, wavy boundary; 2 to 5 inches thick; pH 3.8.
IIBf	7 - 18	Dark grayish brown (2.5Y 4/2, w) or light olive brown (2.5Y 5/4, d) loamy sand; single grain; saturated, flowing; no roots; pH 5.2.

Miscellaneous Soils Common to Both Terrain Systems

Hill Soils

The hill soils were not surveyed in detail in the field, but were delineated by air photo interpretation in both terrain systems. They are thin soils or areas of exposed bedrock on the Pleistocene erosion remnants. They are of very limited value for commercial timber. Individual trees are small and the density of stocking is often low.

RECOMMENDATIONS

Any recommendations for improving tree growth on the soils of the area are hampered by the lack of experimental evidence showing responses to drainage or fertilizers. Therefore, only tentative suggestions can be made to point out the direction that such initial experiments might take. All the soils are acid, some extremely so, and low in plant nutrients except in the upper horizons where organic matter has accumulated. The moderately well drained soils on both parent materials (Kennedy Lake and Ucluelet series) support commercial tree growth. However, the C:N ratio is wide, especially in the upper horizons, and the P content is low. It is often more economical to attempt to improve growth on good soils than to indulge in costly reclamation projects on poor ones. Therefore, the response to N, P, and lime should be tested.

Improvement of growth on the two imperfectly drained soils (Kootowis and Sandhill series) will require adequate drainage prior to fertilization. The surface of the plain is irregular with numerous enclosed depressions. Thus an accurate topographic survey would be necessary before a pattern of ditches could be planned. It would probably be preferable to drain the clay soils, because results with a pan developing in gravels and sands are unpredictable. Response to N, P, and lime could then again be tested.

The very poorly drained soils comprise only 4% of the total area. There is therefore little point in attempting the costly reclamation measures necessary. The clay soils (Tofino series) would need intensive drainage and the extent of those having "cat-clay" qualities should be determined. They should then be avoided. The reclamation of the Wreck Bay series covering only 1% of the total area is not feasible. However, these soils are probably common elsewhere on the west coast of Vancouver Island, and experience in their reclamation in other parts of the world may be of future significance. In Scotland such soils have formed under wet moorland conditions. Regarding their reclamation, Dr. Glentworth of the Macauley Institute of Soil Research, Aberdeen, has stated in a personal communication:

"The cure is evidently not easy, but it will probably be necessary to first of all remove the organic horizons by controlled burning or other means if this is possible and then to prevent the lateral water movement by drainage. Natural regeneration may then complete the cure, but if not, it may be necessary to cultivate the exposed soil completely and deeply. Experience in N.E. Scotland suggests that the basic cause of poor tree growth on our heathland podzolic soils is the lack of aeration—hence the value of cultivation.

"We realize that cultivation will probably not be feasible on account of access and the amount of power required, and hope therefore that regeneration by natural or other means will prove successful following drainage. Areas such as these are, under Scottish conditions, very low in P and a starter dressing of 2 oz of phosphate fertilizer helps seedlings to get a hold (i.e., spread in a ring around the seedling)."

The Oh, Bh1, and Bh2 horizons of the Wreck Bay sandy loam contain between 1.5 and 3.5 ppm of available P. Therefore the addition of phosphate fertilizer would probably be required in the Tofino area as well.

As the Tofino - Port Alberni road is improved and the area becomes more accessible, pressure on the land for recreational and other uses will increase. Any experimental work and subsequent improvement programs should be concentrated in those sections that are definitely to remain commercial forest reserves. These would appear to be inland from the Tofino-Ucluelet road toward Kennedy Lake and Kennedy River.

CLAY MINERAL DISTRIBUTION IN TWO SUBSOILS

The following information is taken from some mineralogical analyses of the marine drift and outwash sediments carried out by N. Keser of the Research Division, British Columbia Forest Service.

Mineralogical analyses were undertaken using a Philips X-ray diffractometer equipped with a proportional pulse-height analyzer. Cu, $K\alpha_1$ ($\lambda = 1.54050$) radiation was employed. The receiving slit was equipped with a Ni filter.

Particle size separation was made according to the procedures presented by Kittrick and Hope (1963). X-ray analyses were run on the Ca- and K-saturated samples of fine clay ($< 0.2\,\mu$), coarse clay ($2-0.2\,\mu$), and silt ($2-50\,\mu$) fractions. For glycerine and heat treatments, the techniques outlined by Mackintosh and Gardner (1966) were followed. No additional treatments were undertaken for identification of kaolinite in the presence of chlorite. The results are shown in Table 4.

The main minerals in the clay fractions ($< 0.2\,\mu$ and $0.2-2\,\mu$) of the Kennedy Lake marine drift are chlorite and illite. The same two minerals form minor constituents of the silt fractions (2–20 and $20-50\,\mu$). Quartz and feldspar occur in moderate to large quantities and amphiboles in small quantities throughout all the fractions. This pattern is not completely comparable to other published results for marine material on Vancouver Island or the lower Fraser Valley. Similar marine drift (Newton stony clay) in the lower Fraser Valley contained montmorillonite as a major constituent and chlorite, illite, feldspar, and quartz as minor constituent minerals in the clay fraction (Clark et al., 1962). Analyses of Alberni marine clay from Vancouver Island have shown it to contain interstratified montmorillonite-chlorite and minor portions of chlorite, montmorillonite, feldspar, and quartz (Clark et al., 1962) and principally chlorite with some interstratified montmorillonite-chlorite, feldspar, and amphiboles (Clark et al., 1963). Mackintosh and Gardner (1966) showed that marine and alluvial materials in the lower Fraser Valley had similar assemblages of minerals. The silt fractions contained quartz, feldspar, mica, and chlorite, whereas the clay fractions contained principally montmorillonite and chlorite. The Kennedy Lake series would therefore be included in a chloritic soil

Table 4. Clay Mineral Distribution in Two Subsoils of the Tofino-Ucluelet Lowland

Soil series	Soil parent material	Soil horizon	Depth	Particle size, μ	Mixed layers	Montmorillonite	Chlorite*	Vermiculite	Illite	Kaolinite	Amphiboles	Quartz	Feldspar
					Relative quantities**								
Kennedy Lake	Marine drift: clay	BC2	3 ft +	<.2	1	-	3-4	-	3	-	1-2	4	4
				.2-2	-	-	4	-	2-3	-	1	3	2
				2-20	-	-	3	-	2	-	2	3-4	4
				20-50	-	-	1	-	1-2	-	2	4	4
Ucluelet	Outwash: sands and gravels	BC	4 ft +	<.2	1	-	2	1	1?	-	1	1	1
				.2-2	1	-	1	1	1	-	1	4	2-3
				2-20	-	-	1	-	-	-	1-2	3	2
				20-50	-	-	1	-	-	-	4	4	4

*Iron-rich chlorite
**1. Trace; 2. Small; 3. Moderate; 4. Large

family, whereas most of the other soils derived from marine sediments of southeastern British Columbia could be in a montmorillonitic family.

The absence of montmorillonite or vermiculite implies that the marine clays of the Kennedy Lake catena will not have marked swelling properties and the sides of drainage ditches will not be excessively unstable.

The minerals in the clay fraction of the outwash are principally quartz and feldspar with minor occurrences of chlorite and vermiculite. The silt fractions contain mainly amphiboles, quartz, and feldspar. This pattern is to be expected from materials that have undergone relatively little weathering.

METHODS OF ANALYSIS

Gravel. Particles over 2 mm in diameter were wet sieved, dried, weighed, and expressed as a percentage by weight of the total sample.

Sand, silt, and clay. The pipette method was used. Results are given as percentages of the fraction less than 2 mm in diameter. Kilmer, V. J., and L. T. Alexander. 1949. Soil Sci. 68:15-24.

Bulk density. This was measured by the clod method. Black, D. A. [Editor in Chief] 1965. Methods of soil analysis. Part I, p. 381-383. Amer. Soc. Agron., Inc., Wisconsin. 2 vol.

pH ($CaCl_2$). Schofield, R. K., and A. W. Taylor. 1955. Soil Sci. Soc. Amer. Proc. 19:164-167.

pH (H_2O_2). 2 ml of 30% H_2O_2 were added to the solution used for the pH ($CaCl_2$) determination in order to oxidize it. The mixture was stirred and the pH measured after about 15 min. This gives an indication of what the soil pH would be after drainage.

Organic matter. Method of Peech, M., et al., 1947, given in Atkinson, H. J., et al., 1958. Chemical methods of soil analysis, Contribution No. 169 (revised), Chem. Div., Sci. Serv., Can. Dep. Agr., Ottawa. p. 16.

Organic carbon. Calculated as 58% of total organic matter.

Total nitrogen. Kjeldahl method given in Atkinson, op, cit. p. 20.

Exchangeable cations. Ca, Mg, and K were extracted with 2 N NaCl after $CaCl_2$ equilibration using the method of Clarke, J. S. 1965. Can. J. Soil Sci. 45:311-322.

Ca and Mg. These were determined by titration with EDTA. Jackson, M. L. 1958. Soil chemical analysis. Prentice Hall, Englewood Cliffs, N.J. Ca alone was determined by CYDTA.

K. This was determined by atomic absorption.

Available phosphorus. Bray method in Atkinson, op. cit. p. 25.

Iron and aluminum. Oxalate extractions were made using the method of McKeague, J. A., and J. H. Day. 1966. Can. J. Soil Sci. 46:13-22. Dithionite extractions were made according to the method of Mehra, O. P., and M. L. Jackson. 1960. Clays and clay minerals. Proc. 7th Conf.: p. 317-327. (Nat. Acad. Sci. – Nat. Res. Council Pub.). Iron and aluminum were then measured colorometrically.

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GLOSSARY

available nutrient. The portion of any element or compound in the soil that can be readily absorbed and assimilated by growing plants. (Available is different from exchangeable.)

base-saturation percentage. The extent to which the adsorption complex of a soil is saturated with exchangeable cations other than H and Al. It is expressed as a percentage of the total cation-exchange capacity.

bulk density. The weight of ovendry soil (105 C) in grams per unit bulk volume. The bulk volume is measured in cubic centimeters at field moisture conditions.

catena. A sequence of soils of about the same age, derived from similar parent materials and occurring under similar climatic conditions, but having different characteristics because of variations in relief and in drainage.

cat clay. Acid soil containing iron hydroxy sulfates resulting from the oxidation of sulfides.

cation-exchange capacity. The total exchangeable cations that a soil can adsorb expressed in milliequivalents per 100 g of soil or of other adsorbing material such as clay. This is sometimes called "total-exchange capacity," "base-exchange capacity," or "cation-adsorption capacity."

climax. A plant community of the most advanced type capable of development under and in equilibrium with the prevailing environment.

chroma. The relative purity, strength, or saturation of a color; directly related to the dominance of the determining wavelength of the light and inversely related to grayness; one of the three variables of color. See *Munsell color system, hue,* and *value, color.*

color. See *Munsell color system.*

evapotranspiration. The combined loss of water from a given area and during a specific period of time by evaporation from the soil surface and by transpiration from plants. Potential evapotranspiration is the maximum transpiration that can occur in a given weather situation with a low-growing crop that is of large extent and completely covers the ground and is not short of water.

gravel. Rock fragments from 2 mm to 3 inches in diameter.

horizon. See *soil horizon.*

hue. One of the three variables of color. It is caused by light of certain wavelengths and it changes with the wavelength. See *Munsell color system, chroma,* and *value, color.*

illuvial horizon. A soil horizon in which material carried from an overlying layer has been precipitated from solution or deposited from suspension. It is the layer of accumulation.

iron pan. A thin indurated soil horizon in which iron is a main constituent of the cementing material. Several kinds of cementing materials occur: (i) iron-organic matter, (ii) hydrous oxides of Mn and Fe, and (iii) hydrous iron oxides.

leaching. The removal from the soil of materials in solution.

mottles. Spots or blotches of different color or shades of color interspersed with the dominant color.

Munsell color system. A color designation system that specifies the relative degrees of the three simple variables of color: hue, value, and chroma. For example: 10YR 6/4 is a color (of soil) with a hue of 10YR, a value of 6, and a chroma of 4. These notations can be translated into several different systems of color names as desired. See *chroma, hue,* and *value, color.*

parent material. The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil is developed by pedogenic processes.

permeability, soil. (i) The ease with which gases, liquids, or plant roots penetrate or pass through a bulk mass of soil or a layer of soil. Because different soil horizons vary in permeability, the particular horizon being studied should be designated. (ii) The property of a porous medium that relates to the ease with which gases, liquids, or other substances can pass through it.

pH, soil. The negative logarithm of the hydrogen-ion activity of a soil. The degree of acidity (or alkalinity) of a soil as determined by means of a glass, quinhydrone, or other suitable electrode or indicator at a specified moisture content or soil-water ratio, and expressed in terms of the pH scale.

porosity. The volume percentage of the total bulk not occupied by solid particles.

potential evapotranspiration. See *evapotranspiration.*

profile, soil. A vertical section of the soil through all its horizons and extending into the parent material.

reaction, soil. The degree of acidity or alkalinity of a soil, which is usually expressed as a pH value. Descriptive terms commonly associated with certain ranges in pH are: extremely acid, < 4.5; very strongly acid, 4.5–5.0; strongly acid, 5.1–5.5; moderately acid, 5.6–6.0; slightly acid, 6.1–6.5; neutral, 6.6–7.3; slightly alkaline, 7.4–7.8; moderately alkaline, 7.9–8.4; strongly alkaline, 8.5–9.1; and very strongly alkaline, > 9.1.

series, soil. The second-lowest category in the system of soil classification for Canada. This is the basic unit of soil classification and consists of soils that are essentially alike in all the main profile characteristics except the texture of the surface.

soil horizon. A layer of soil or soil material approximately parallel to the land surface; it differs from adjacent genetically related layers in properties such as color, structure, texture, and consistence, and chemical, biological, and mineralogical composition. The following is a list of the designations and some of the properties of soil horizons. More detailed definitions of some horizons may be found in *The System of Soil Classification for Canada.*

Organic layers contain more than 30% organic matter. Two groups of these layers are recognized:

O—An organic layer developed under poorly drained conditions and that is often peaty.

Of—The least decomposed kind of O layer. It contains large amounts of well-preserved fiber.

Om—An intermediately decomposed O layer containing less fiber than an Of layer.

Oh—The most decomposed O layer. This humic layer contains little raw fiber.

L, F, and H—These are organic layers developed under imperfectly to well-drained conditions and they are often composed of forest litter.

L—The original structures of the organic material are easily recognizable.

F—The accumulated organic material is partly decomposed.

H—The original structures of the organic material are unrecognizable.

Master mineral horizons and layers contain less than 30% organic matter.

A—A mineral horizon formed at or near the surface in the zone of removal of materials in solution and suspension or maximum in situ accumulation of organic matter or both.

B—A mineral horizon characterized by one or more of the following:

1. An enrichment in silicate clay, iron, aluminum, or humus.
2. A prismatic or columnar structure that exhibits pronounced coatings or stainings associated with significant amounts of exchangeable sodium.
3. An alteration of hydrolysis, reduction, or oxidation to give a change in color or structure from horizons above or below or both.

C—A mineral horizon comparatively unaffected by the pedogenic processes operative in A and B, except gleying, and the accumulation of carbonates and more soluble salts.

R—Underlying consolidated bedrock.

Roman numerals are prefixed to horizon designations to indicate unconsolidated lithologic discontinuities in the profile. Roman numeral I is understood for the uppermost material and therefore is not written. Subsequent contrasting materials are numbered consecutively in the order in which they are encountered downward, that is, II, III, etc.

Lower-case suffixes

b—Buried soil horizon.

c—A cemented (irreversible) pedogenic horizon.

ca—A horizon of secondary carbonate enrichment where the concentration of lime exceeds that in the unenriched parent material.

cc—Cemented (irreversible) pedogenic concretions.

e—A horizon characterized by removal of clay, iron, aluminum, or organic matter alone or in combination and higher in color value by one or more units when dry than an underlying B horizon. It is used with A, (Ae).

f—A horizon enriched with hydrated iron. It usually has a chroma of 3 or more. The criteria for an f horizon (except Bgf) are: the oxalate-extractable Fe + Al exceeds that of the IC horizon by 0.8% or more, and the organic matter to oxalate-extractable Fe ratio is less than 20. These horizons are differentiated on the basis of organic matter content into:

Bf, less than 5% organic matter.

Bfh, from 5 to 10% organic matter.

Bhf, greater than 10% organic matter.

g—A horizon characterized by gray colors or prominent mottling indicative of permanent or periodic intense reduction, e.g., Aeg, Btg, Bg, and Cg.

gf (used with B)—The dithionite-extractable Fe of this horizon exceeds that of the IC by 1% or more and the dithionite-extractable Al does not exceed that of the IC by more than 0.5%.

h—A horizon enriched with organic matter.

Ah—An A horizon of organic matter accumulation. It contains less than 30% organic matter. It is one Munsell unit of color value darker than the layer immediately below or it has at least 1% more organic matter than the IC or both.

Ahe—This horizon has been degraded as evidenced by streaks and splotches of light and dark gray material and often by platy structure.

Bh—This horizon contains more than 2% organic matter and the organic matter to oxalate-extractable Fe ratio is 20 or more.

j—This is used as a modifier of suffixes e, g, n, and t to denote an expression of but failure to meet the specified limits of the suffix it modifies, e.g., Aej—an eluvial horizon that is thin, discontinuous, or faintly discernible.

k—Presence of carbonate.

m—A horizon slightly altered by hydrolysis, oxidation, or solution, or all three to give a change in color or structure or both.

n—A horizon in which the ratio of exchangeable Ca to exchangeable Na is 10 or less.

p—A layer disturbed by man's activities. Ap.

s—A horizon containing detectable soluble salts.

sa—A horizon of secondary enrichment of salts more soluble than Ca and Mg carbonates where the concentration of salts exceeds that present in the unenriched parent material.

t—A horizon enriched with silicate clay as indicated by: a higher clay content (by specified amounts) than the overlying eluvial horizon, a thickness of at least 5 cm, oriented clay in some pores or on ped surfaces or both, and usually a higher ratio of fine (< 0.2 micron) to total clay than the IC horizon.

x—A horizon of fragipan character.

z—A permanently frozen layer.

soil reaction. See *reaction, soil* and *pH, soil.*

soil structure. The aggregation of primary soil particles into compound particles, which are separated from adjoining aggregates by surfaces of weakness. Aggregates differ in grade (distinctness) of development and grade is described as structureless (no observable aggregation or no definite orderly arrangement but amorphous if coherent or single grained if noncoherent) weak, moderate, and strong. The aggregates vary in class (size) and are described as fine, medium, coarse, or very coarse. The size classes vary according to the type (shape) of structure. The types of structure mentioned in the report are:

granular—having more or less rounded aggregates without smooth faces and edges, relatively nonporous.

platy—having thin, platelike aggregates with faces mostly horizontal.

prismatic—having vertical prisms with well-defined faces and angular edges.

blocky—having blocklike aggregates with sharp, angular corners.

subangular blocky—having blocklike aggregates with rounded and flattened faces and rounded corners.

An aggregate is described in the order of grade, class, and type. Two examples of this convention are: strong, medium, blocky; moderate, coarse, granular.

soil texture. The percentages of sand, silt, and clay in a soil determine its texture. Size groups from 2 mm to 0.05 mm in diameter are called sand, those from 0.05 mm to 0.002 mm are called silt, and those less than 0.002 mm in diameter are called clay. Sands are coarse textured, loams are medium textured, and clays are fine textured.

solum (sola). The upper horizons of a soil in which the parent material has been modified and within which most plant roots are confined. It consists usually of A and B horizons.

value, color. The relative lightness or intensity of color and approximately a function of the square root of the total amount of light. One of the three variables of color. See *Munsell color system, hue,* and *chroma.*

water table. Elevations at which the pressure in the water is zero with respect to the atmospheric pressure. This may be called groundwater surface, free water surface, or groundwater elevation.

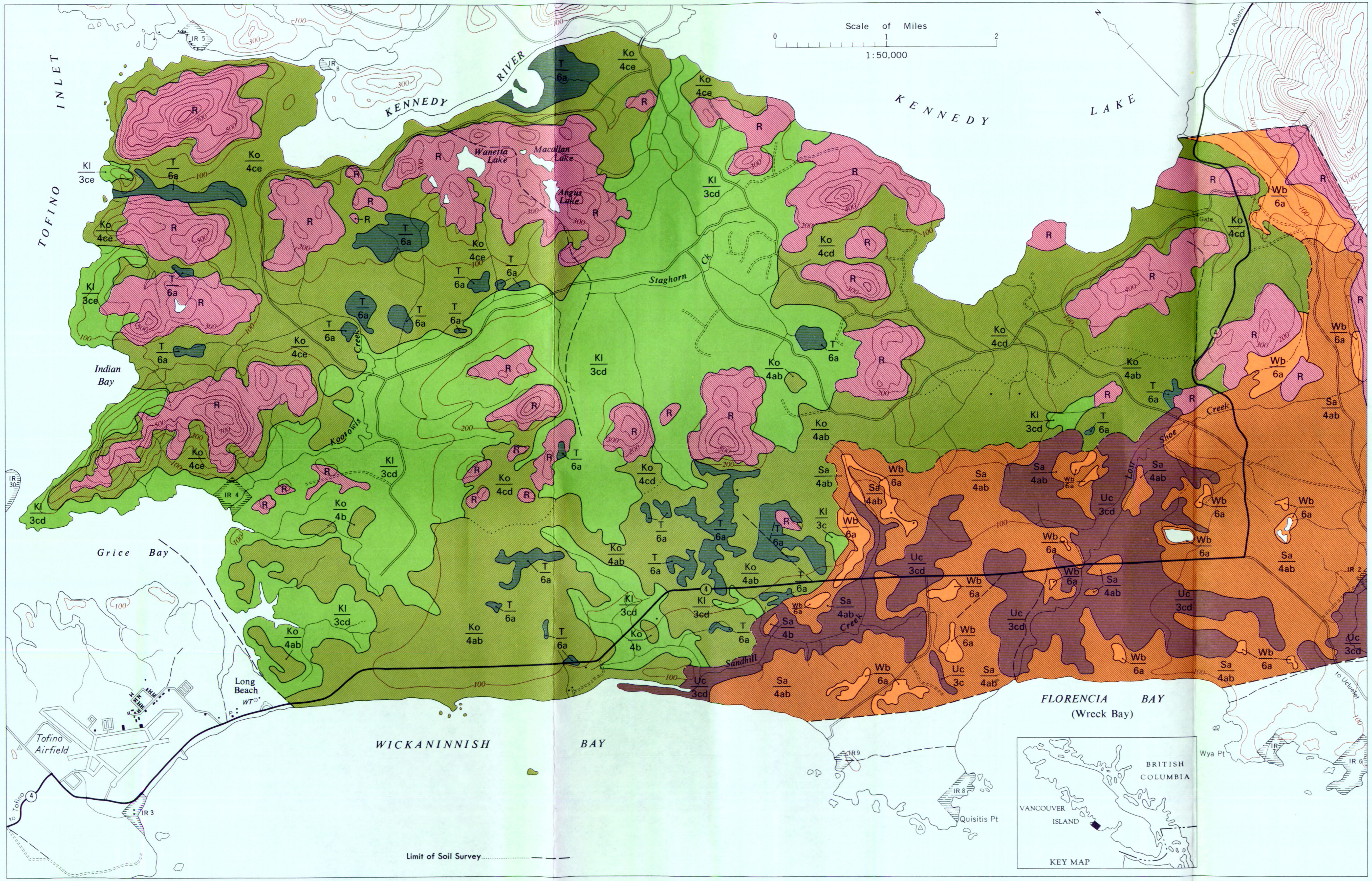
APPENDIX I

LIST OF VEGETATION

bulrush	*Scirpus* sp.
bunchberry	*Cornus canadensis* L.
bush, copper	*Cladothamnus pyrolaeflorus* Bong.
cedar, western red	*Thuja plicata* D. Don.
cranberry, small	*Vaccinium oxycoccus* L.
crowberry, black	*Empetrum nigrum* L.
cedar, yellow	*Chamaecyparis nootkatensis* (D. Don.) Spach.
fern, deer	*Blechnum spicant* (L.) Roth
fir, amabilis	*Abies amabilis* (Dougl.) Forbes
fir, grand	*Abies grandis* (Dougl.) Lindl.
hemlock, western	*Tsuga heterophylla* (Raf.) Sarg.
huckleberry, tall red	*Vaccinium parvifolium* Smith
laurel, bog	*Kalmia polifolia* Wang.
mnium, dotted	*Mnium punctatum* Hedw.
moss, sphagnum	*Sphagnum recurvum* Beauv.
	Sphagnum papillosum Lindb.
	Sphagnum mendocinum Sull. & Lesq.
pine, lodgepole	*Pinus contorta* Dougl.
rhytidiadelphe	*Rhytidiadelphus* sp.
rushes	*Juncus* spp.
salal	*Gaultheria shallon* Pursh.
sedges	*Carex* spp.
spruce, Sitka	*Picea sitchensis* (Bong.) Carr.
tea, Labrador	*Ledum groenlandicum* Oeder

SOIL MAP OF THE TOFINO-UCLUELET LOWLAND

VANCOUVER ISLAND, B.C.



LEGEND

SOIL SYMBOL AND COLOUR	SOIL SERIES	CLASSIFICATION	SOIL PARENT MATERIALS	DRAINAGE CLASS
Soils of the Tofino Terrain System: Kennedy Lake catena				
Kl	Kennedy Lake	Orthic Dystric Brunisol	Marine drift: stony clay with sand lenses	Moderately well drained (3)
Ko	Kootowis	Gleyed Orthic Dystric Brunisol	Marine drift: stony clay with sand lenses	Imperfectly drained (4)
T	Tofino	Rego Humic Gleysol	Marine drift: stony clay with sand lenses	Very poorly drained (6)
Soils of the Ucluelet Terrain System: Ucluelet catena				
Uc	Ucluelet	Orthic Ferro-Humic Podzol	Outwash: sands and gravels	Moderately well drained (3)
Sa	Sandhill	Gleyed Orthic Ferro-Humic Podzol	Outwash: sands and gravels	Imperfectly drained (4)
Wb	Wreck Bay	Placic Humic Podzol	Outwash: sands and gravels	Very poorly drained (6)
Miscellaneous Soils Common to Both Terrain Systems				
R	Hill Soils	Thin soils and bare rock	Exposed bedrock and shallow drift	Rapidly to well drained

COMPLEX TOPOGRAPHY
Multiple Slopes

	Slope %
a — depressional to level	0-.5
b — very gently sloping	.5-2
c — gently sloping	2-5
d — moderately sloping	6-9
e — strongly sloping	10-15

CONVENTION

Soil Symbol $\frac{\text{Soil}}{\text{Drainage Class} \quad \text{Topography}}$ Example $\frac{\text{Uc}}{\text{3cd}}$

Soil boundaries

Soil boundaries (uncertain)

Slope Class boundaries

Compiled, drawn and published by the Cartography Section, Soil Research Institute, Research Branch, Canada Department of Agriculture, Ottawa, 1969.