REGIONAL GROUNDWATER POTENTIAL
FOR
SUPPLYING IRRIGATION WATER: 1985

DUNCAN TO NANOOSE BAY

K.D. Ronneseth
Ministry of Agriculture and Food

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ACKNOWLEDGEMENTS

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1. INTRODUCTION

The Ministry of Agriculture and Food in conjunction with the Agricultural Land Commission are involved in a detailed assessment of the agricultural capability of the east coast of Vancouver Island. An analysis of the hydrological data was identified as an important requirement in the above assessment with groundwater being a major component.

This report and accompanying maps provides a discussion and analysis of developed and potential aquifers, for the areas between Duncan and Nanoose Bay (Figure 1), based on presently available groundwater and geologic data. The map sheets which cover the study area include 92B.081, 082, 091, 092; 92F.020, 030, 040; 92G.001, 002, 011 and 021 (1:20,000 scale). These map sheets are identified as Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 respectively.

The hydrogeological information, thematically presented on the map sheets, are based on the tabulated data from approximately 2500 water well records, water well location maps (both on file with the Groundwater Section, Ministry of Environment), published surficial geology maps and reports (Fyles, 1963; Halstead, 1966; Leaming, 1968; Muller, 1977; Muller and Atchison, 1971), terrain maps (Ministry of Environment, British Columbia) and soil maps and reports (Ministry of Agriculture and Food and Ministry of Environment, British Columbia).

Tabulated data from water well records (e.g., aquifer characteristics, depth to bedrock, etc.) and coal exploration test holes (depth to bedrock, thickness of overburden, etc.) were transferred to water well location maps (scale 1:12,000) which were used as a working base. Surficial geology/-terrain units and glacial features (e.g., delta kames) which were considered hydrogeologically significant in terms of groundwater potential were

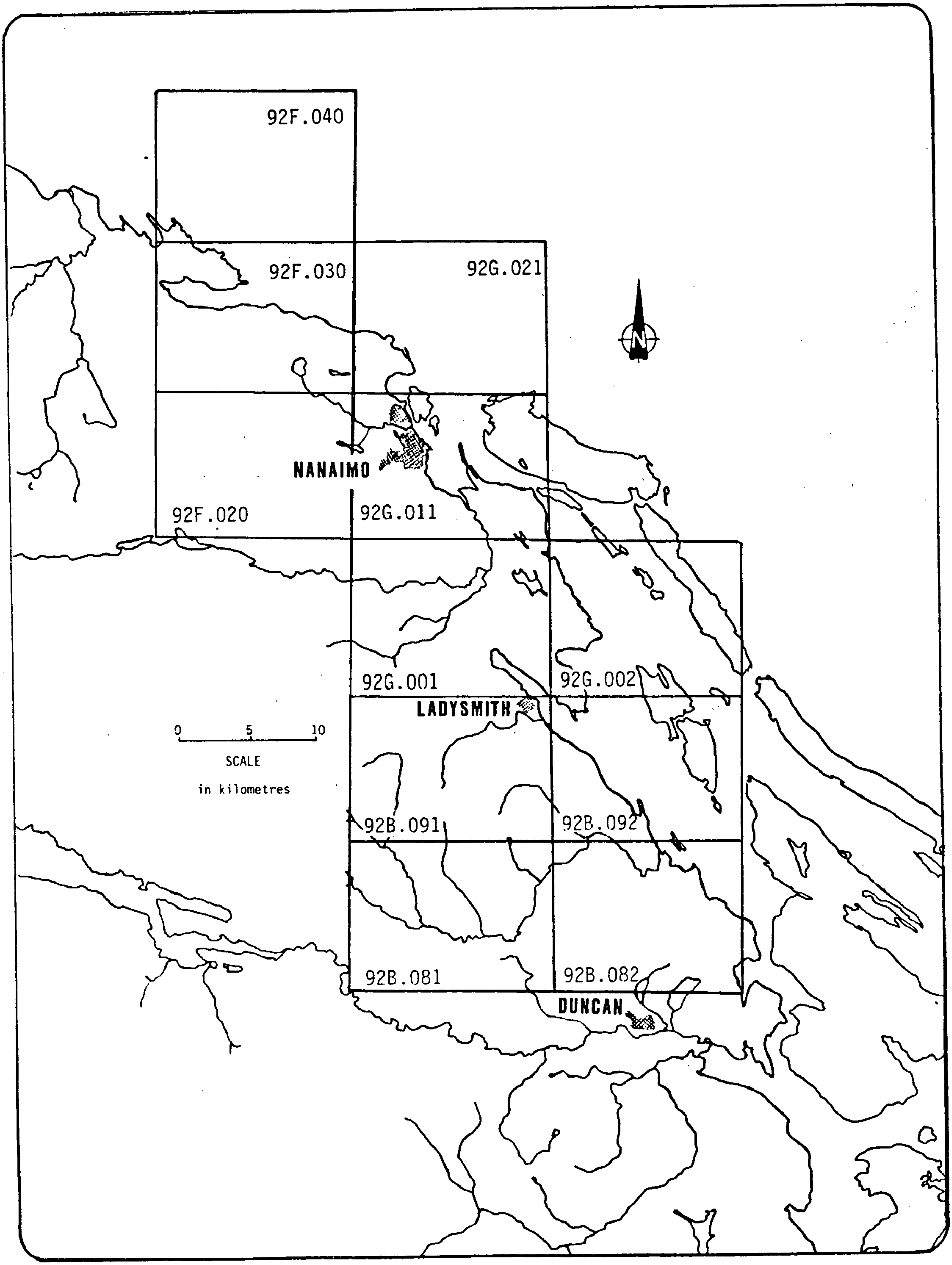


FIGURE 1: Index Map of Study Area.

transferred to these same maps. A synthesis of this data was then transferred to the final 1:20,000 scale base maps.

2. PHYSIOGRAPHY

The major geomorphic features of the study area are the result of structural, erosional and depositional processes. Folding and faulting of the bedrock, erosion and repeated glaciation, isostatic and eustatic changes of sea level have all contributed to the physiographic features of the southeast coast of Vancouver Island. The dominant features are the eastern face of the northwest-trending Vancouver Island Ranges of the Insular Mountain Physiographic Division with elevations to 1340 metres and an undulating coastal lowland of the Coastal Trough Physiographic Division, rising from sea level to approximately 150 metres and ranging from 1 to 14 kilometers in width. The study area is crossed by the Chemainus and Nanaimo River Valleys and is bounded by the South Englishman River Valley on the north and by the Cowichan River Valley on the south.

3. BEDROCK GEOLOGY

According to Muller (1977), Vancouver Island is the main component of the Insular Belt, the westernmost major tectonic subdivision of the Canadian Cordillera. The study area contains Paleozoic rocks (a volcanic and a greywacke-argillite formation of the Sicker Group), Lower Mesozoic rocks (a volcanic formation of the Vancouver Group), Middle Mesozoic rocks (batholiths and stocks of granitoid rocks of the Island Intrusions) and Upper Mesozoic rocks (consisting of cyclical upward fining sequences of conglomerate, sandstone, shale and coal of non-marine or near deltaic origin, suceeded by marine sandstone, shale or thin bedded and graded shale-siltstone sequences from the Nanaimo Group). The coastal lowlands are principally underlain by the Nanaimo Group.

4. UNCONSOLIDATED DEPOSITS

Most of the unconsolidated materials found in the study area may be attributed to the regimen and wasting of glacial ice during the Late Pleistocene. Though some of the unconsolidated deposits are the result of older glacial (Dashwood Drift) and interglacial (Mapleguard and Cowichan Head Sediments) activity, the majority of the deposited sediments are from the Fraser Glaciation. The Fraser Glaciation probably represents the same geologic-climatic time period as the classical Late Wisconsin Glaciation of the mid-continent region (Alley and Chatwin, 1979). Halstead (1966) and Fyles (1963) have mapped the surficial unconsolidated sediments within the study area at a scale of 1:63,360.

A stratigraphic framework of unconsolidated sediments and a chronology of Late Pleistocene environments in the study area, is shown in Figure 13.

5. GROUNDWATER POTENTIAL

5.1 Bedrock

Groundwater within the bedrock can be found in fractures, along bedding plane partings, in the inter-flow zones of lava, in the inter-granular openings in the rock, and in the case of limestone, in the channels formed by the dissolution of the rock by water. Water wells drilled on Vancouver Island, indicate fractures, bedding plane partings and solution channels are probably the main sources of groundwater from the bedrock. Most of the approximately 1100 bedrock wells in the study area are completed in rocks of the Nanaimo Group, principally shales and sandstones. The rapid accumulation of sediments which make up these rocks, accounts for their being poorly sorted, massive and, in general, lacking in pore spaces and conduits for the transmission of water (Halstead and Treichel, 1966). Water wells drilled in these rocks

YEARS BEFORE PRESENT (Not to Scale)	CLIMATIC UNITS	GEOLOGIC UNITS	ENVIRONMENT	STRATIGRAPHY
Present				
5,000	HOLOCENE	SALISH SEDIMENTS	FLUVIAL	Gravel, sand, silt, clay, peat; alluvial fan deposits; blocks and rubble; peat and muck
10,000		CAPILANO SEDIMENTS	MARINE AND GLACIO-MARINE GLACIO-LACUSTRINE	Silt, clay, stony clay, sandy gravel generally underlain by clay; stony gravel, stony loam Sand and gravel, laminated silty and clay
15,000	FRASER GLACIATION	VASHON DRIFT	GLACIO-FLUVIAL GLACIAL	Gravel, sand and silty forming ice-contact deltas Grey till, sand to clayey texture
20,000		QUADRA SAND	GLACIO-FLUVIAL	Sand, gravel and silt
25,000				
30,000	OLYMPIA NON-GLACIAL INTERVAL	COWICHAN HEAD FORMATION	FLUVIAL ESTURINE MARINE	Silt, gravel, sand, peat, peaty soil, and driftwood Clay, stony clay, silt containing marine shells, local basal laminated clay and silt
60,000				
	SALMON SPRINGS GLACIATION	DASHWOOD DRIFT	GLACIO-MARINE GLACIAL	Grey till, silty to sandy texture contains silty and gravel lenses
?				
	PUYALLUP NON-GLACIAL INTERVAL	MAPLEGUARD SEDIMENTS	FLUVIAL LACUSTRINE	Sand, silt, minor clay and gravel

Figure 13: CLIMATIC GEOLOGIC UNITS, STRATIGRAPHY AND LATE PLEISTOCENE ENVIRONMENTS OF THE STUDY AREA after Clague (1981, 1977 & 1976) Alley & Chatwin (1979), Armstrong et al (1965) & Halstead (1966)

indicate fractures and bedding plane partings are the main sources of groundwater. Water wells completed in sandstone generally reported higher yields than wells completed in shales. Two hundred and twenty-seven wells were observed to be completed in sandstones, 308 in shales, 262 in shaley sandstone and 31 in conglomerate. Thirty-six wells were observed to be completed in granite and two in basalt. Two hundred and thirty-two other wells were also completed in bedrock, however, the type of bedrock was not reported.

The possibility of obtaining adequate supplies of groundwater for irrigation purposes from these sources are generally considered to be poor and although a few bedrock wells in the study area have been reported to yield between 1 and 6 L/s (six litres per second is significant when considering irrigation requirements), long duration pumping tests would be required to verify if bedrock aquifers are capable of a sustained high withdrawal rate.

Examples of bedrock aquifers capable of yielding sufficient supplies of groundwater for irrigation purposes can be found in the Mill Bay and Saanich regions of southern Vancouver Island where well yields up to 16 L/s have been obtained. It is not known if comparable high yielding bedrock aquifers exist in the study area. To identify such aquifers would require detailed geologic mapping, aerial photograph analysis, and possibly geophysical investigations, as well as test drilling. These procedures can be both time-consuming and expensive.

5.2 Unconsolidated Deposits

Most of the groundwater used on Vancouver Island comes from unconsolidated deposits which receive water from infiltration of either precipitation or surface water sources. The amount of water obtainable from these materials, depends on the permeability of the aquifer material, the thickness and extent of the aquifer, the rate of aquifer recharge and on well construction.

The unconsolidated deposits which are hydrogeologically significant in terms of groundwater potential for irrigation purposes are primarily comprised of sand and/or gravel. One water well completed in a sand and gravel aquifer (Lantzville area) was reported to yield 9 L/s. The confined sand and gravel zone was 0.3 metres in thickness. Thickness of any saturated sand and/or gravel deposit 0.3 metres or greater are considered significant in terms of groundwater potential. The deposits which fall into this category are listed and discussed below:

1) The shore, deltaic, fluvial and alluvial deposits of the Salish Sediments. These deposits range up to 10 metres in thickness. The primary target for groundwater exploration would be the fluvial deposits near present day stream channels and deltas. These would include the valleys and/or deltas of Somenos, Bonsall, Millstone, Bonell and Nanoose Creeks and the Chemainus and Nanaimo Rivers.

2) Terraced fluvial deposits which include deltaic, channel, floodplain and alluvial fan deposits along with some marine and/or glacio-marine deposits of the Capilano Sediments. These deposits range up to 10 metres in thickness and 3000 metres across. The deltaic deposits would be primary target areas for groundwater exploration. Major examples of terraced fluvial deposits can be found southwest of Chemainus, the area around Cassidy, along the Nanaimo River and along Bonell and Nanoose Creeks.

3) The glaciofluvial deposits which include hummocky, knob and kettle, ridged, esker, terrace and pitted terrace, kame terrace, kame delta and ice contact alluvial fan deposits of the Vashon Drift. These deposits are found resting upon the ground moraine of the Vashon

Drift. Usually located within a couple of miles of the mountain slopes, these deposits may range up to 2 kilometers wide and 6 kilometers long. One such deposit exists in the Nanaimo River - Haslam Creek area west of Cassidy and locally may exceed 15 metres in thickness. It is known that a major aquifer exists within this delta/terrace deposit. The kame terraces and kame deltas would be primary target areas for groundwater exploration. Another area of glacio-fluvial deposits can be found north-west of Duncan, along the Nanaimo River, along the N. Nanaimo River and south-west of Brannen Lake.

Lenses of sand and/or gravel are associated with the ground moraine deposits of the Vashon Drift. Though these lenses are potential aquifers their location and viability must be confirmed by drilling, which can be both expensive and time consuming.

4) The glaciofluvial deposits of the Quadra Sediments (Fyles, 1963) known as the Quadra Sand (Clague, 1977). The groundwater potential of this geologic unit merits an expanded understanding of its distribution and origin.

Quadra Sand is found in the northern portion of the study area, usually below the 100 metre elevation level. Comprised predominantly of sand with minor silt and gravel these deposits locally exceed 30 metres in thickness. Water well logs have reported greater than 20 metres of sand which possibly belong to the Quadra Sand Unit. Overlain by glacial sediments (mainly till) of the Fraser Glaciation and underlain by sediments of the Olympia Interglacial interval the current theory on the origin of Quadra Sand is summarized by Clague (1977) below:

> "The sand was deposited, in part, as distal outwash aprons at successive positions in front of and perhaps along the margins of glaciers moving from the Coast Mountains into the Georgia Depression and Puget Lowland during Late Wisconsin time. After deposition at a site, but before burial by ice, the sand was dissected by meltwater and the eroded detritus was transported farther down the basin to sites where aggradation continued."

An extensive deposit of Quadra Sand is believed to exist in a 1/4 to 2 kilometer wide belt from Northwest Bay past Nanoose Harbour to Cottle Hill west of Lantzville. The inferred distribution of Quadra Sand is shown in Figure ~~13~~ 14. Quadra Sand may be located elsewhere in the study area. Aquifers consisting primarily of sand have been encountered but it is unknown if these sands are of the Quadra formation. The extensiveness of the Quadra Sand, its thickness and locally proven yields of 3.5 L/s within the study area and greater than 6 L/s outside the study area, makes this deposit a primary target for groundwater exploration.

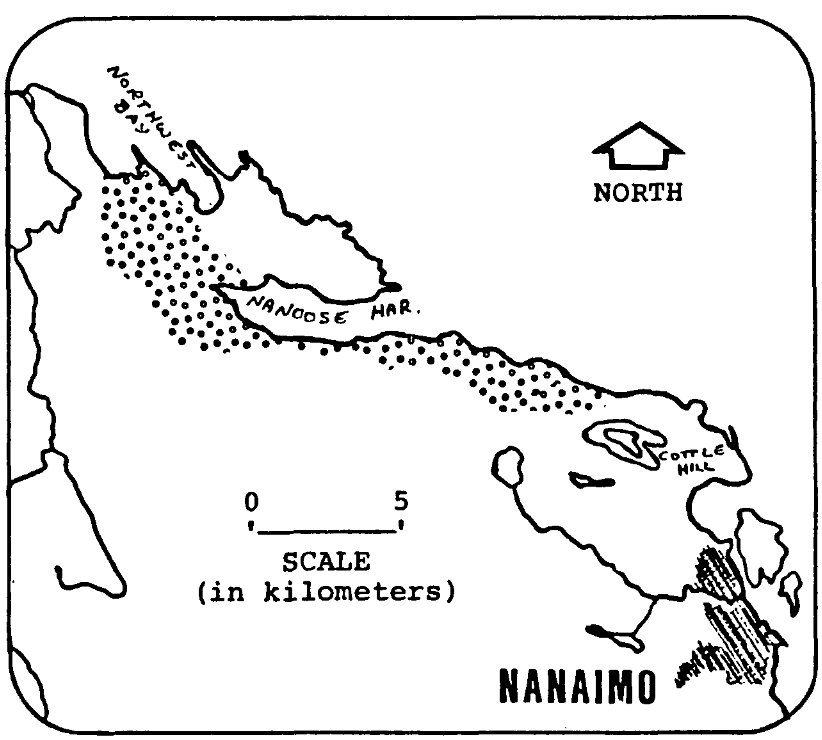


Figure 14
Inferred distribution of Quadra Sand (after Fyles 1963, Clague 1977 and water well records on file with Groundwater Section).

The following is a summary of groundwater data from water well records in the study areas. Many of the wells were completed in one or more of the deposits just described.

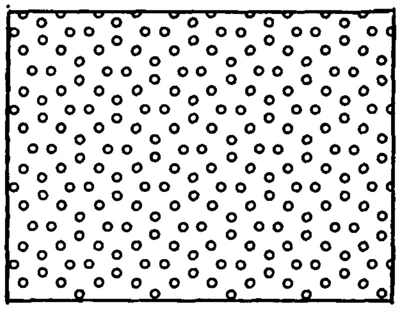
Approximately 1/3 of the water wells in the study area were completed in unconsolidated materials.

Over 460 water well records showed wells completed in sand/or gravel ranged in depth from one to 99 metres. The interpreted depth to the top of a sand and/or gravel aquifer based on over 320 water well records ranged from one to 98 metres. Over 320 water well records showed interpreted aquifer thicknesses ranging from 0.3 to 26 metres.

Wells completed in bedrock reported yields ranging from 0.1 to 6.3 L/s and wells completed in sand and/or gravel reported yields ranging from 0.1 to 400 L/s. Sixty-five wells completed in bedrock reported yields between 1 and 3 L/s versus 81 wells completed in sand and/or gravel. Five wells completed in bedrock reported yields greater than 5 L/s versus 29 for wells completed in sand and/or gravel. A more efficient development of the wells completed in sand and/or gravel will often yield higher productivity.

6. EXTENT OF DEVELOPED AND POTENTIAL AQUIFERS

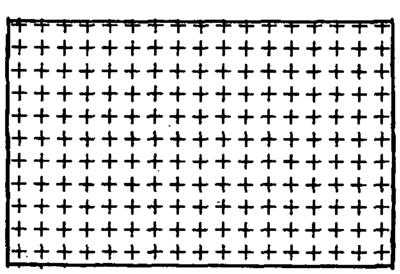
The following is a description and the limitations of each component shown on the 1:20,000 scale base maps. (Figures 2-12)



POTENTIAL UNCONSOLIDATED UNCONFINED AQUIFERS: These areas outline the surficial extent of unconsolidated deposits primarily comprised of sand and/or gravels. They outline areas where there is a high probability of locating water-bearing sand and/or gravel aquifers but does not imply the existence of water-bearing sand and/or gravel aquifers. In some areas for example the sand and gravel deposits may be very thin and dry throughout their entire thickness.

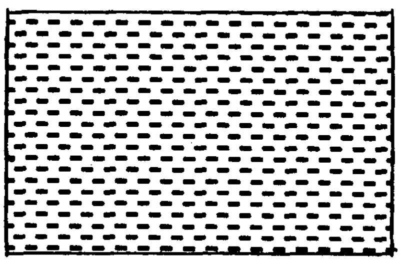
These areas outline potential unconfined aquifers at surface, it does not show distribution at depth. This is especially relevant to the Quadra Sand and possibly to some pre-Fraser Glaciation unconsolidated sediments (e.g., Mapleguard sediments) which may underlie younger deposits (marine clays for example) in the region.

The surficial geology units which make up these areas were transferred first from 1:63,360 and 1:50,000 scale mapping to 1:12,000 scale water well location maps, and then to 1:20,000 scale cadastral maps. Minor boundary errors may exist therefore on the larger scale mapping.

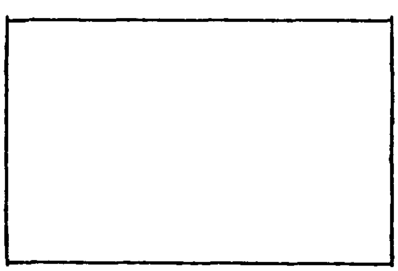


DEVELOPED UNCONSOLIDATED AQUIFERS: These areas outline where sand and/or gravel aquifers (greater than 0.3 metres in thickness) have been identified at depth based on water well lithology records. These aquifers may be either confined or unconfined.

The boundaries of these areas were arbitrarily set at a 100 metre radius from a data point (water well) which identified a sand and/or gravel aquifer greater than 0.5 metres in thickness. Where two wells, located within 400 metres of each other, show similar lithologies and the geomorphology of the area was homogeneous, the boundaries were extended to include the area between the two wells.



LOW PERMEABLE UNCONSOLIDATED DEPOSITS: These areas outline where the unconsolidated deposits at surface (predominantly tills, silts and/or clays) are generally unsuitable as aquifer materials due to their low permeability. However, suitable aquifer materials may and do exist at depth as evidenced throughout these areas where site specific data are available. Where ground moraine deposits have been mapped in these areas, locally there may be sand and/or gravel deposits found at surface or in lenses at depth. Also, older geologic units (e.g., Quadra Sand) that are significant aquifers may be overlain by the marine and moraine deposits. Productive aquifers may be found in these older geologic units. The boundaries were also transferred from Fyles (1963) and Halstead (1966) surficial geology maps (1:63,360 scale) and Ministry of Environment terrain maps (1:50,000 scale). Minor boundary errors therefore may exist on the larger scale mapping.



BEDROCK AQUIFERS: These areas identify where bedrock is located at or near ground surface and/or where well logs indicate bedrock aquifers. The boundaries for these areas were also arbitrarily set at 100 metre radius from a data point (e.g., bedrock well or rock outcrop). This distance was extended to 400 metres between data points if water well lithology and the surface morphology so warranted.

▲ Water wells where yields greater than 3 L/s have been reported. Where these wells are found in Area B these areas show the highest potential for obtaining groundwater supplies to meet irrigation requirements.

△ Water wells where yields between 1 and 3 L/s are reported. These areas also show high potential for obtaining irrigation supplies of groundwater.

7. WATER QUALITY

The concentration and composition of dissolved constituents in a water determine its quality for irrigation use. Three of the characteristics of an irrigation water that appear to be the most important in determining its quality are the total concentrations of soluble salts, the relative proportion of sodium to other cations and the concentrations of boron and other elements that may be toxic.

The total concentration of soluble salts can be expressed in terms of its electrical conductivity and is often expressed as micromhos/cm at 25°C. The higher the concentration of soluble salts and minerals the higher the conductivity. The electrical conductivity of the 9 laboratory analyses of groundwaters from unconsolidated aquifers ranged from 41 to 340 micromhos/cm. Six of these waters are in the low salinity hazard class and three are in the medium salinity hazard class (Richards, 1969).

According to Richards (1969):

"Low salinity water can be used for irrigation with most crops with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability. Medium salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control."

The electrical conductivity of the 12 laboratory analyses of groundwaters from bedrock aquifers ranged from 312 to 6900 micromhos/cm. Six of these waters are in the medium salinity hazard class, three are in the high salinity hazard class and two are in the very high salinity hazard class (Richards, 1969).

According to Richards (1969):

"High salinity water cannot be used on soils with restricted drainage. Even with adequate drainage, special management of salinity control may be required and plants with good salt tolerance should be selected. Very high salinity water is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt tolerant crops should be selected."

The very high saline waters found in two of the bedrock wells are probably the result of sea water intrusion. The water from one of these wells had conductivity readings of 6900 micromhos/cm. Richard's (1969) upper limit in his salinity hazard classification was 5500 micromhos/cm.

A salty taste in the groundwater was recorded on 22 water well records. The distribution of these wells can be seen in figure 15. This implies a high chloride reading of greater than 350 mg/L (Anderson, 1973). Though this reading may or may not indicate a high level of total dissolved solids, the sodium absorbtion ratio and the conductivity reading are likely to be high. These 22 wells were mostly completed in shale, though some wells were reported to be completed in clays or sandstones. Water quality analyses would be required to verify comments on salty tasting groundwaters and if so, to determine if these groundwaters are within acceptable limits for irrigation use.

The relative proportion of sodium to other cations (usually calcium and magnesium) in groundwaters may make some waters undesirable for some crops. This relationship is usually expressed as the sodium absorption ratio (SAR) where SAR $= Na^{+}/\sqrt{(Ca^{++}+Mg^{++})/2}$ and can be used for identifying the suitability of groundwaters for irrigation purposes. The formula applies where all concentrations are expressed in epm. Applying the SAR formula to eight laboratory analyses revealed the sodium hazard level as being low in the groundwaters of the unconsolidated aquifers. Applying the SAR formula to 10 laboratory analyses of groundwaters from bedrock aquifers revealed the sodium hazard level as being low in four water samples, medium in one sample, high in one sample and very high in four samples.

According to Richards (1969):

"Low sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium. Medium sodium water will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. This

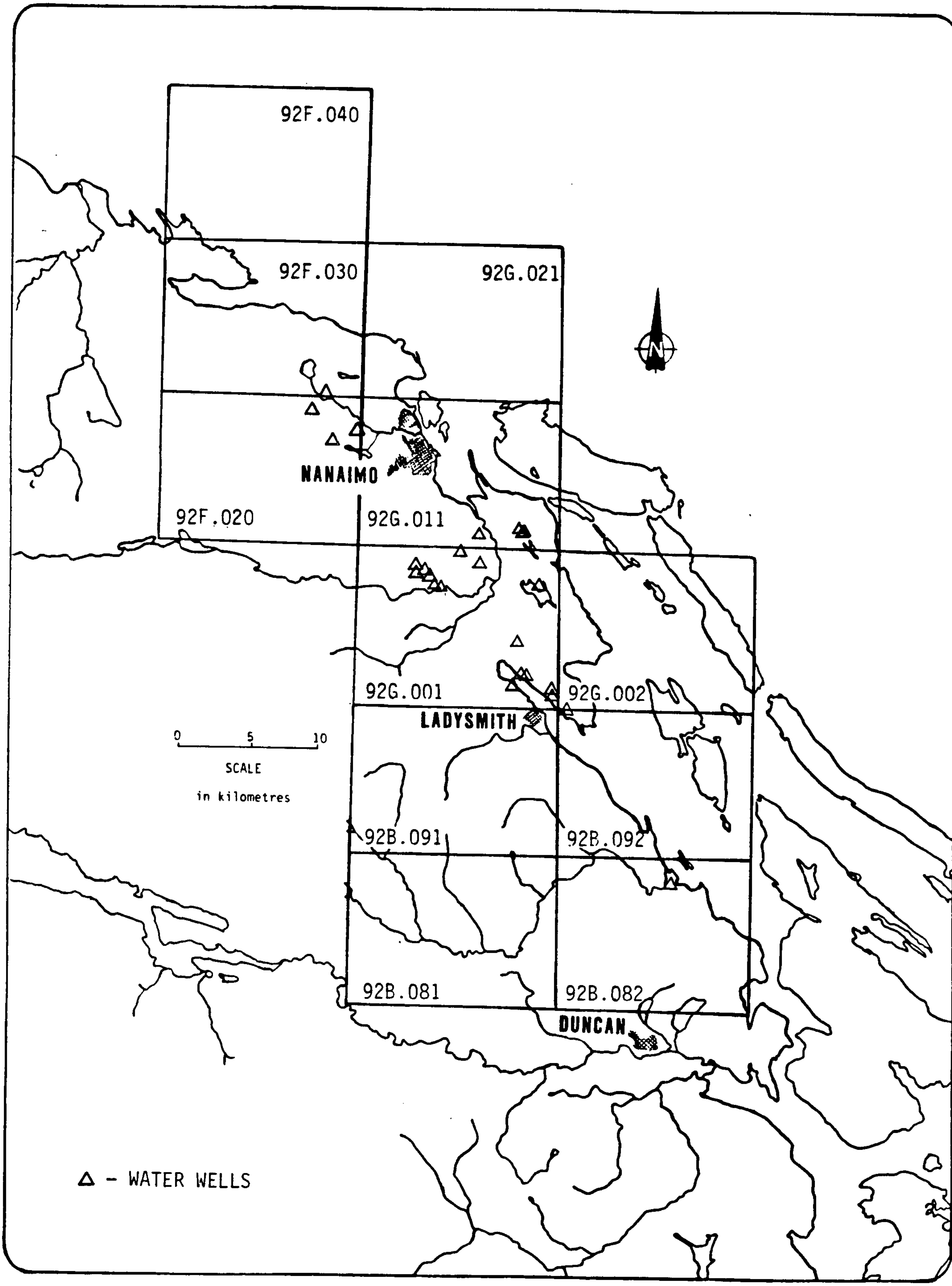


FIGURE 15: Water Wells Where a Salty Taste to the Water was Reported.

water may be used on coarse textured or organic soils with good permeability. High sodium water may produce harmful levels of exchangeable sodium in most soils and will require special soil management - good drainage, high leaching and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity. Very high sodium water is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or the use of gypsum or other amendments may make the use of these waters feasible. Sometimes the irrigation water may dissolve sufficient calcium from calcareous soils to decrease the sodium hazard appreciably, and this should be taken into account in the use of low salinity-high sodium and low salinity-very high sodium waters. For calcareous soils with high pH values or for non-calcareous soils, the sodium status of waters in classes low salinity-high sodium, low salinity-very high sodium and medium salinity-very high sodium may be improved by the addition of gypsum to the water. Similarly, it may be beneficial to add gypsum to the soil periodically when medium salinity-high sodium and high salinity-medium sodium waters are used."

The majority of these salinity-sodium combinations are found in the study area. It should be restated that most sources of groundwater on the east coast of Vancouver Island capable of yielding quantities suitable for irrigation purposes will come from unconsolidated aquifers. The salinity and sodium hazard were generally reported to be low.

Another important characteristic of irrigation waters are concentrations of boron and other elements that may be toxic. Based on nine low

Total Dissolved Solids readings, it is probable that toxic elements found in most groundwaters from unconsolidated aquifers will be within acceptable limits. High levels of Boron (2.68 mg/L), however, have been found in the Cretaceous bedrock in other parts of Vancouver Island. It is not known if high levels of toxic elements are present in the study area, especially in the bedrock groundwaters.

8. CONCLUSIONS

On a regional basis, there is a high potential for locating groundwater supplies capable of meeting irrigation requirements in the coastal plain region of the study area. The largest groundwater reserves in the area are contained in recent alluvial deposits, terraced fluvial and deltaic deposits, and in the Quadra Sand and other sediments beneath the Vashon Drift.

Though there is a paucity of well log information available for much of the study area, suitable geologic deposits indicate the potential availability of groundwater for irrigation purposes. Even where water well log information is available, most water well logs reported yields from sand and/or gravel aquifers at less than 2 L/s. This is usually the result of the immediate needs of the water user. A single family home only requires a well yield of 0.2 L/s. A more efficient development of the same aquifer will often yield higher productivity.

Natural water quality is expected to be acceptable from the groundwaters of unconsolidated deposits. Not enough data is available on the water quality of bedrock aquifers but comments from a dozen water well logs indicate the need for more water quality analyses. The few analyses of groundwaters from unconsolidated aquifers, indicate a low to medium salinity hazard and a low proportion of sodium to other cations. Special irrigation practices are usually not necessary with these water types. The few analyses of groundwaters from bedrock aquifers report the salinity and sodium hazards ranging from low to very high. This variability in quality from bedrock aquifers stresses the need for adequate quality analyses to determine suitability for use. One area of concern is man induced pollution to groundwater. A number of landfill sites are located in these same sand and/or gravel deposits on Vancouver Island which contain productive aquifers. Groundwater withdrawals from these areas should always be analysed for toxic elements such as heavy metals.

This report is regional in scope and identifies areas which have the potential to supply irrigation water. It does not provide a quantitative assessment of water availability for a site specific location. To provide such an assessment, more accurate delineation of aquifer boundaries and estimation of groundwater recharge, movement, aquifer parameters and withdrawal would be required on a site specific basis.

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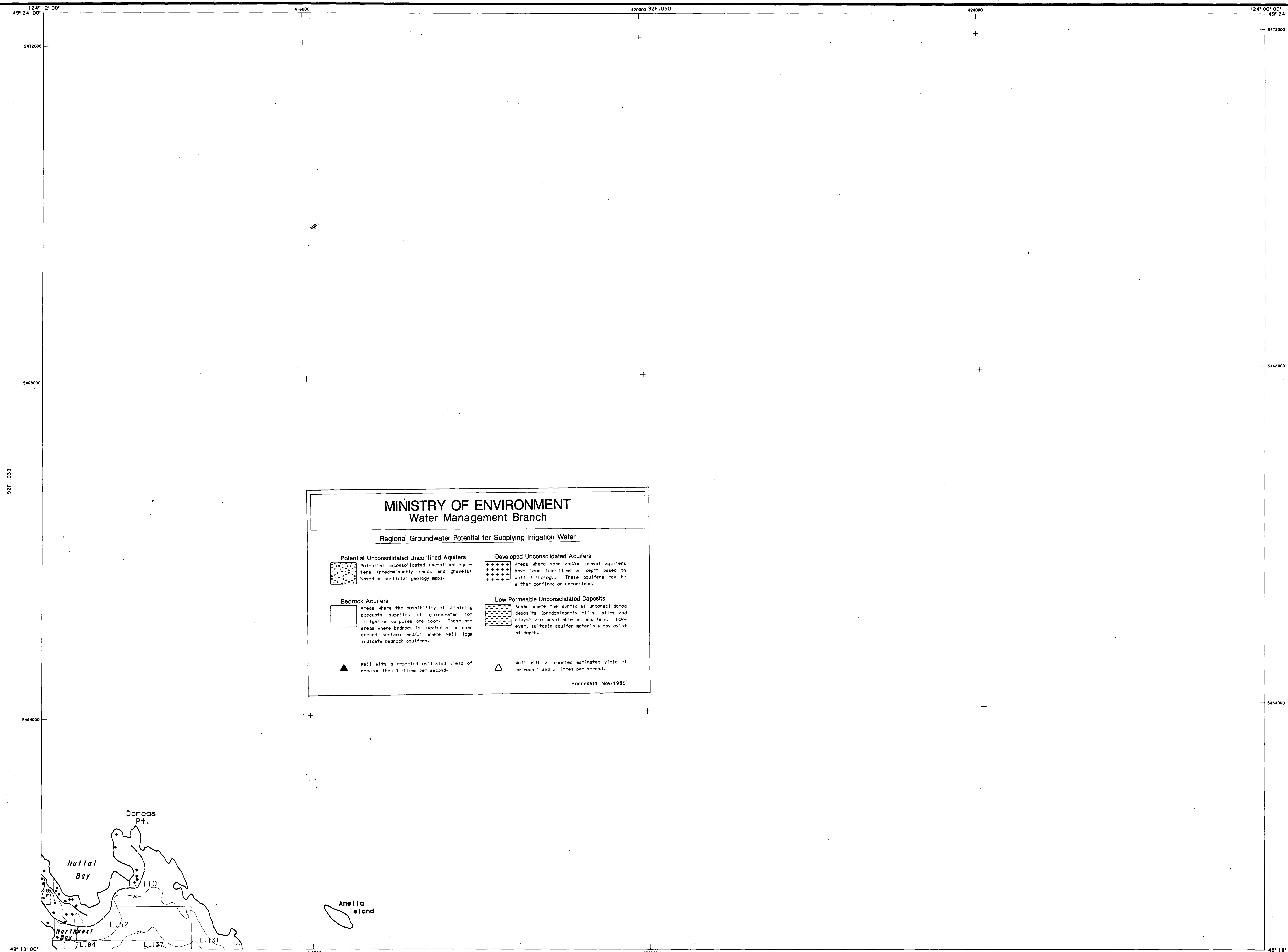


MINISTRY OF ENVIRONMENT
Water Management Branch

Regional Groundwater Potential for Supplying Irrigation Water

Potential Unconsolidated Unconfined Aquifers
Potential unconsolidated unconfined aquifers (predominantly sands and gravels) based on surficial geology maps.

Developed Unconsolidated Aquifers
Areas where sand and/or gravel aquifers have been identified at depth based on well lithology. These aquifers may be either confined or unconfined.

Bedrock Aquifers
Areas where the possibility of obtaining adequate supplies of groundwater for irrigation purposes are poor. These are areas where bedrock is located at or near ground surface and/or where well logs indicate bedrock aquifers.

Low Permeable Unconsolidated Deposits
Areas where the surficial unconsolidated deposits (predominantly tills, silts and clays) are unsuitable as aquifers. However, suitable aquifer materials may exist at depth.

▲ Well with a reported estimated yield of greater than 3 litres per second.

△ Well with a reported estimated yield of between 1 and 3 litres per second.

Ronneseth, Nov/1985

PROVINCE OF BRITISH COLUMBIA — MINISTRY OF ENVIRONMENT

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976,81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: MARCH 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: NANAIMO AND NEW WESTMINSTER
LAND TITLE DIST.: VICTORIA AND VANCOUVER

DIST. LOT AND TP. SEC.
SUBDIVISION LOT

AIR PHOTO CENTRE

BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
SWAMP
DEPRESSION
TREED SWAMP

ROADS PAVED
GRAVEL
ROUGH
TRAIL
RAILWAY
ABAND.
POWER LINE
FENCE
FLUME

SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL 20 METRES

PLANIMETRIC DIGITAL
CADASTRAL DIGITAL
CONTOUR

SEE INDEX 92F
PROJECT No. 83-035PC

92F.040

MINISTRY OF ENVIRONMENT
Water Management Branch

Regional Groundwater Potential for Supplying Irrigation Water

Potential Unconsolidated Unconfined Aquifers
Potential unconsolidated unconfined aquifers (predominantly sands and gravels) based on surficial geology maps.

Developed Unconsolidated Aquifers
Areas where sand and/or gravel aquifers have been identified at depth based on well lithology. These aquifers may be either confined or unconfined.

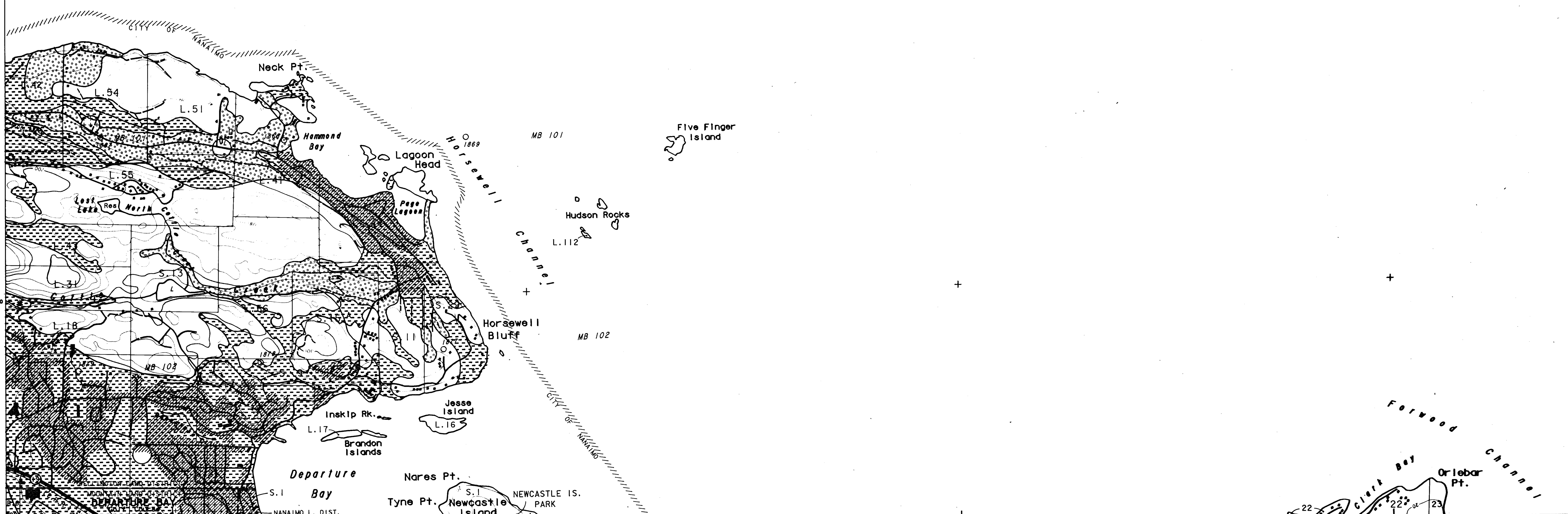
Bedrock Aquifers
Areas where the possibility of obtaining adequate supplies of groundwater for irrigation purposes are poor. These are areas where bedrock is located at or near ground surface and/or where well logs indicate bedrock aquifers.

Low Permeable Unconsolidated Deposits
Areas where the surficial unconsolidated deposits (predominantly tills, silts and clays) are unsuitable as aquifers. However, suitable aquifer materials may exist at depth.

▲ Well with a reported estimated yield of greater than 3 litres per second.

△ Well with a reported estimated yield of between 1 and 3 litres per second.

Ronneseth, Nov/1985



49° 18' 00" 124° 00' 00" | 428000 | 432000 | 436000 | 440000 | 123° 48' 00" 49° 18' 00"

5460000 | 5456000 | 5452000

92F.030

49° 12' 00" 124° 00' 00" | 428000 | 432000 | 92G.011 | 436000 | 440000 | 49° 12' 00" 123° 48' 00"

PROVINCE OF BRITISH COLUMBIA | MINISTRY OF ENVIRONMENT

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976-81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: JULY 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: MOUNTAIN, NANAIMO AND WELLINGTON
LAND TITLE DIST.: VICTORIA

DIST. LOT AND TP. SEC.
SUBDIVISION LOT

AIR PHOTO CENTRE

BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
SWAMP
DEPRESSION
TREED SWAMP

ROADS PAVED / GRAVEL / ROUGH / TRAIL
RAILWAY / ABAND.
POWER LINE
FENCE
FLUME

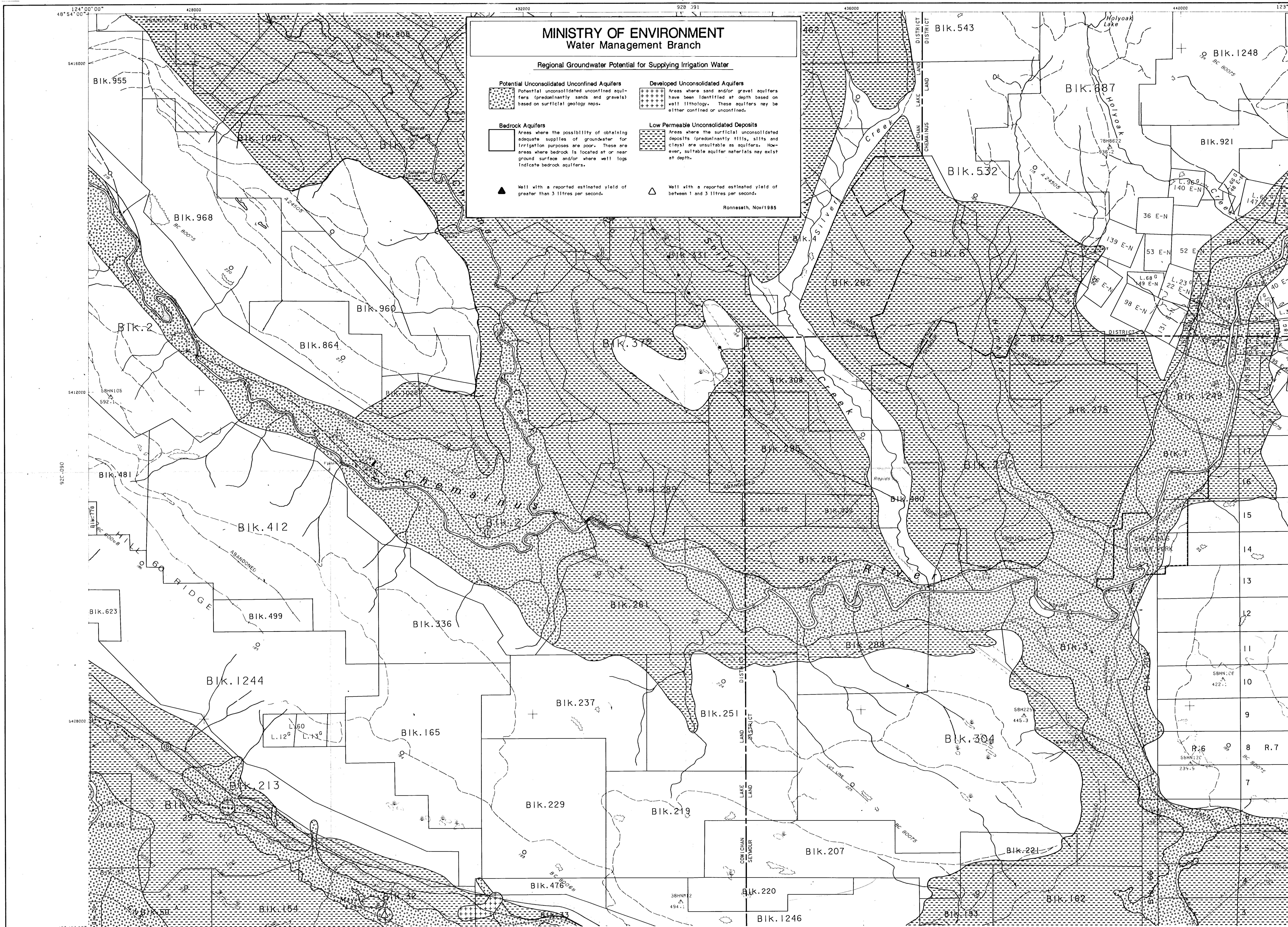
SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL 20 METRES

PLANIMETRIC DIGITAL
CADASTRAL DIGITAL

CONTOUR

SEE INDEX 92G | PROJECT No. 83-036PC

92G.021



PROVINCE OF BRITISH COLUMBIA	MINISTRY OF ENVIRONMENT	

MAPPING CONTROL: FEDERAL GOV'T.
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. & FEDERAL
DATE OF PHOTOGRAPHY: 1976 81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE AS AT DATE OF PHOTOGRAPHY

BASE COMPLETED:
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:
LATEST PLAN No.:
LAND DISTRICTS: CHEMAINUS, COWICHAN LAKE & SEYMOUR
LAND TITLE DISP.: VICTORIA

DIST. LOT & TP. SEC.
SUBDIVISION LOT

TRIANGULATION STATION WITH ELEVATION
SURVEYED CONTROL POINT WITH ELEVATION
BENCH MARK
AIR PHOTO CENTRE
SURVEYED LOT TIE

BUILDING
CONTOURS & ELEVATION
APPROX. CONTOUR
WOODED AREA
SWAMP
CULTIVATED
DEPRESSION
SCRUB
TREED SWAMP
ORCHARD

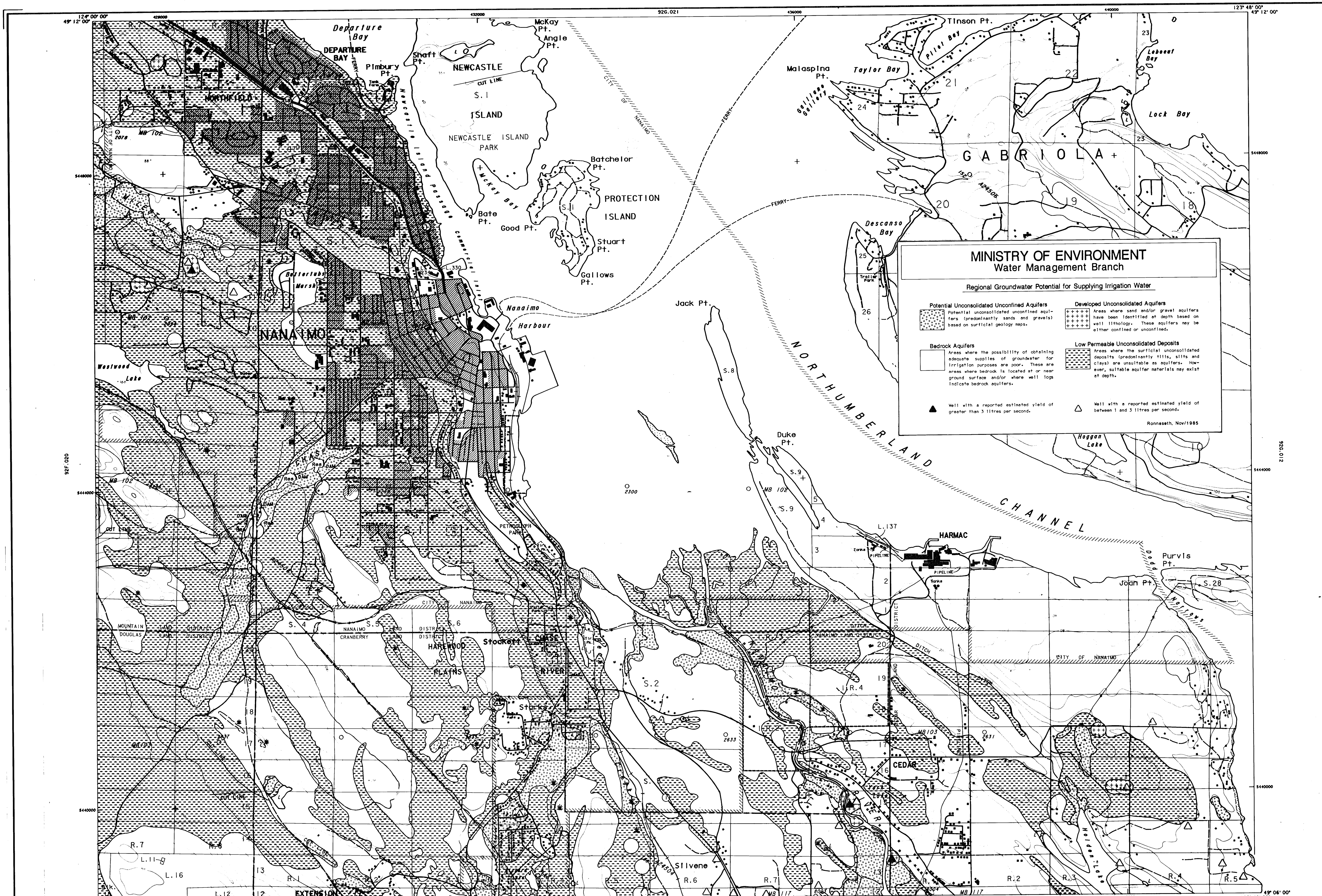
ROADS — PAVED, ROUGH, GRAVEL, TRAIL
RAILWAY
POWER LINE — ON POLE, ON TOWER
FENCE
FLUME

SCALE : 1:20000
200 0 200 400 600 800 METRES
CONTOUR INTERVAL METRES

PLANIMETRIC
NEG. No. 214892
CADASTRAL
DIGITAL

SEE INDEX 92B-C
PROJECT No. 81-023P-C

92B.081



Province of British Columbia
Ministry of Environment

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976-81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: AUGUST 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: CEDAR CRANBERRY, DOUGLAS, MOUNTAIN AND NANAIMO
LAND TITLE DIST.: VICTORIA

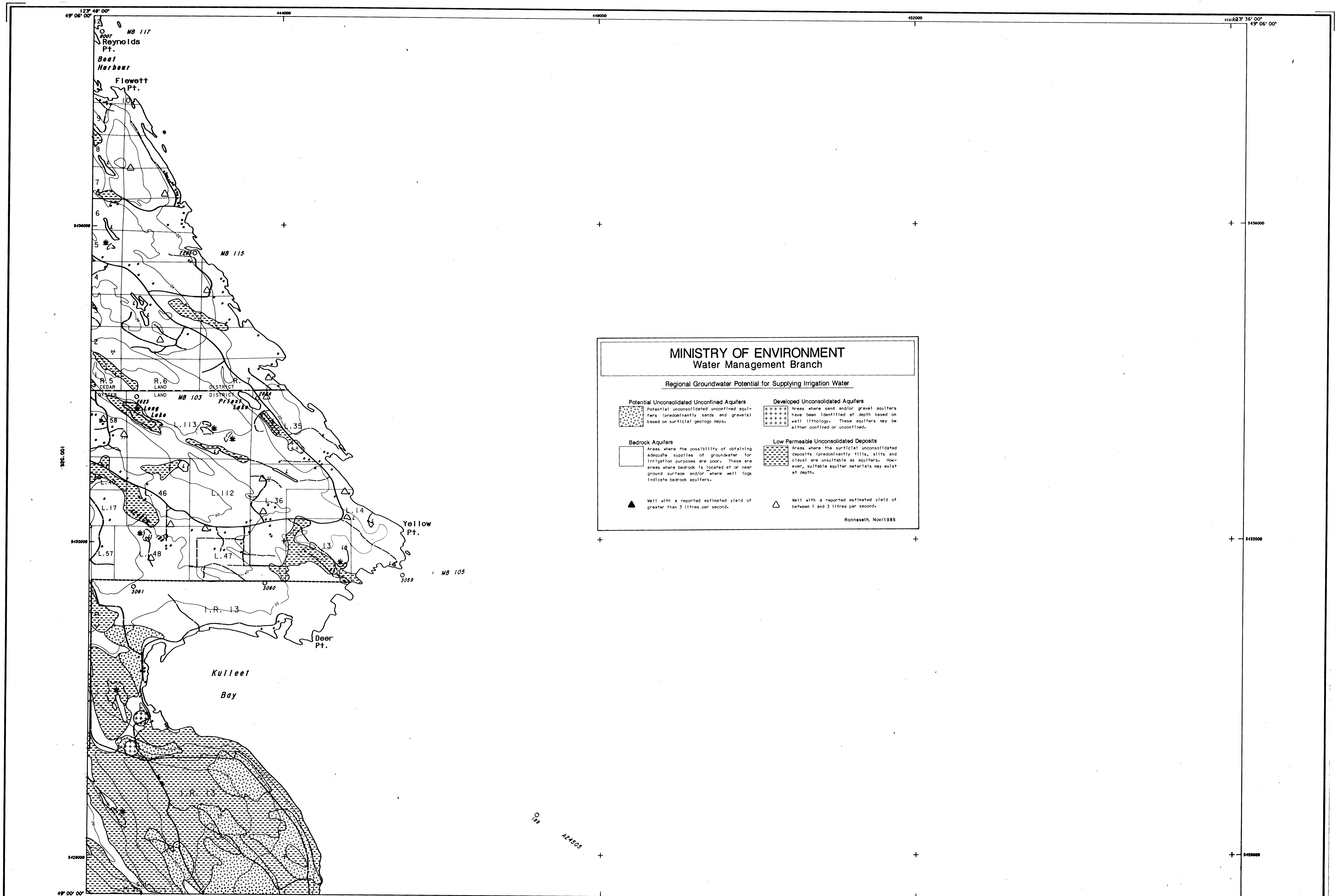
DIST. LOT AND TP. SEC.
SUBDIVISION LOT
AIR PHOTO CENTRE
BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
SWAMP
DEPRESSION
TREED SWAMP
ROADS PAVED / GRAVEL
ROUGH / TRAIL
RAILWAY
ABAND.
POWER LINE
FENCE
FLUME

SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL 20 METRES

PLANIMETRIC DIGITAL
CADASTRAL DIGITAL
CONTOUR

SEE INDEX 92G
PROJECT No. 83-035PC

92G.011



PROVINCE OF BRITISH COLUMBIA — MINISTRY OF ENVIRONMENT

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976-81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: JULY 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: CEDAR, COWICHAN, NANAIMO AND OYSTER
LAND TITLE DIST.: VICTORIA

DIST. LOT AND TP. SEC.
SUBDIVISION LOT

AIR PHOTO CENTRE

BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
DEPRESSION
SWAMP
TREED SWAMP

ROADS PAVED / GRAVEL / ROUGH / TRAIL
RAILWAY ABAND.
POWER LINE
FENCE
FLUME

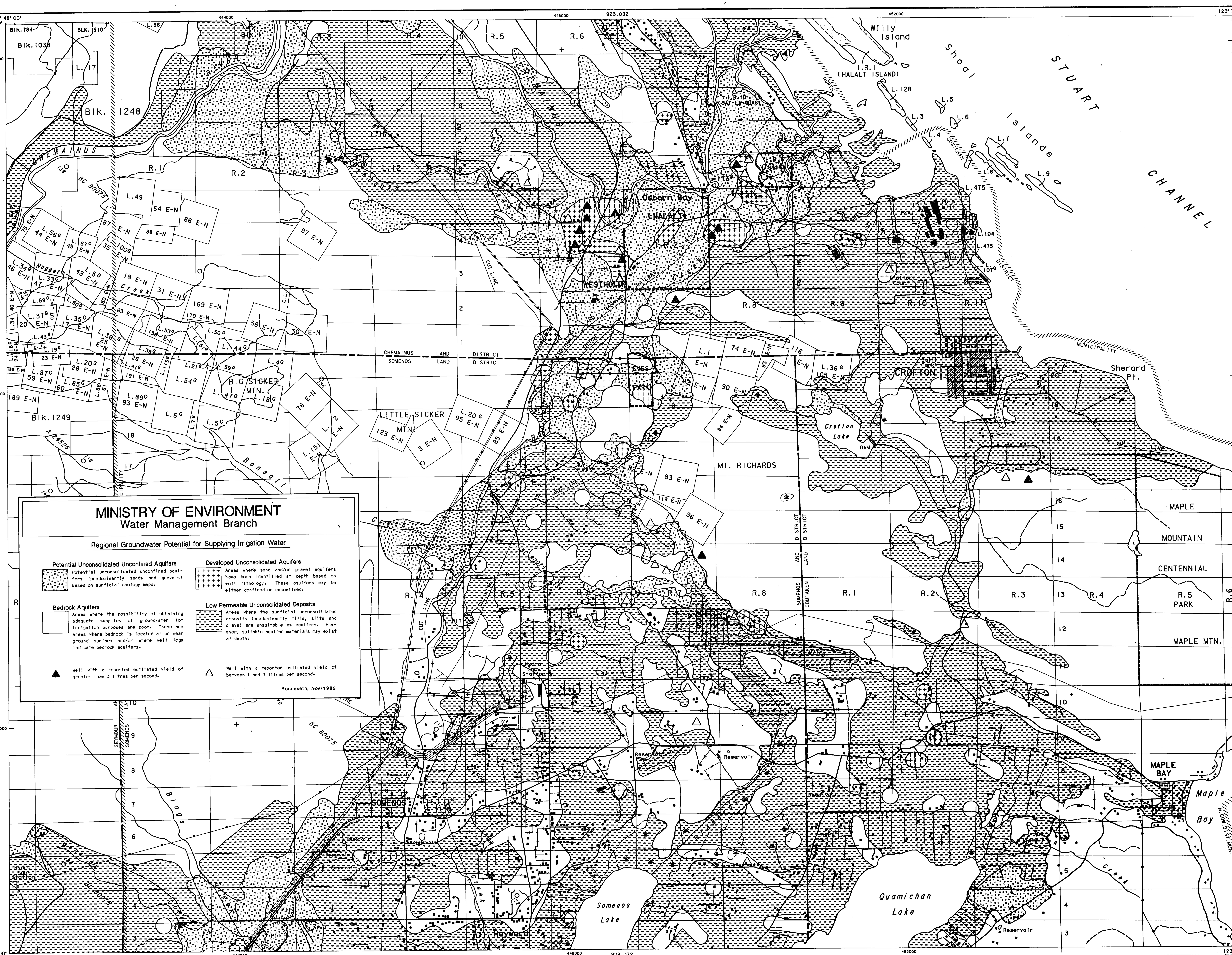
SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL 20 METRES

PLANIMETRIC DIGITAL
CADASTRAL DIGITAL
CONTOUR

SEE INDEX
PROJECT No. 83-03SPG

92G.002

92G.002



PROVINCE OF BRITISH COLUMBIA	MINISTRY OF ENVIRONMENT	MAPPING CONTROL: FEDERAL GOVERNMENT DATUM OF ELEVATIONS: GEODETIC AIR PHOTOGRAPHY: B.C. AND FEDERAL DATE OF PHOTOGRAPHY: 1976,81 U.T.M. GRID: ZONE 10 (1975) SHORELINE: HIGH WATER MARK	BASE COMPLETED: APRIL 1984 BASE SOURCE: PHOTOGRAMMETRIC REVISION DATE: LAND DISTRICTS: CHEMAINUS, COMIAKEN, COWICHAN, SOMENOS AND SEYMOUR LAND TITLE DIST.: VICTORIA	DIST. LOT AND TP. SEC. SUBDIVISION LOT AIR PHOTO CENTRE BUILDING CONTOURS AND ELEVATION 500 APPROX. CONTOUR SWAMP DEPRESSION TREED SWAMP ROADS PAVED GRAVEL ROUGH TRAIL RAILWAY ABAND. POWER LINE FENCE FLUME	SCALE : 1:20000 200 0 200 400 600 800 METRES CONTOUR INTERVAL METRES	PLANIMETRIC DIGITAL CADASTRAL DIGITAL SEE INDEX 92B PROJECT No. 83-035PC 92B.082

PROVINCE OF BRITISH COLUMBIA — MINISTRY OF ENVIRONMENT

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976, 81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: APRIL 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: BRIGHT, CHEMAINUS, COWICHAN LAKE, AND OYSTER
LAND TITLE DIST.: VICTORIA

DIST. LOT AND TP. SEC.
SUBDIVISION LOT

AIR PHOTO CENTRE

BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
SWAMP
DEPRESSION
TREED SWAMP

ROADS PAVED, GRAVEL, ROUGH, TRAIL
RAILWAY, ABAND.
POWER LINE
FENCE
FLUME

SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL METRES

PLANIMETRIC DIGITAL
CADASTRAL DIGITAL

SEE INDEX 92B
PROJECT No. 83-035PC

92B.091

MINISTRY OF ENVIRONMENT
Water Management Branch

Regional Groundwater Potential for Supplying Irrigation Water

Potential Unconsolidated Unconfined Aquifers
Potential unconsolidated unconfined aquifers (predominantly sands and gravels) based on surficial geology maps.

Developed Unconsolidated Aquifers
Areas where sand and/or gravel aquifers have been identified at depth based on well lithology. These aquifers may be either confined or unconfined.

Bedrock Aquifers
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Low Permeable Unconsolidated Deposits
Areas where the surficial unconsolidated deposits (predominantly tills, silts and clays) are unsuitable as aquifers. However, suitable aquifer materials may exist at depth.

▲ Well with a reported estimated yield of greater than 3 litres per second.

△ Well with a reported estimated yield of between 1 and 3 litres per second.

Ronneseth, Nov/1985

PROVINCE OF BRITISH COLUMBIA — MINISTRY OF ENVIRONMENT

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976,81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: APRIL 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: CHEMAINUS, COWICHAN, AND OYSTER
LAND TITLE DIST.: VICTORIA

DIST. LOT AND TP. SEC.
SUBDIVISION LOT

AIR PHOTO CENTRE

BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
SWAMP
DEPRESSION
TREED SWAMP

ROADS PAVED / GRAVEL
ROUGH / TRAIL
RAILWAY — ABAND.
POWER LINE
FENCE
FLUME

SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL METRES

PLANIMETRIC DIGITAL
CADASTRAL DIGITAL

SEE INDEX 92B
PROJECT No. 83-035PC

92B.092

PROVINCE OF BRITISH COLUMBIA | MINISTRY OF ENVIRONMENT

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976,81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: MARCH 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: DUNSMUIR, NANAIMO, NANOOSE, MOUNTAIN AND WELLINGTON
LAND TITLE DIST.: VICTORIA

DIST. LOT AND TP. SEC.
SUBDIVISION LOT

AIR PHOTO CENTRE

BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
DEPRESSION
SWAMP
TREED SWAMP

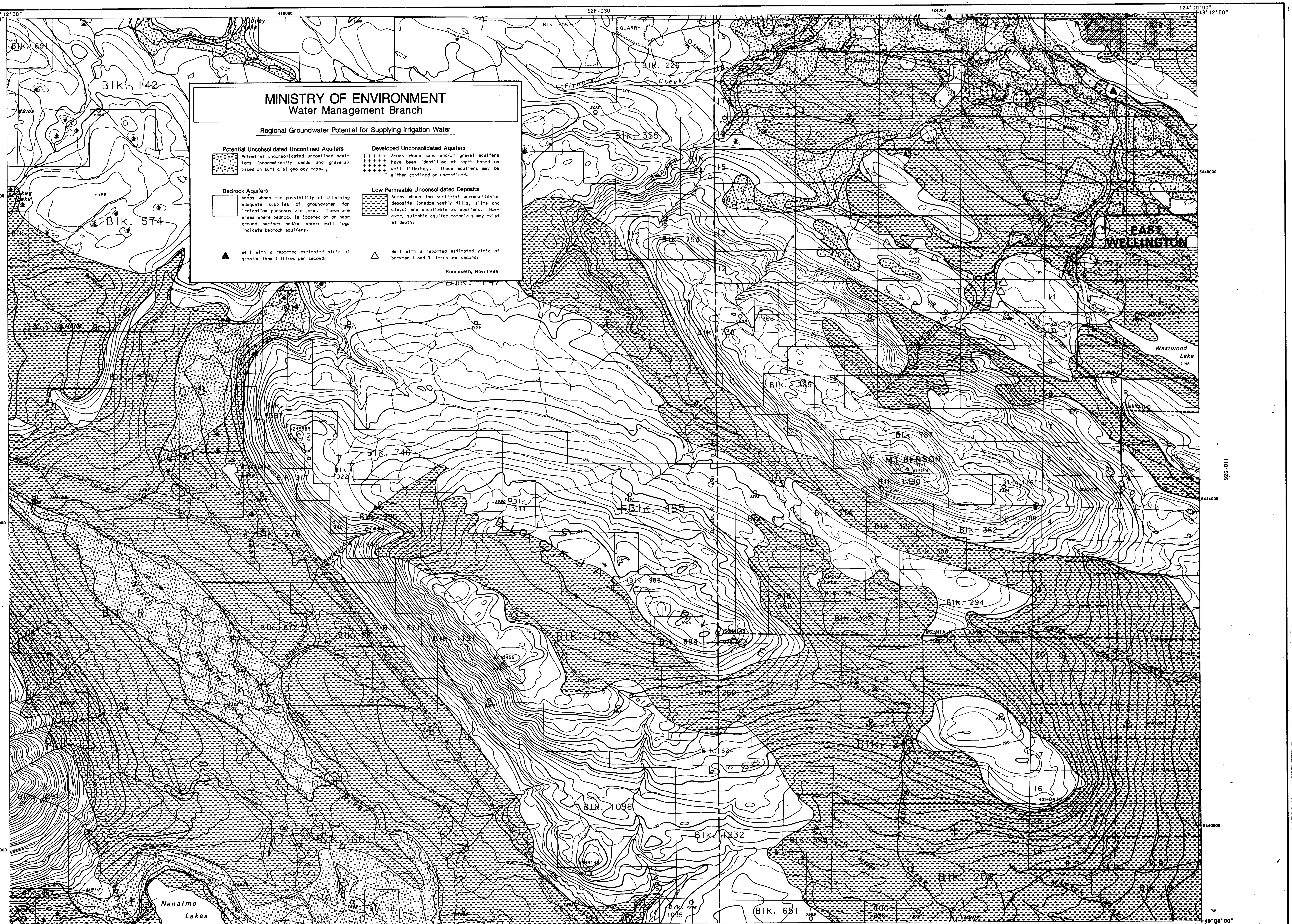
ROADS PAVED / GRAVEL / ROUGH / TRAIL
RAILWAY / ABAND.
POWER LINE
FENCE
FLUME

SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL 20 METRES

PLANIMETRIC DIGITAL | CONTOUR
CADASTRAL DIGITAL

SEE INDEX 92F | PROJECT No. 83-03PC

92F.030



Province of British Columbia | Ministry of Environment

MAPPING CONTROL: FEDERAL GOV'T.
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. & FEDERAL
DATE OF PHOTOGRAPHY: 1976-81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE AS AT DATE OF PHOTOGRAPHY

BASE COMPLETED:
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:
LATEST PLAN No.:
LAND DISTRICTS: DOUGLAS, DUNSMUIR & MOUNTAIN
LAND TITLE DIST.: VICTORIA

DIST. LOT & TP. SEC.
SUBDIVISION LOT

TRIANGULATION STATION WITH ELEVATION
SURVEYED CONTROL POINT WITH ELEVATION
BENCH MARK
AIR PHOTO CENTRE
SURVEYED LOT TIE

BUILDING
CONTOURS & ELEVATION 500
APPROX. CONTOUR
WOODED AREA
SWAMP
CULTIVATED CULT.
DEPRESSION
SCRUB S
TREED SWAMP
ORCHARD ORCH.

ROADS PAVED / ROUGH
GRAVEL / TRAIL
RAILWAY
POWER LINE ON POLE / ON TOWER
FENCE
FLUME

SCALE : 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL 20 METRES

PLANIMETRIC
NEG. No. 214927
CADASTRAL
DIGITAL

CONTOUR

SEE INDEX 92F
PROJECT No. 81-023P-C
92F.020

PROVINCE OF BRITISH COLUMBIA

MINISTRY OF ENVIRONMENT

MAPPING CONTROL: FEDERAL GOVERNMENT
DATUM OF ELEVATIONS: GEODETIC
AIR PHOTOGRAPHY: B.C. AND FEDERAL
DATE OF PHOTOGRAPHY: 1976-81
U.T.M. GRID: ZONE 10 (1975)
SHORELINE: HIGH WATER MARK

BASE COMPLETED: JULY 1984
BASE SOURCE: PHOTOGRAMMETRIC
REVISION DATE:

LAND DISTRICTS: BRIGHT, CEDAR, CRANBERRY, DOUGLAS, NANAIMO AND OYSTER
LAND TITLE DIST.: VICTORIA

DIST. LOT AND TP. SEC.
SUBDIVISION LOT

AIR PHOTO CENTRE

BUILDING
CONTOURS AND ELEVATION 500
APPROX. CONTOUR
SWAMP
DEPRESSION
TREED SWAMP

ROADS PAVED
GRAVEL
ROUGH
TRAIL
RAILWAY
ABAND.
POWER LINE
FENCE
FLUME

SCALE 1:20000
200 0 200 400 600 800
METRES
CONTOUR INTERVAL METRES

PLANIMETRIC DIGITAL
CADASTRAL DIGITAL

SEE INDEX 92G

PROJECT No. 83-035PC

92G.001