GEOLOGICAL SURVEY OF CANADA
OPEN FILE REPORT 3069

RECENT GEOLOGICAL EVOLUTION OF KINGSBURG BEACH, LUNENBURG COUNTY, NOVA SCOTIA

R.B. Taylor, J. Shaw, D. Frobel and A.G. Sherin

1995

Front Cover: Aerial oblique view of the village of Kingsburg and Kingsburg Pond taken October 2, 1992. The north end of Kingsburg Beach in the foreground has a cuspate lower beach morphology backed by a gravel storm ridge and low erosional bank. Some of the coarser material was added by the landowners to slow shoreline erosion. Backshore dunes are absent at this end of Kingsburg Beach because of the scarcity of sand and the effects of human activities. The primary dune begins at the left side of the photo and extends southward. The main paved road leading from Kingsburg toward Rose Bay is visible at the back central part of the photograph.

Geological Survey of Canada
Open File Report 3069

RECENT GEOLOGICAL EVOLUTION OF KINGSBURG BEACH, LUNENBURG COUNTY, NOVA SCOTIA

R.B. Taylor, J. Shaw, D. Frobel and A.G. Sherin

Geological Survey of Canada
Atlantic Geoscience Centre
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

January 1995

The main text was originally prepared as a contract report for the
Nova Scotia Department of Natural Resources

SUMMARY

1. Kingsburg Beach is one part of an extensive sequence of beach ridge, lagoonal and flood tidal and lacustrine deposits at the head of Kings Bay. The deposits accumulated primarily between circa 1500 years BP and 600 years BP when relative sea level was lower. Based on the depth of coring in the marine and freshwater sediments in Kingsburg Pond, the thickness of unconsolidated deposits could be as much as 9 m.

2. Kingsburg Pond was initally part of Kings Bay. It gradually became less marine as its connection to the bay was restricted by spit growth and beach ridge progradation. The pond became fresh following the closure of the inlet circa 600 years BP. The pond was therefore freshwater when the first European settlers arrived. In 1994 the deepest part of the pond is 2.7 m and most of the bottom is covered by a soupy organic-rich mud (gyttja).

3. Progradation of Kingsburg beach continued after the closure of the inlet to Kingsburg Pond. The sand dunes that presently cover Kingsburg Beach formed at a time when there was a greater availability of sand. There is evidence that the dunes have aggraded by as much as a metre since the mid 1970s.

4. The Kingsburg beach complex is one of about twenty sites in the province known to have a nearly complete suite of relict, prograded beach ridges, freshwater / lagoon deposits and modern beach features.

5. The scarcity of new sediment being added to Kingsburg Beach from offshore or alongshore has resulted in a slow retreat of the beach crest and a recycling of the beach material to maintain seasonal beach profile adjustments and the integrity of the overlying dunes. Kingsburg Beach has the inherent ability to recover from storm damage because of the abundance of underlying beach building material, i.e. sand and gravel.

6. Maintaining the integrity of the present sand dunes is critical to reducing or preventing widespread flooding of the backshore lowland by the sea. Wave overtopping is more frequent today at the north end of Kingsburg Beach, where there is no dune, than along the central part of the beach where the beach crest is an estimated 0.5 m higher.

7. It is expected that sea level will rise by approximately 39 cm in the next century along the Atlantic coast of Nova Scotia (Shaw et al., 1993). However, if the global climate change senarios are accepted, the total rise in sea-level could be almost 90 cm (66 cm eustatic rise plus local crustal subsidence) by the year 2100 AD (World Meteorological Organization, 1992). One consequence will be increases in the backshore water table and pond water levels. The backshore lowlands will become increasingly submerged and the width of Kingsburg Beach exposed above water will decrease.

8. At present, the frequency and extent of wave overwashing is much greater for the low barrier beach fronting Dry Spitz Pond than Kingsburg Beach. Given the same sediment supply or an increase in sediment supply in the future, the integrity of the beach fronting Dry Spitz Pond could improve, at least until the adjacent bedrock, anchoring the beach, becomes submerged by rising sea levels.

TABLE OF CONTENTS

Appendices

INTRODUCTION

Kingburg Beach is located on the South Shore of Nova Scotia, roughly 70 km west of Halifax, at the head of Kings Bay, Lunenburg County (Fig. 1). Kingburg Beach and the adjacent lands were given protected beach status in April of 1993 by the Nova Scotia Legislature under the Nova Scotia Beaches Protection Act. Kingsburg Beach is subdivided into many small narrow lots extending perpendicular to shore. Ownership of some parts of the coastal lowland and rights to use the access road along the back of the beach are hotly debated. There are also very emotional debates between permanent residents and seasonal residents concerning the management of the coastal area. Some private land owners of the beach want to develop housing units in the primary dune. Legal proceedings were begun by some residents against the crown because the Beach Protection Act restricts their development plans. This study is one of a number of studies commissioned by the Nova Scotia Department of Natural Resources to examine the physical and biological resources of Kingsburg Beach designated under the Beaches Protection Act (Fig.1). The primary objectives of this study are:

(1) to develop a chronology of the physical evolution of Kingsburg Beach;
(2) to compare the evolution of Kingsburg Beach with that of other coastal systems in Nova Scotia and;
(3) to assess the future stability of Kingsburg Beach and adjacent lands.

Our study area includes the subtidal, intertidal and subaerial beach, including the sand dunes, the relict backshore beach deposits and the pond that is enclosed by beach deposits.

Although partly financed by the Nova Scotia Department of Natural Resources, the study forms part of ongoing research by the Atlantic Geoscience Centre (AGC) into the geological evolution of coastal features in Atlantic Canada and the physical response of coastal features to fluctuating sea levels during the past several thousand years. This report is essentially the same as the one submitted to the Nova Scotia Department of Natural Resources (Taylor and Shaw, 1994). Only the appendix has been expanded.

FIELD SURVEYS

Initial plans were to core the bottom sediment in Kingsburg Pond from the ice surface in February 1994, but conflicting information about the depths of the pond (reported depths ranged from 10-40 feet) necessitated a more detailed sounding survey of the pond before core sites could be selected. Echosounding surveys of Kingsburg Pond were completed on June 6, 1994 using a Raytheon DE 719 B sounder with a 200 kHz transducer. On the basis of the soundings, four coring sites were selected along a 150 m transect that extended from the deepest to the shallowest parts of the pond. The coring was completed using an Eijkelkamp auger and a simple, 7.7 cm diameter push corer with aluminum tubing. Details of the field surveys and coring techniques are elaborated in Appendix E. The maximum penetration of the pond sediment was with the Eijelkamp auger which reached a depth of 3.16 m below the pond bottom. The Eijkelkamp auger was also used to obtain cores of the peat deposits and surficial sediment on the beach ridge complex adjacent to Kingsburg Pond (Fig. 1).

Horizontal control for the sounding surveys and core sites was provided by a Geodimeter 140H infrared electronic total station surveying instrument. Global positioning of the instrument site and core sites was provided by a Magellan GPS NAV 5000 Pro portable receiver. Vertical control for the surveys was difficult because of the absence of Geodetic or Land Registry benchmarks. The elevation of the instrument site and pond water level were tied into sea level on Kingsburg Beach

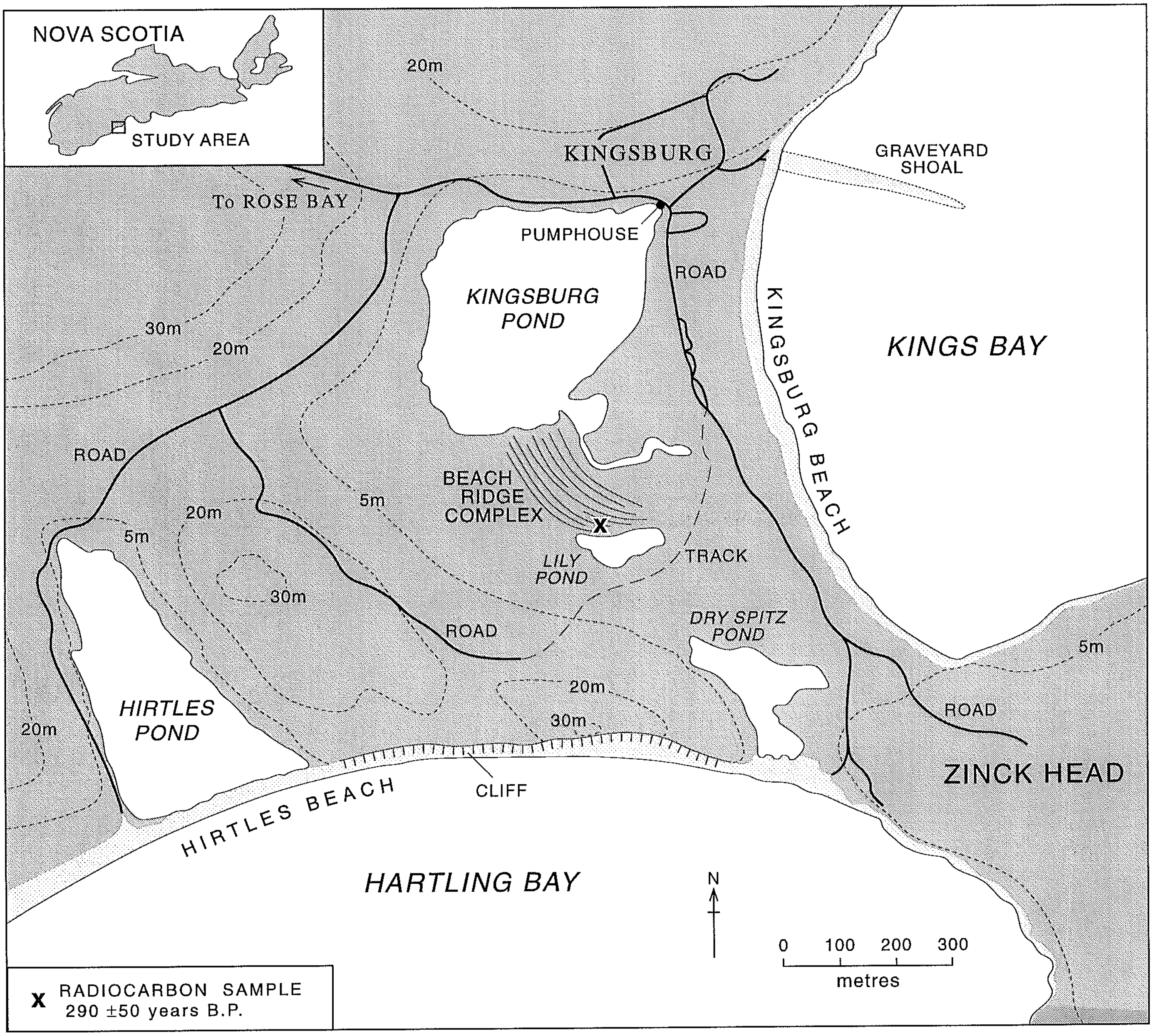


Figure 1. Map of Kingsburg Beach, Nova Scotia showing the location of Kingsburg Pond, the relict beach ridge complex and core 007 where peat was collected for radiocarbon dating. The map is based on the 1:10,000 scale topographic map sheet (LRIS, 1982).

on June 9, 1994.

Sub-samples from the cores were selected for ^{14}C dating (Table 1), organic carbon analysis (Table 2) and benthic foraminiferal analysis (Appendix A).

GEOMORPHOLOGY AND SEDIMENTOLOGY

Kingsburg Pond

Physical Character: Kingsburg Pond is the largest of three ponds that lie in the coastal lowland between Kings Bay and a drumlin terrain which extends to more than 30 m above sea level (Fig. 1, 2). The pond forms the catchment for a small local watershed. In June 1994 the water level of the pond was 0.6 m above mean sea level and 0.3 m below high tide level. Using surveyed sea level and the tide tables for Lunenburg (CHS, 1994) the elevation of the pond surface was calculated to be 0.836 m above present geodetic zero (datum). The pond is protected from the sea and Kings Bay by Kingsburg Beach which at the northern end is only 200 m wide, with a crest elevation of 3.9 to 4.1 m above geodetic datum (Fig. 2, Front cover) .

The shores of Kingsburg Pond are fringed by narrow beaches and low cut banks consisting of a mixture of sand to boulder size clasts. The southwestern edge of the pond is marked by vegetation (mainly *Typha* and *Scirpus sp.*) growing in water depths of up to 1 m. A low ridge which occurs intermittently in the wetlands, near the base of a drumlin, may mark the remnants of a road that used to wind along the south side of the pond from the settlement of Kingsburg (K.A. Spidle, local resident, pers. comm., 1994).

Echosounding surveys were completed in June 1994 (Fig. 3). Kingsburg Pond consists of a single basin with a shallow platform extending into it from the southwest shore (Fig. 4a). The pond slopes are steepest along its north and east shores, and maximum water depths of 2.7 m occur within the north-central part of the pond (Fig. 4, 5). Water depths adjacent to the pumphouse in Kingsburg are 1.3 to 1.4 m (line 1, Fig. 5). The shallowest water lies within the small embayment at the southwest end of the pond where depths are 0.6 to 1.0 m and a small bar extends across the mouth of the embayment (Fig. 6). The topography and extent of the platform that exists along the southwest side of the pond is defined by cross-sectional diagrams of the pond bottom (Fig. 5, 6). There is no evidence of the platform along survey lines 1 and 5, but lines 3, 4 and 6 illustrate the marked decrease in water depth toward the southwest. The morphology of the platform on line 6 suggests that it probably consists of sediment which has infilled and extended northward into water depths of nearly 2 m.

Echograms taken within the pond showed two bottom reflectors. The water depths mapped on Figure 4a are measured to the first reflector which is the top of a soupy organic-rich mud (gyttja) which blankets most of the pond. The second reflector is observed only in water depths greater than 2 m. It marks where the organic -rich mud becomes firmer and more compact, or a more sandy mud layer lies beneath or within the gyttja (Fig. 4b, 5).

Sediment Stratigraphy: A total of six cores were collected from Kingsburg Pond in June 1994. At two locations two types of corers were used (Fig. 3, 6, cores 001 and 002, and 005 and 006) because the wide diameter push corer provided a more continuous record of the sediment stratigraphy. The deepest penetration into the pond sediment was 316 cm at core site 002 (Fig. 3, 6). The thickness of unconsolidated deposits seaward of the pond could be as much as 9 m, based on the depth of core penetration and the surveyed elevations to the modern beach crest (Fig. 2).

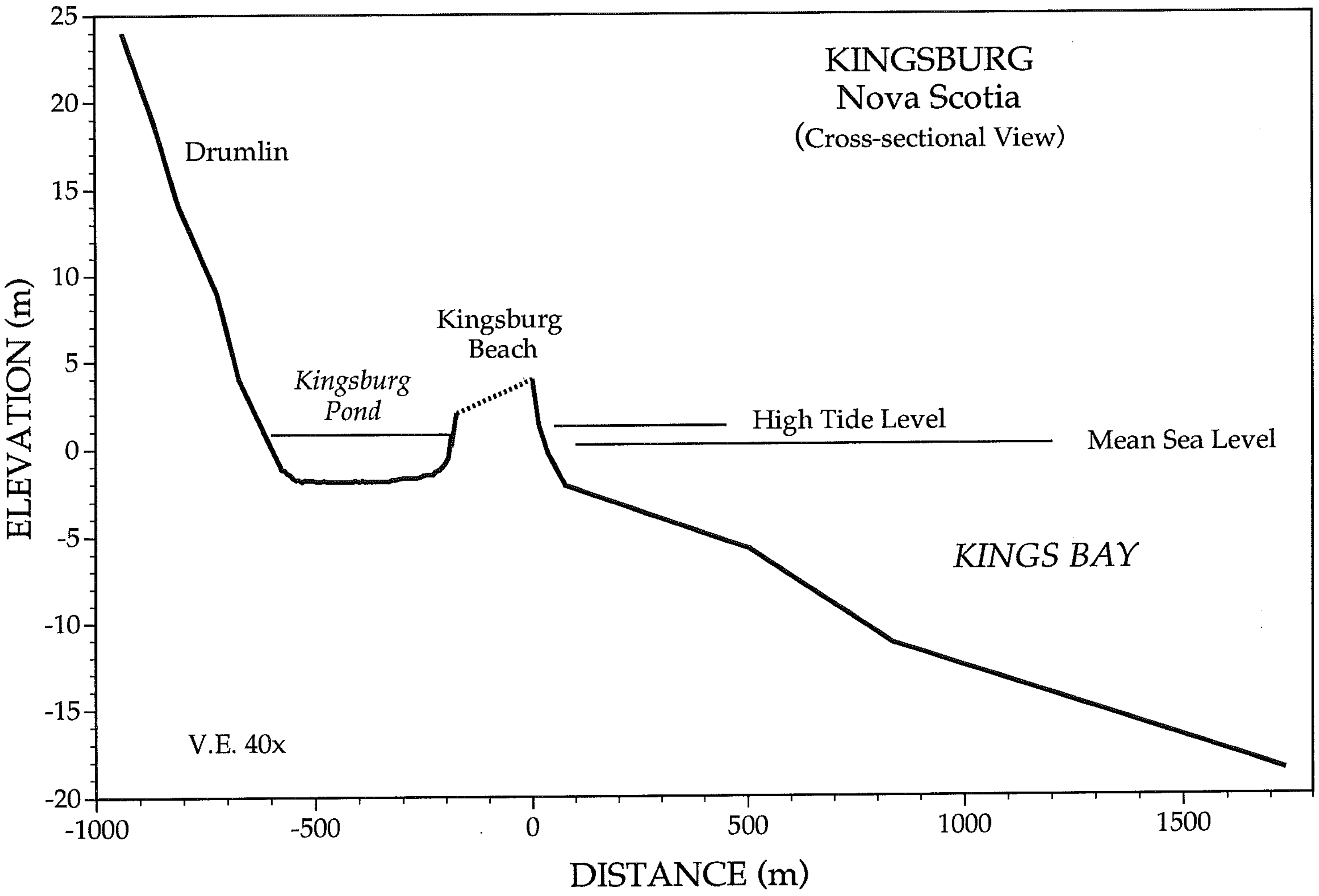
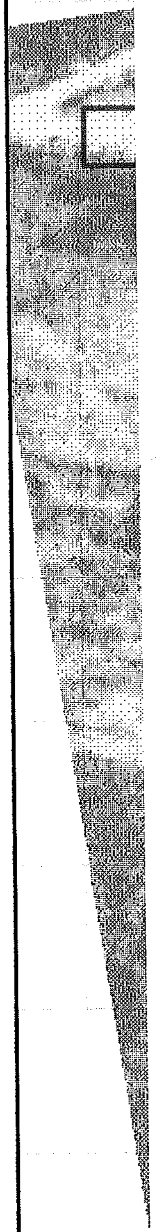


Figure 2. Generalized cross-sectional profile of the terrain adjacent to Kingsburg Pond showing the relative positions of water levels in Kingsburg Pond and Kings Bay. No survey points were taken from between the pond and the beach crest. The cross-section is based on information taken from the 1:10,000 orthophoto map (LRIS, 1982), Hydrographic chart 4384 (CHS, 1973), Pond survey line 2 (Fig. 3, 5) and other survey points completed in 1994 during this study.

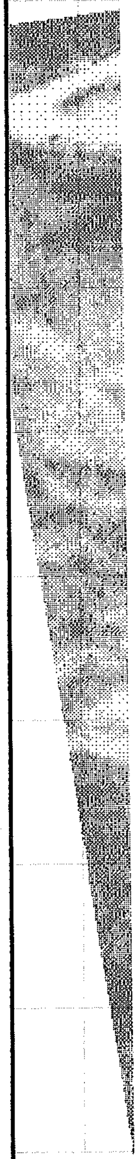
39895

Road



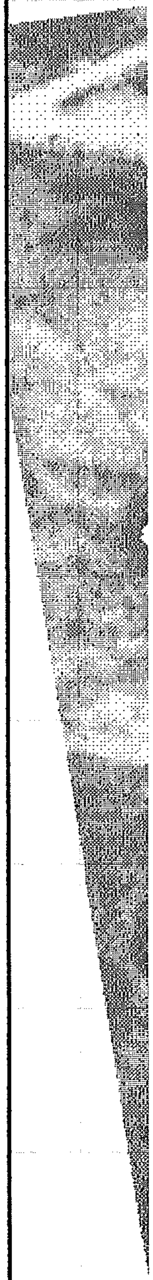
3989

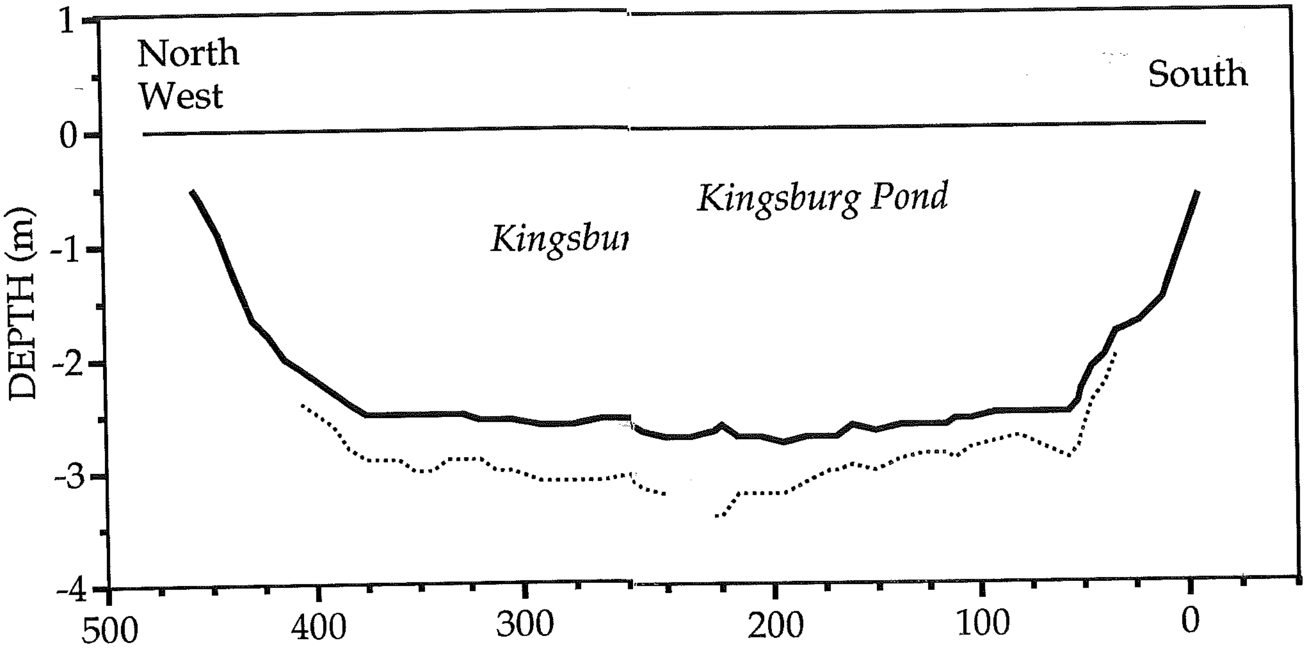
Roa



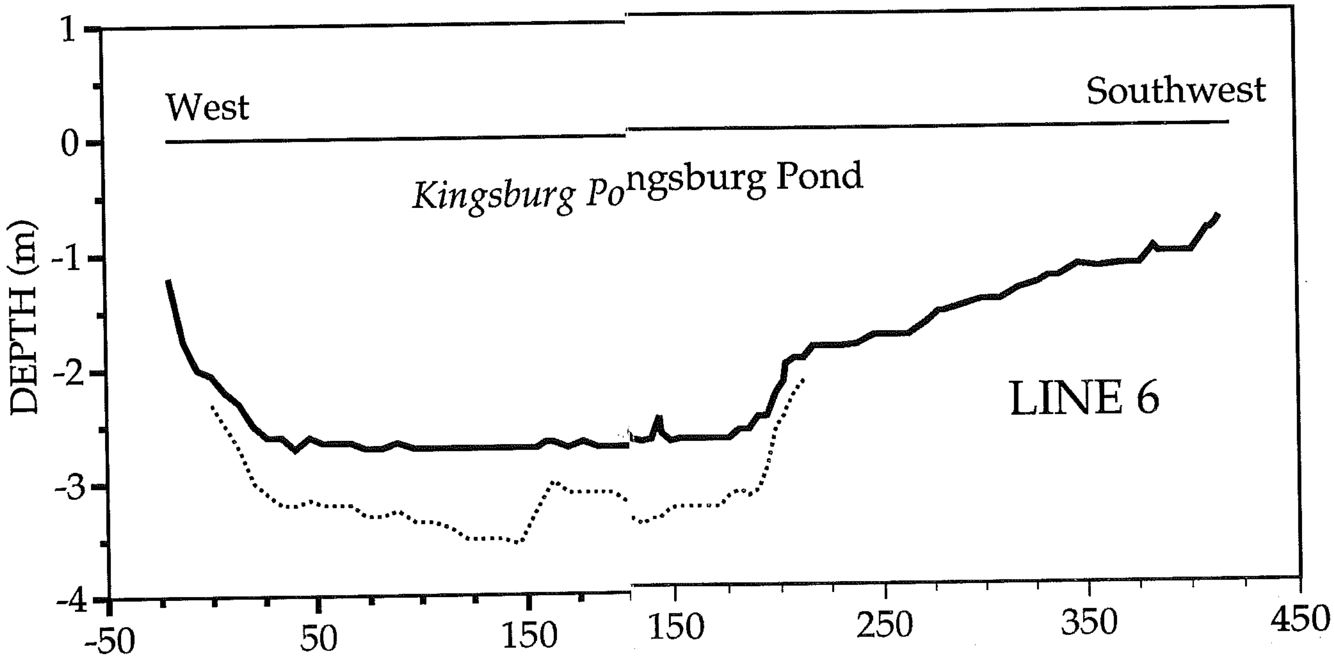
398950

Road

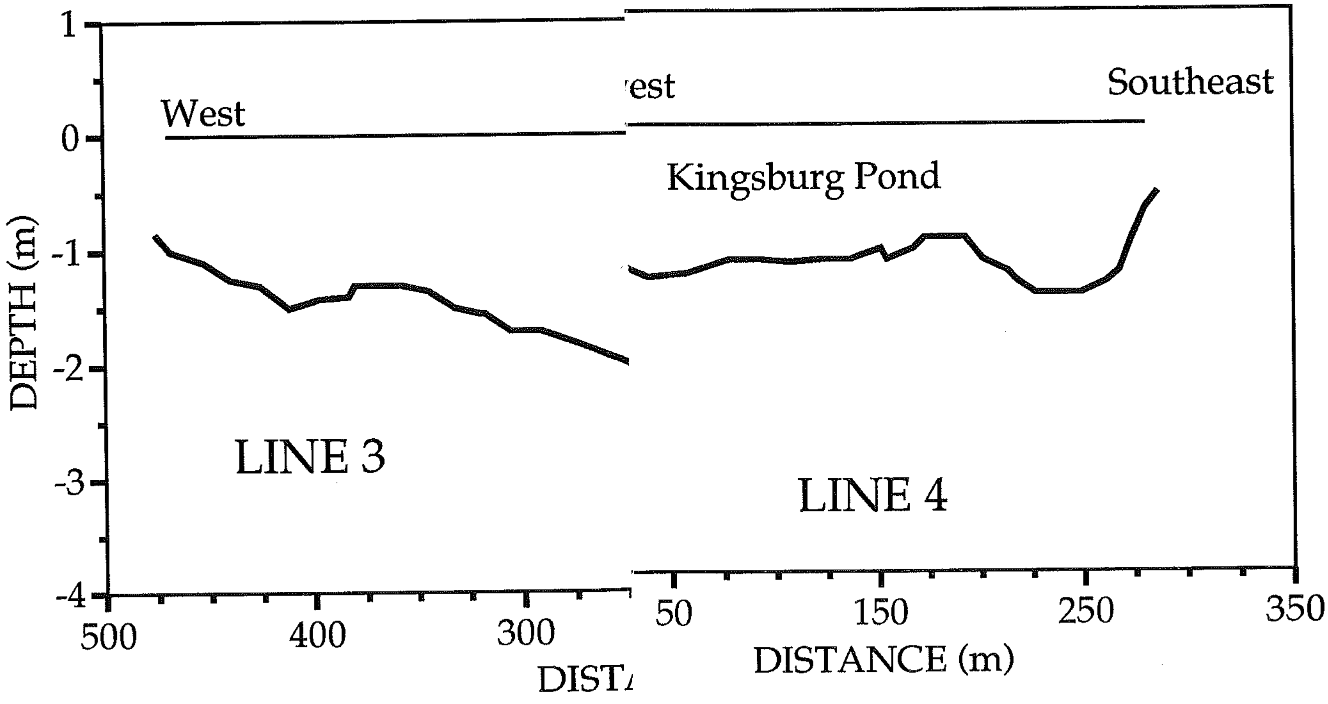




North
West
South
Kingsbur
Kingsburg Pond
DEPTH (m)
1
0
-1
-2
-3
-4
500
400
300
200
100
0



West
Southwest
Kingsburg Po
ngsburg Pond
LINE 6
DEPTH (m)
1
0
-1
-2
-3
-4
-50
50
150
150
250
350
450



West
est
Southeast
Kingsburg Pond
LINE 3
LINE 4
DEPTH (m)
1
0
-1
-2
-3
-4
500
400
300
50
150
250
350
DIST
DISTANCE (m)

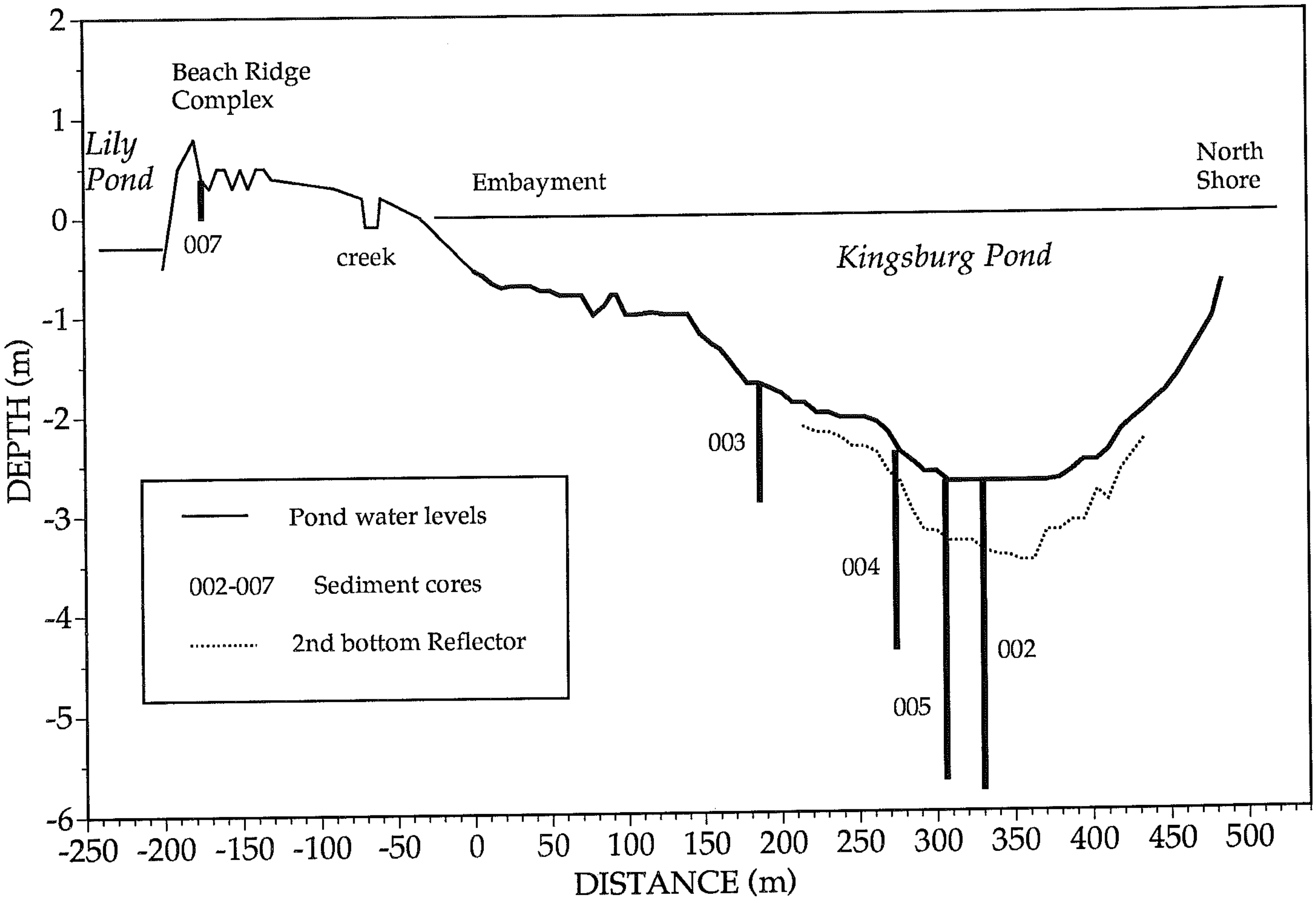


Figure 6. Cross-sectional view of topography from north shore of Kingsburg Pond to the Lily Pond (see Fig. 1, 3 for location) showing the relative topographic position of the sediment cores taken from Kingsburg Pond and the adjacent beach ridge complex. The profile from the south side of Kingsburg Pond to Lily Pond (thinner line) is schematic only because no surveys could be completed.

Table 2.
Percent organic carbon content in sediment samples collected from core 94304-006, Kingsburg Pond, Nova Scotia (analysis completed by W. LeBlanc, Atlantic Geoscience Centre).

Sample Depth In Core (cm)	Percent Organic Carbon
39-40	18.00
49-50	17.70
59-60	15.80
67-68	0.32
80-81	8.70
90-91	0.93
100-101	5.10
116-117	6.50

Cores from beneath the shallow platform consist of 30-35 cm of soft, soupy dark brown gyttja above at least 100 cm, and probably 150 cm of well- sorted dark gray medium sand containing shell fragments (core 003, Fig.7). Nearer the toe of the platform the gyttja thickens to 55 cm over sand (core 004), and in the deepest part of the pond the gyttja is 102 cm to 105 cm thick.

At core sites 001/002, and 005/006 the soft upper gyttja was separated from a lower zone of dark olive gray sandy gyttja by a thin (2 to 4 cm) well sorted medium to fine sand. The sand, which was very similar to the sand cored beneath the platform, lies at depths ranging from 102 to 107 cm. Beneath the sand, a sandy gyttja consisting of organic mud with disseminated layers of medium to fine sand overlies a more massive sandy gyttja in the lowest part of the cores. The lowest part of the cores contained scattered granules and platy pebbles as well as shell fragments. A shell fragment sampled in core 006 at 111.5 cm depth was identified as a freshwater mussel by T. Cole (Atlantic Geoscience Centre). A piece of alder was also sampled from between 111-114 cm in core 006. The wood was identified by H. Jetté (Geological Survey of Canada, Appendix C).

Six subsamples were collected from core 006 for benthonic foraminifera analysis by James A. Ceman (see full report in Appendix A). Three environmental zones were identified within the core.

Zone 1 (70-119 cm) is divided into two parts. The lower part (104-119 cm depth in core) consists of massive sandy gyttja. *Eggerella advena* and *Trochammina ochracea* are abundant in the lower part. The upper part of zone 1 (70-100 cm) contains laminated sediment with a decreasing number of foraminiferal tests. The distribution of foraminifera suggest that the marine influence was initially greater and became either periodic or less frequent from the lower to the upper part of zone 1.

Zone 2 (65-70 cm) consists of well sorted sand. This zone has a high proportion of marine foraminifera, particularly *Eggerella advena.*

Zone 3 (0-65 cm) consists of a massive gyttja (organic mud) that contained very few or no foraminifera. It was concluded that there was very little or no marine water influence during the deposition of the upper gyttja unit.

No samples were analysed from the soupy surface pond sediment. The sample interval used in the foraminiferal analysis was not small enough to detect short term incursions of salt water into the pond during storm wave overtopping events. It would also not record the influx of marine water when the pond was artificially connected to the sea by trenches, sluice ways and pipes designed to relieve the high water levels around the pond.

Eight samples were selected from core 006 for organic carbon analysis by W. LeBlanc at the Atlantic Geoscience Centre (Table 2). The results show a large increase in percent organic carbon in the upper core sediment, i.e. Zone 3. The increase reflects a decrease in the relative amount of inorganic sediment entering the pond at that time. The smallest percentage of organic carbon was associated with Zone 2, the layer of well sorted sand. In the lower part of core 006 (Zone 1) the percent organic carbon is less than the upper core and fluctuates.

Kingsburg Beach-Ridge Complex

Physical Character and Stratigraphy: The beach ridge complex between Kingsburg and Lily ponds consists of a series of low arcuate ridges (< 0.5 m high) and swales (Fig. 1). These ridges are easily identified on the vertical air photos (Fig. 8) but they are partially obscured in the field by vegetation. Initially it was thought that the beach ridges may extend into Kingsburg Pond,

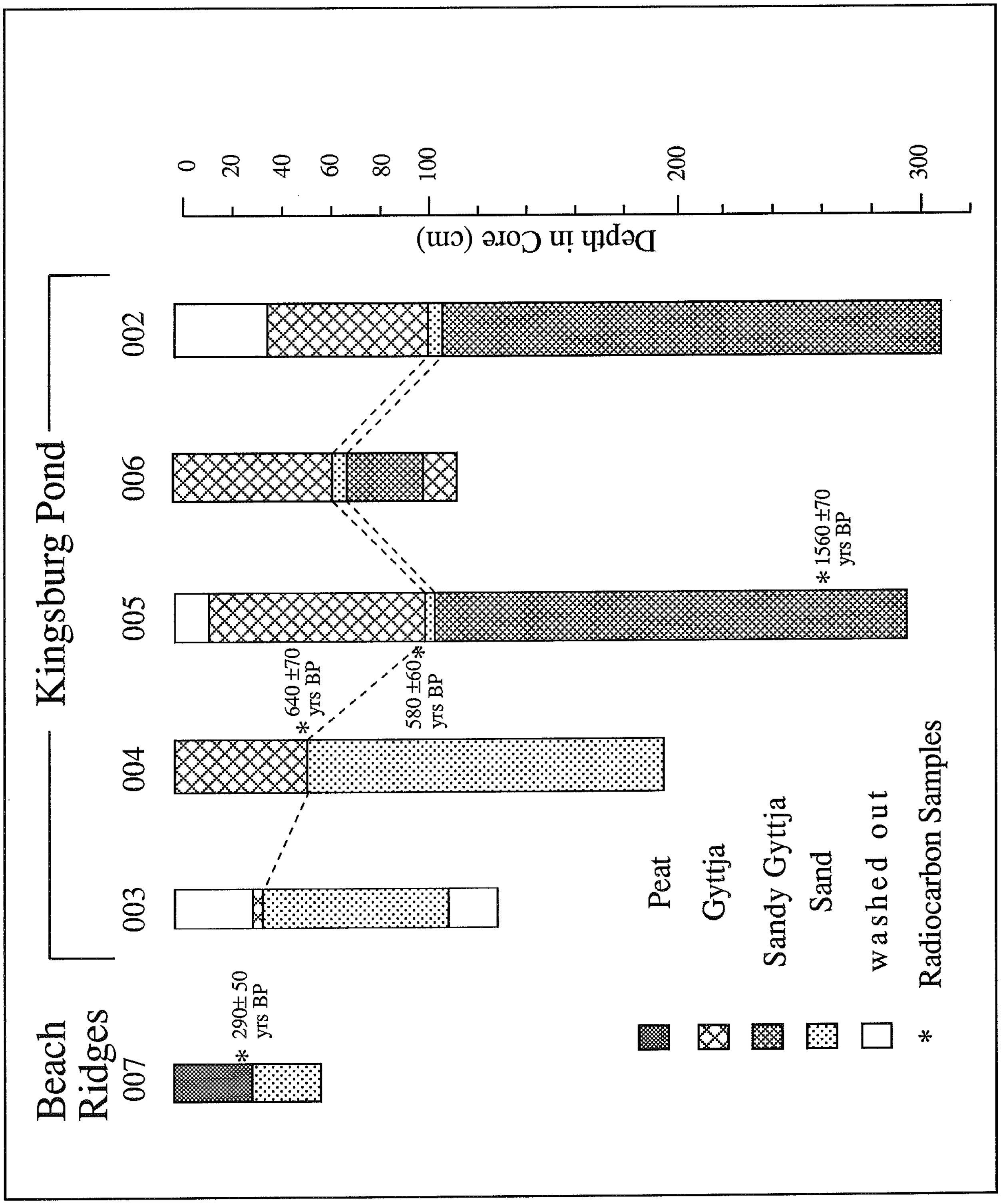


Figure 7. Sediment stratigraphy observed in six cores, five collected from Kingsburg Pond and one from the beach ridge complex of Kingsburg Beach. There was roughly 82 cm of compaction in Core 006 which penetrated 196 cm into the pond sediment. The location of the cores is shown in figures 1, 3 and 6.

but there was no evidence observed on the echograms. The only suggestion of ridges was observed in the second bottom reflector on survey line 2 (Fig. 3, 5) which exhibited a ridge and swale topography. These features could not be confirmed.

Onshore, the highest and most prominent beach ridges lie along the east flank of Kingsburg, Lily and Dry Spitz Pond (Fig. 1,8). There is evidence in the oral history that the ridge along Kingsburg Pond may have formed the foundation of a road, so its surface may have been modified. Therefore, sampling of the beach-ridge complex was focused farther from the village and along the ridges adjacent to Lily Pond.

The surface stratigraphy was documented using the Eijkelkamp auger. On average the swales consist of 5 to 23 cm of well humified peat over sand, and the ridge crests are covered by a thin cover (10 cm) of sand overlying sub-rounded platy cobbles and pebbles. The ridges are vegetated by *Myrica gale* and *Spiraea* sp., while *Potentilla* sp. and *Juncus* sp. are common in swales. More detailed sampling, including the collection of samples 007 and 008, was completed at the eastern base of the prominent ridge flanking Lily Pond. The ridge, which is vegetated by *Alnus* and Filicales (crest), and *Myrica gale* (flanks), is composed of gravel which extends beneath the water into the pond. In the adjacent swale to the east, *Potentilla* sp., *Juncus* sp. and *Sphagnum* sp. occur, forming a floating mat in places. The shallow stratigraphy near the base of the ridge consists of 30 cm of poorly humified, reddish brown peat with a few fibres, and woody roots or stems (up to 10 cm long, 1.5 cm diameter) at its base. The peat overlies a well-sorted grey medium sand with a few pebbles. Multiple samples of the basal layer of peat were collected for ^{14}C dating (Fig.1, Table 1).

Additional sampling and surveying of the beach ridges relative to the modern beach were terminated because persons demanded that we leave the area (Fig. 9). Surveys of the modern beach, dune crest and backshore by Hale (1992) near the central part of Kingsburg beach, show that the crest is 3.1 m above high tide (4.5 m above geodetic datum). The dune crest at the present beach is estimated to be nearly 3 m above the older beach ridges. The thickness of unconsolidated coastal deposits at the central part of the beach is at least 2.5 m beneath the relict ridges and nearly 6 m beneath the modern beach crest. Drilling or seismic surveys would be required to confirm the total thickness of coastal deposits.

GEOCHRONOLOGY OF COASTAL DEPOSITS IN AND ADJACENT TO KINGSBURG POND

Four samples were submitted to Beta Analytic Inc. for ^{14} Carbon dating (Table 1, Appendix D). Three were from cores 004 and 005 collected from Kingsburg Pond and the fourth, sample 007, was from the beach-ridge complex (Fig. 1, 2, Table 1, Appendix D). Two core samples from the gyttja /sandy gyttja interface were dated using the AMS (accelerator mass spectometry) method. A third sample was large enough for conventional dating (with an extended count). The sample of dense peat from the beach-ridge complex was also large enough for using conventional dating methods.

The results suggest that the thin sand layer in cores 001/002 and 005/006 and the top of the sandy platform (Fig. 7) were deposited in Kingsburg Pond before 580 ±60 to 640 ±70 radiocarbon years before present (BP [before 1950 AD]). Beneath the sand, the organic layer sampled at 270-280 cm in core 005 provided an age of 1560 ±70 radiocarbon years BP (Beta 73538, Table 1). This date provides an indication when the deepest sediment sampled in the pond was deposited and when the pond was more marine influenced (J. Ceman, Appendix A).

Table 1. Radiocarbon age determinations from samples collected from Kingsburg, Nova Scotia.

Core No.	Measured ^{14}C age (years BP)	$^{13}C/^{12}C$ Ratio (‰)	Corrected * ^{14}C age (years BP)	Calibrated ** ^{14}C age (calendar years)	Lab No. Collector No.#	Material	Geodetic Elevation (m)	Environment
004	620 ± 70	-23.5	640 ± 70	1346± 41 AD	Beta-73536 CAMS-14467 94304-004 (50-55)#	gyttja	-2.07 to -2.12	gyttja/sand contact flood tidal deposit
005	645 ± 60	-28.9	580 ± 60	1366± 40 AD	Beta-73537 ETH-12566 94304-005 (100-102)	gyttja	-2.88 to -2.90	gyttja/sand contact flood tidal deposit
005	1500 ± 70	-21.0	1560 ± 70	506± 71 AD	Beta-73538 94304-005 (270-280)	gyttja	-4.60 to -4.70	gyttja with sand laminae (brackish pond)
007	330 ± 50	-27.6	290 ± 50	1605± 95AD	Beta-73539 94304-007 (28-30)	peat	approx +1.3	beach-ridge complex

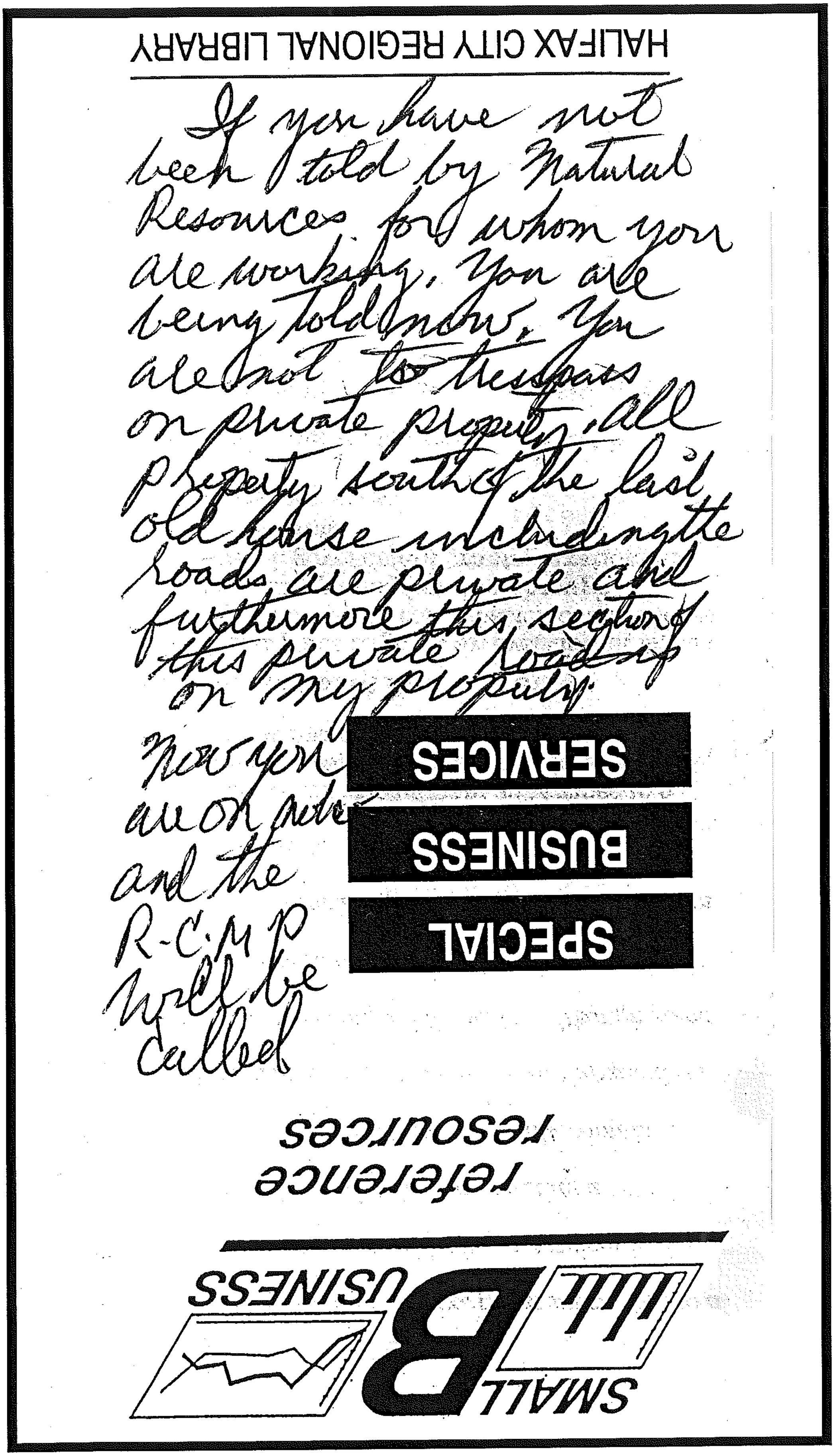
Samples Beta 73536 and 73537 were analysed using AMS techniques and samples Beta 73538 and 73539 were analysed using conventional ^{14}C techniques. Dates are reported in radiocarbon years before present (RCYBP) (present =1950 A.D.).

* ^{14}C dates were normalized to -25 per mil. $^{13}C/^{12}C$.

** The calibrated ^{14}C calendar year was determined using CALIBETH 1.5b (1991), a program for calibration of radiocarbon dates (Kromer and Becker; Linick, Long, Damon and Ferguson, Stuiver and Pearson, 1993).

Cruise no., core no. and sample location in core (depth in cm).

Figure 8. A 1945 aerial view of Kingsburg, Nova Scotia showing the flood-tidal deposit (A) in Kingsburg Pond, waves breaking on Graveyard shoal (B) in Kings Bay, the backshore relict beach ridges (C), the bedrock (D) adjacent to Dry Spitz Pond, and Kingsburg (E) and Hirtles (F) beaches (photo A8808-113, National Air Photo Library, Ottawa).



If you have not
been told by Natural
Resources for whom you
are working. You are
being told now. You
are not to trespass
on private property. all
property south of the last
old house including the
roads are private and
furthermore this section of
this private road is
on my property.
Now you
are on notice
and the
R.C.M.P
will be
called

Figure 9. Conducting research in the vicinity of Kingsburg Beach was at times very challenging.

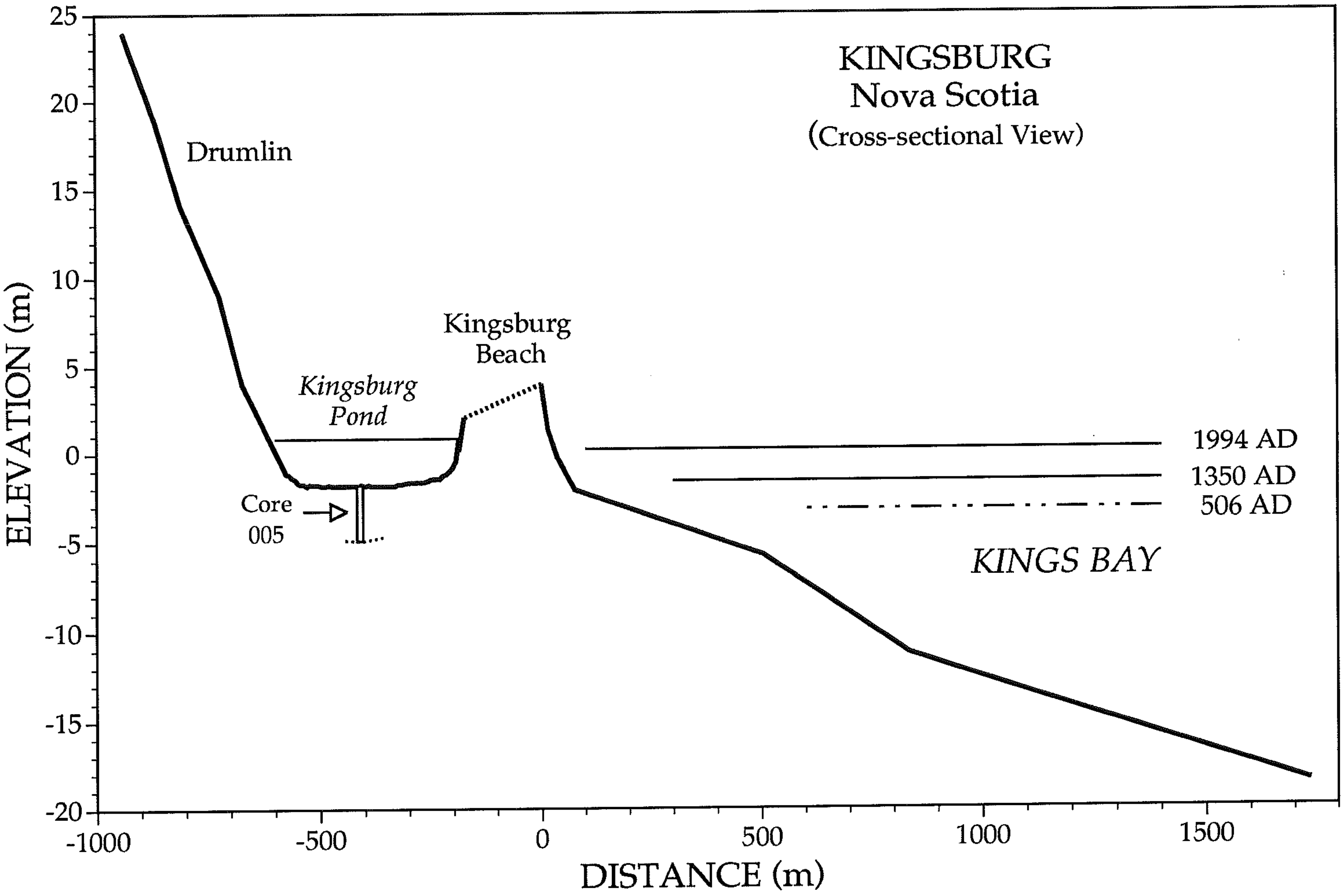


Figure 10. Generalized cross-section (V.E. 40x) of the Kingsburg coastline and the relative positions of mean sea levels in 1994, 1350 and 506 AD, which correspond to the ages of the samples dated and shown in Figure 7. The present water level in Kingsburg Pond and the position of core 005, which represents the deepest penetration into pond sediment (dotted line), are also illustrated.

Basal peat sampled (Beta 73539 Table 1, Fig. 1,7) from the base of the beach ridge adjacent to Lily Pond provided an age of 290 ±50 radiocarbon years BP. Peat began to grow across the beach ridges as conditions became wetter, possibly as a result of a rising water table. The date also represents a minimum age for the beach ridges, although they probably developed much earlier.

COASTAL EVOLUTION

In an earlier study of the Holocene history of Kings and Hartling Bays, Urquhart (1977) found little evidence of any barrier beaches forming in Kings Bay. He concluded that the sources of sediment for building Kingsburg Beach were mainly derived from glacial and offshore sources. Although he showed the presence of two small drumlins, one on each side of Kings Bay, he felt that the volume of sediment and good anchor points required to build offshore barriers were both absent for such features to develop in Kings Bay. He concluded that the "history of Kings Bay thus merely involves the slow incursion of the sea."

A new model for the evolution of the coast over the past 1500 years is proposed for Kingsburg Beach. The reconstruction of beach development is based on published relative sea-level curves (Shaw et al., 1993) bathymetric charts, shoreline recession rates for the area, as well as the geomorphic, sedimentologic and benthonic foraminifera information collected in the Kingsburg area during 1994 (Fig.10). The chronology is based on the ^{14}C dates determined from samples collected in 1994, the relative position of coastal features to each other, and their position relative to the deposits dated (Fig.7).

The rate of relative sea-level rise for the past two centuries is estimated at 37 cm/century based on 20th century tidal records from Halifax and St. Margarets Bay (roughly 70 km and 50 km east of study site) and other historical evidence (Grant, 1975; Shaw et al., 1993). There is geological evidence which suggests that the rise in relative sea level was less, i.e. 20 cm /century, before this and during the past 2000 years. The mean sea level positions for 1350 AD and 500 AD are calculated using the above rates of sea-level change (Fig. 10). Geological changes in shoreline position are estimated using sea-level curves and bathymetric charts. The mean rate of coastal retreat along the Atlantic coast of Nova Scotia since 5000 years BP has been estimated at 0.3 m /a (Shaw et al., 1993). Field measurements of cliff-top positions along Hartling Bay between 1980 and 1994 showed average and maximum recession values of 0.6 m/a and 1.4 m/a (Taylor et al., 1985, Shaw et al., 1993).

One of the primary factors that control coastal evolution is sediment supply (Forbes and Taylor 1987, Forbes et al., 1989, Shaw et al., 1990, 1993). Coastal retreat is often counterbalanced by local stability or even progradation where large volumes of sediment are supplied to the littoral zone either by the erosion of glacial deposits or from the disintegration of older beach systems (Shaw et al., 1993). Prograded beach- and dune- ridge complexes can form despite a rising sea level. Schematic sketches of the suggested evolution of Kingsburg Beach since circa 1500 years BP have been drawn taking the above information into account (Fig. 11).

Stage 1 (Circa 1500 BP): Before 1500 years BP (Fig. 11a) Kingsburg Pond was open to the sea. Spits were developing across the seaward side of the pond, especially from the north. It is postulated that a low rocky promontory, or small rock based drumlin was controlling beach development at the south side of the pond (a, Fig. 11a). The only evidence of this promentory today is the small bathymetric high just off central Kingsburg Beach and the slightly higher onshore terrain just south of Lily Pond. Beach ridges were also building south of Lily Pond. The source of sediment for beach and spit development would have been offshore and alongshore. Sources from alongshore would have included the till covered shores now marked by Graveyard

Shoal (Fig.1, 8), a few small drumlins (b,c, Fig 11a, - similar to the drumlin on Zinck Head; Urquart, 1977, Fig. 7) and possibly a low, till covered, central promontory (a, Fig 11a). At the south end of the lowland, Dry Spitz Pond was substantially larger than today. It is not certain how high or wide the barrier beach fronting it was, but there it is probable that an ephemeral outlet to the sea existed, similar to the outlet that exists at Romkey Pond in Hartling Bay.

Stage 2 (Circa 600 BP): Between 1500 and 600 years BP (Fig. 11b) a substantial increase in sediment supply to the shore zone resulted in beach ridge progradation across the seaward and south side of the pond (1, Fig 11b). Piper et al. (1986) concluded that nearshore sands and gravels were reworked deposits mainly from offshore sources. The sediment had migrated landward during the Holocene transgression. At or before 600 years BP, the supply of sand must have been even greater than before at the head of the bay, as suggested by the influx of sand into Kingsburg Pond and the formation of a flood tidal deposit (3, Fig. 11B), and the continued progradation of Kingsburg Beach. Shoreline retreat of unconsolidated deposits must have increased.

The inlet may have been intermittently closed off prior to 600 years BP as suggested by the intermittent sand and gyttja layers, the fluctuating percentage of organic carbon and the foraminifera observed in the lower part (zone 1) of core 006. Beach progradation also was occurring at the south end of Kingsburg (2- Fig. 11b). The beach ridges were probably gravel dominated but were fronted by a sandy shoreface since there is sand overlying and mixed with the older deposits.

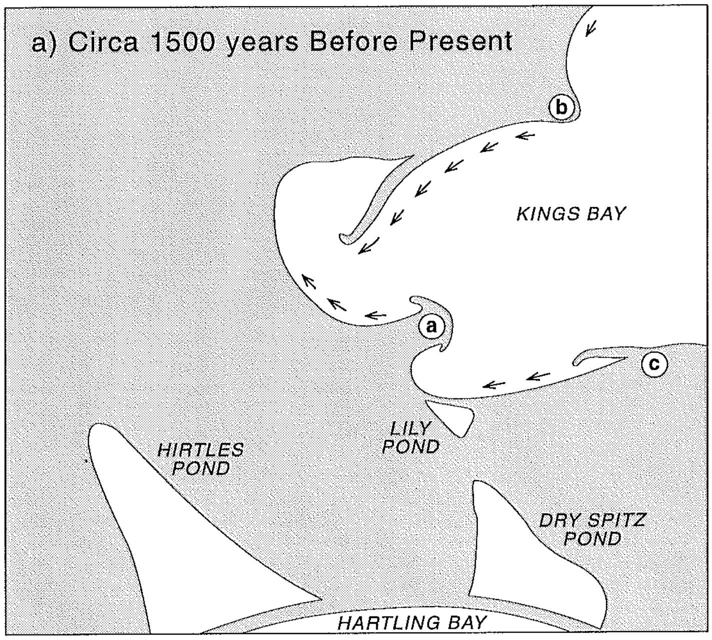
Dry Spitz barrier beach continued to migrate landward and infill the pond. The presence of *in situ* salt marsh deposits at 3.1 m below high water level off Hirtles Beach (Urquhart, 1977) confirms a rising relative sea level and the landward migration of the beach.

Stage 3 (Post 600 BP): The sediment stratigraphy and analysis of benthonic foraminifera suggest that the inlet became choked by sediment and the embayment closed off from the sea circa 600 yrs BP (Fig. 11c). The similarity in dates from the base of the organic-rich mud sampled in cores 004, 005 and 002, and the similarity in texture of the underlying sand, suggest that the sand in both cores is closely related. Furthermore the strong marine signal (i.e. foraminifera) in the sand suggests that the thin band of sand in cores 005 and 002 may be the result of a storm event that transported substantial amounts of sediment into the inlet and the deeper basin. The storm event may have been responsible for the final closure of the inlet.

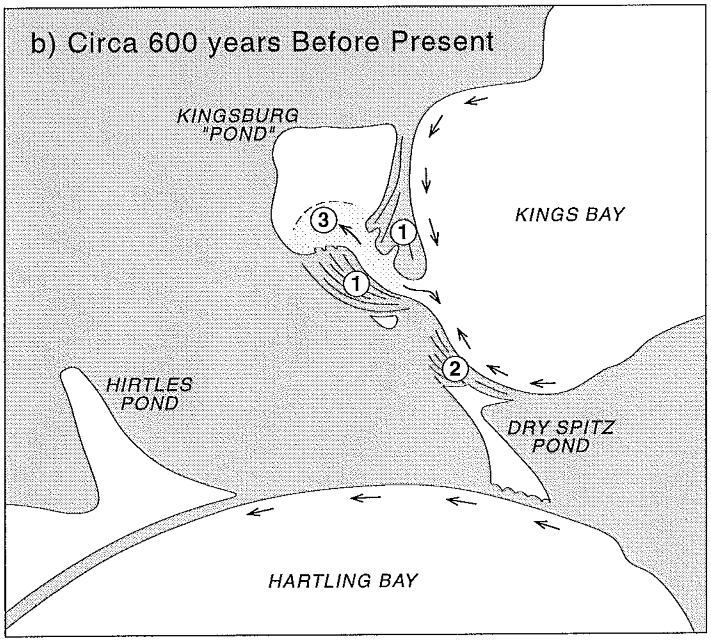
Once the pond was isolated from the sea, the primary supply of sediment to Kingsburg Pond was from grasses, sedges and other plants fringing the shore. An organic-rich mud or gyttja covers most of the pond bottom. The long-term estimated average rate of mud accumulation in the deeper part of the pond is 1.6 mm/yr. However intermittent short term larger influxes of sediment may occur during heavy precipiation, spring snow melt and algal blooms during the summer (Mike Crowell, Jacques-Whitford Environment Ltd., pers. comm., 1994). Mud accumulation across the relict flood tidal deposit in the pond has been less because of its shallow depth and consequent greater wave reworking during strong winds or periods of low water.

After 600 years BP, and possibly earlier, the water table in the coastal lowland continued to rise, partly as a result of rising sea levels, and partly as a result of poor drainage. The swales between the beach ridges adjacent to the pond became wetter and peat began to grow. The age of the peat sampled from the swale adjacent to Lily Pond (290 ± 50 radiocarbon years BP, Fig.1) provides a good estimate of when the swales of the beach ridge complex became wet. The date also confirms that the beach ridges were formed before 300 years BP, although they were probably built much earlier.

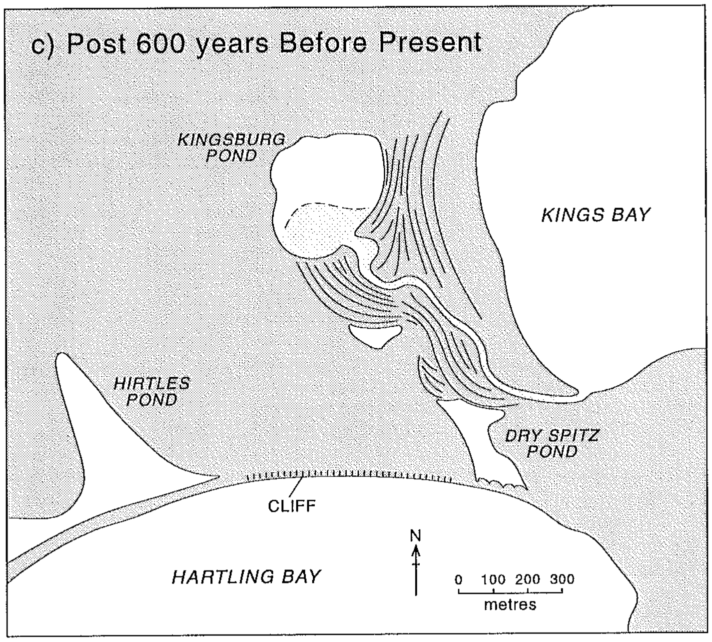
Figure 11. Sketches of the recent geological evolution of Kingsburg Beach, Nova Scotia :



a) Circa 1500 years BP
a,b,c, indicate potential sediment sources; arrows show the inferred direction of sediment transport;



b) Circa 600 years BP
1, 2 indicate areas of prograded beach ridges, 3 marks the flood-tidal deposit;



c) Post 600 years BP
This shows Kingsburg Beach which extended farther seaward than in 1994, and the inferred position of the stream outlet from Kingsburg Pond to Kings Bay.

Although the inlet to Kingsburg Pond was closed, there is map evidence that a stream flowed from the pond toward the south end of Kingsburg Beach and Kings Bay or Hartling Bay at various times. In the 1940s a man-made channel drained the pond to the sea through the central part of Kingsburg Beach (CHS chart 4384). The channels were primarily freshwater outlets rather than inlets since the analyses of the cores from Kingsburg Pond suggest that there has been little or no marine influence since 1346 ± 41 years AD (600 radiocarbon years BP). Therefore, KingsburgPond appears to have been fresh before the arrival of the first European settlers. However, it should be noted that the sample interval used in the analyses of the pond sediment in this study (Appendix A) would not be able to identify short period incursions of saltwater that might have occurred, e.g during storm overwash events. One such storm event is described by local residents as having occurred during the 1950s or 1960s when there was widespread wave overtopping of the beach and flooding of the backshore.

The age of the primary dune at Kingsburg is not known, but the comments by K. Spidle (local resident, pers. comm., 1994) about the early settlers using trees in the dunes to trap sand suggests that they may not have been very high at that time or else they were unstable. In any case, at sometime in the past (possibly as far back as 1350 AD) the supply of wind blown sand increased, resulting in dune growth. It does not take long for dunes to develop given a good vegetation cover and an abundant supply of wind blown sediment. On Sable Island vegetated dunes were observed to aggrade at rates of 0.3 to 1.0 m /a (Taylor and Frobel, 1990).

Mr. Spidle (local resident, pers. comm., 1994) also heard that trenches were dug through the beach by the early settlers to help drain the backshore; this confirms that drainage has been a problem from the beginning of settlement. During the 1900s several different techniques were used to drain floodwaters from around Kingsburg Pond, including open ditches, gates and a sluiceway, and pumps.

The barrier beach fronting Dry Spitz Pond has continued to migrate rapidly landward throughout the past 1000 years. Sediment from the adjacent cliffs appears to have been transported mostly to the west. Any sediment carried eastward must have assisted in maintaining the barrier at Dry Spitz Pond, because more and more sediment would have been washed over the low beach crest and deposited in the pond. Today, the size of the pond is constrained to the east by bedrock (Fig.8) and to the west by higher ground.

COMPARISONS WITH OTHER NOVA SCOTIAN BEACHES

Kingsburg Beach has been described in previous reports by Urquhart (1977), Munroe (1982) and Hale (1992). In another study which parallels this one, Jacques Whitford Environmental Limited and Canadian Seabed Research Limited (1994) discuss detailed beach characteristics and the historical and seasonal changes in the morphology of the modern beach. Therefore, few comments are made in this report about the modern beach. On the basis of extensive field observations in the province, we would conclude that Kingsburg Beach is not dissimilar in character, from other mixed-sediment beaches in Nova Scotia. However, Kingsburg Beach is capped by a well developed, nearly continuous, vegetated sand dune along all but its northern end. Hale (1992) listed Kingburg as one of forty-five sites in Nova Scotia with a coastal sand dune system that extends over 1 km in length. Hale (1992) also concluded that the primary dune ridge along Kingsburg Beach is half a metre higher than the average elevation of dunes she measured along the Atlantic coast of Nova Scotia. The dune crest elevation at the central part of Kingsburg Beach was 3.1 m above high tide level (4.4 m above geodetic datum). Although these dunes are not the highest in Lunenburg County (at Crescent Beach the dunes reach 6.5 m above geodetic datum) their extent and continuity are greater than most other beaches in the province.

One method of comparing the physical character and coastal evolution at Kingsburg with other coastal sites around the province, is to examine some of the major geomorphological elements that exist in the backshore. These include: drumlins, freshwater ponds, and prograded beach features.

Drumlin Coast: Drumlins are elongated hills consisting of mud to boulder size material deposited by glaciers. Drumlins are an important component of the coastline. The affect of drumlins on shoreline stability changes with time. Where drumlins occur at the present shoreline and are exposed to wave attack, they are the primary source of sediment for beach building. They are also anchor points for holding barrier beaches in place (Boyd et al 1987; Forbes and Taylor, 1987). However, as sea level rises, and wave attack increases, the drumlins are consumed by the sea leaving only shoals of coarse material which have more of an affect on local wave dynamics than sediment supply.

Drumlins of Kings and Hartling Bays are part of one of the largest drumlin fields in Nova Scotia (Munroe, 1982, Forbes and Taylor, 1987). In Hartling Bay the drumlins are exposed to wave attack. Therefore they have more of an effect on present shoreline stability than those in Kings Bay which either occur as relic features offshore or farther inland beyond the reach of waves. The drumlins that occur in the backshore will become the primary sediment supply of future beaches if sea level rises high enough to allow waves to erode them. Drumlins are not unique to Kings and Hartling bays, they are found in several parts of Nova Scotia including the west coast, the Eastern Shore of mainland Nova Scotia and southern Cape Breton Island.

Freshwater Ponds: Other coastal bodies of water in Nova Scotia have switched from freshwater to estuarine or marine conditions as sea level has risen, e.g. Bedford Basin; fewer have switched from marine to fresh because this requires a permanent closure of inlets and the formation of landlocked ponds. One example which appears to be similar to Kingsburg Pond is Freshwater Lake at Ingonish Beach, Cape Breton Highlands National Park. Many cases can be cited where back-barrier ponds are opened and closed on a regular basis, because of natural or man-induced causes. These ponds tend to be brackish.

The best documented cases in Nova Scotia where large bodies of water have switched from freshwater to estuary, or back again, are Lawrencetown and Porters Lakes, Halifax County (Honig, 1987; Laidler, 1990; and Boyd and Honig, 1992). Porters Lake which has a very narrow connection with the ocean today has switched from freshwater lake to estuary to freshwater lake to estuary again over the past 2000 years. The switches were closely related to changes in the outer coastline. At Porters Lake the transition to freshwater conditions resulted from the growth of Lawrencetown Beach which closed the former estuary entrance at about 1600 years BP. The switch back to estuary was circa 500 years BP. The changes reflect the same processes that closed off Kingsburg Pond, and while the timing of the switches in environments is relatively similar in both places, the changes to freshwater versus estuarine conditions were completely opposite. Porters Lake became estuarine and Kingsburg Pond became freshwater. The differences in environmental changes reflect the stage the local shore is at within the natural cycle of coastal development. Kingsburg Pond represents one of the few documented cases in Nova Scotia where a water body has switched from marine to fresh.

Prograded Coastal Features: Prograded beach ridges such as those between Lily and Kingsburg ponds are found in other parts of Nova Scotia. A few examples include Lawrencetown and Conrads beaches on the Eastern Shore (Boyd et al, 1987, Taylor et al, 1985), Ragged Head, Guysborough County (Stea et al., 1992), Merigomish, on the Northumberland Strait shore (Stea et al., 1992) and Aspy Bay, Cape Breton Island (Taylor et al., 1991). Most sites are characterized by several sequences of gravel beach ridges which have formed in response to new supplies of sediment or readjustments in the local shoreline. The relict beach ridges are much lower than the present beach because they were built during a time of lower relative sea level. As a consequence, those found within bays or estuaries are partially or completely submerged today. Many of the subaerial ridges, e.g. Conrads Beach, are covered by younger aeolian deposits. Within Lunenburg County, Kingsburg Beach is one of the widest beach complexes and the fifth longest beach with sand dunes mapped by Hale (1992). The longest beaches are Crescent and Cherry Hill. Kingsburg is one of about twenty sites which contain a well preserved suite of relict prograded beach ridges in the province.

Summary: Kingsburg Beach does not contain the largest, best developed, or any unique coastal geomorphologic features found in Nova Scotia. However, it is one of about twenty sites in the province that exhibit a nearly complete suite of prograded relict beach ridges and modern coastal features. Furthermore, from a scientific viewpoint, Kingsburg Pond is valuable because of the relatively undisturbed sedimentary record that lies within it. Analysis of the pollen and microfossils, e.g. diatoms, contained in the lake sediment may enable the reconstruction of past changes in local climate, vegetation and land use patterns.

IMPLICATIONS FOR FUTURE COASTAL STABILITY

Extrapolation of the present tide gauge trends, suggests that sea level will rise by about 39 cm in the next century (Shaw et al., 1993). However, if the global climate change senarios are accepted, the total sea-level rise could be almost 90 cm (66 cm eustatic rise plus local crustal subsidence) in Atlantic Nova Scotia by the year 2100 AD (World Meteorological Organization, 1992). The implications of the changes in sea level for Kingsburg Beach are two fold. Firstly, the level from which waves attack the shoreline will increase, which means that if the elevation of the dune or beach crest is not increased, there will be increased overtopping or overwashing by waves. Secondly, the water table in the backshore lowlands will continue to rise in response to these sea-level changes. This means that the lowland will become increasingly submerged in the future and there will be an increased frequency of high water levels during storms. Another consequence will be a decrease in beach width exposed above water.

Evidence from other sites in Nova Scotia (Shaw et al., 1993, Forbes et al., 1990) has shown the interplay between rising sea levels and sediment supply. Rising sea level does not cause universal coastal retreat. Progradation of the shore can occur where an abundance of sediment is released into the littoral system. In contrast, a dwindling sediment supply results in cannibalization of the prograded deposits by slow retreat of the beach front, and an associated growth in crest height. If beach or dune crest elevation can not be maintained, wave overtopping becomes more frequent and the beaches begin to fail and migrate landward (Forbes et al., 1991).

The future stability of Kingsburg Beach depends primarily on the availability of sediment, i.e. sand and gravel for beach maintenance and building. Urquhart (1977) concluded that very little new sediment is being added to Kings Bay by shore erosion. There is an unknown quantity of mobile sand and gravel lying within Kings Bay. Jacques Whitford and Canadian Seabed Research (1994) documented a landward retreat of 0.15 to 0.45 m/a for the dune crest of Kingsburg beach since the 1940s. The only evidence of seaward dune progradation is at the south end of the beach. It is concluded from these studies that the present supply of <u>new</u> sediment to Kingsburg is insufficient to offset natural changes caused by rising sea level, storms, and other factors, e.g. sediment extraction. There is some evidence that the dune crest, at least along the central part of Kingsburg beach, has increased in elevation by as much as a metre. Urquhart (1977, p.14) states "the storm berm crest rises about 2 m from the normal high water mark" while Hale (1992) and Canadian Seabed Research (1994) show on cross profiles of the beach that the dune crest is at 3 m elevation. A similar trend was observed between 1978 and 1994 at Hirtles Beach, Hartling Bay (Fig 1,8), where a 0.5 m high sand dune built overtop of the gravel storm ridge. Both of these cases may reflect the general increase in beach sand levels observed along many South Shore beaches during the 1980s. A consequence of the higher sand levels was an expansion and building of the adjacent coastal sand dunes. Much of this dune growth was lost at Crescent and several other beaches along the South Shore during recent fall and winter storms, e.g. Halloween 1991 storm (Taylor, 1993).

At Kingsburg Beach it appears that sediment is being recycled from the beach face to maintain the sand dune crest. We know from the evolution of Kingsburg Beach that it is composed of an extensive sequence of unconsolidated relict coastal deposits which could be eroded and liberated by waves as the beach face recedes. Furthermore, the older backshore beach ridges are composed of coarser sediment which provides a stronger core or foundation for the beach against wave attack, and a source of good beach building material. Therefore, despite the depleted supply of new sediment from alongshore or offshore, the rate of recession at Kingsburg Beach is not anticipated to be rapid or dramatic, provided that the integrity and elevation of the dune crest can be maintained. It is the sand dune which has been, and is, protecting the backshore from widespread flooding from the sea. Sand dunes are easily eroded by waves. The dune crest at Kingsburg is still vulnerable to wave attack and collapse if the present beach face does not aggrade or prograde. Given a quick succession of fall or winter storms, increased wave overtopping and a short-term reduction in dune crest could lead to flooding of the backshore before the beach can recover and rebuild itself using its underlying sediment supply.

The stage of degradation at the barrier beach fronting Dry Spitz Pond is much further advanced than at Kingsburg Beach. From the geologic reconstructions of the shoreline at Dry Spitz Pond, it seems that the barrier beach has migrated rapidly landward. The present beach crest is not high enough to prevent wave overwashing. However, because the length of the beach has been reduced (it is constrained by the drumlin to the west and bedrock outcrops to the southeast) less sediment is required to maintain it. If the present sediment supply continues, or increases, it is likely that this beach can be rebuilt. Wave overtopping and beach migration would be reduced and the south end of the Kingsburg lowland would be better protected from the sea, at least until the low rock (Fig. 8) next to the beach becomes submerged by the expected rising sea levels. At that point a substantially larger input of sediment will be required to maintain a barrier beach across the south entrance to the Kingsburg lowlands.

SUMMARY

1. Kingsburg Beach is one part of an extensive sequence of beach ridge, flood tidal, lagoonal and lacustrine deposits at the head of Kings Bay. The deposits accumulated primarily between circa 1500 years BP and 600 years BP, when relative sea level was lower. Based on the depth of coring in the marine and freshwater sediments in Kingsburg Pond, the thickness of unconsolidated deposits could be as much as 9 m.

2. Kingsburg Pond was initally part of Kings Bay. It gradually became less marine as its connection to the bay was restricted by spit growth and beach ridge progradation. The pond became fresh following the closure of the inlet circa 600 years BP. The pond was therefore freshwater when the first European settlers arrived.

3. Progradation of Kingsburg Beach continued after the closure of the inlet to Kingsburg Pond. The sand dunes that presently cover Kingsburg Beach formed at a time when there was a greater availability of sand. There is evidence that the dunes have aggraded by as much as a metre since the mid 1970s.

4. The Kingsburg beach complex is one of about twenty sites in the province known to have a nearly complete suite of relict, prograded beach ridges, freshwater / lagoonal deposits and modern beach features.

5. The scarcity of new sediment being added to Kingsburg Beach from offshore or alongshore has resulted in a slow retreat of the beach crest and a recycling of the beach material to maintain seasonal beach profile adjustments and the integrity of the overlying dunes. Kingsburg Beach has the inherent ability to recover from storm damage because of the abundance of underlying beach building material, i.e. sand and gravel.

6. Maintaining the integrity of the present sand dunes is critical to reducing or preventing widespread flooding of the backshore lowland by the sea. Wave overtopping is more frequent today at the north end of Kingsburg Beach, where there is no dune, than along the central part of the beach, where the beach crest is an estimated 0.5 m higher.

7. It is expected that sea level will rise by approximately 39 cm in the next century along the Atlantic coast of Nova Scotia (Shaw et al., 1993). However, if the global climate change senarios are accepted, the total sea-level rise could be almost 90 cm (66 cm eustatic rise plus local crustal subsidence) by the year 2100 AD (World Meteorological Organization, 1992). One consequence will be increases in the backshore water table and pond water levels. The backshore lowlands will become increasingly submerged and the width of Kingsburg Beach exposed above water will decrease.

8. At present, the frequency and extent of wave overwashing is much greater for the low barrier beach fronting Dry Spitz Pond than Kingsburg Beach. Given the same sediment supply or an increase in sediment supply in the future, the integrity of the beach fronting Dry Spitz Pond could improve, at least until the adjacent bedrock, anchoring the beach, becomes submerged by rising sea levels.

ACKNOWLEDGEMENTS

Piecing together the recent geological evolution of Kingsburg Beach was only possible with the assistance of a number of persons. Thanks are extended to Fred Jodrey who assisted in the field, to Tony Cole, Bill LeBlanc, Jim Ceman and H. Jetté who provided laboratory analyses of the samples (see appendices) and Jean Ponsford and Bob Archer for assistance in the core lab. We also thank Don Forbes (Atlantic Geoscience Centre) and David Liverman (Geological Survey, Natural Resources, Government Newfoundland and Labrador) who reviewed and provided comments on this manuscript. We thank Mr. K. Spidle and Mr. S. Mosher (residents of Kingsburg) for telling us a little about the history of Kingsburg and for their interest and assistance with this study. Financial support for the field surveys and dating of samples was provided by the Nova Scotia Department of Natural Resources. All other costs were provided by the Geological Survey of Canada.

REFERENCES

Boyd, R., Bowen, A.J., and Hall, R. K. 1987. An evolutionary model for transgressive sedimentation on the Eastern Shore of Nova Scotia. In: D.M. Fitzgerald and P.S. Rosen eds. Glaciated Coasts, Academic Press, San Diego p. 87-114.

Boyd, R. and Honig, C. 1992. Estuarine sedimentation on the Eastern Shore of Nova Scotia. Journal of Sedimentary Petrology, Vol. 62: 562-583.

CHS (Canadian Hydrographic Service) 1973. Chart 4384, Nova Scotia, Southeast coast Pearl Island to Cape La Have, 1: 39,023 scale.

Fisheries and Oceans, 1994. Canadian tide and water tables 1994, Volume 1 Atlantic coast and Bay of Fundy, 45 p.

Forbes, D.L. and Taylor, R.B. 1987. Coarse-grained beach sedimentation under paraglacial conditions, Canadian Atlantic coast. In: D.M. Fitzgerald and P.S. Rosen (eds.) Glaciated Coasts, Academic Press, San Diego; p. 51-86.

Forbes, D.L., Taylor, R.B., and Shaw, J. 1989. Shorelines and rising sea levels in Eastern Canada. Episodes 12; p. 23-28.

Forbes, D.L., Taylor, R.B., Shaw, J. Carter, R.W.G. and Orford J.D. 1990. Development and stability of barrier beaches on the Atlantic coast of Nova Scotia; p 83-98. In Proceedings Canadian Coastal Conference 1990 (Kingston, Ontario) National Research Council, Ottawa.

Forbes, D.L., Taylor, R.B., Orford, J.D., Carter, R.W.G. and Shaw, J. 1991. Gravel barrier migration and overstepping, Marine Geology, 97; p. 305-313.

Grant, D. R. 1975. Recent coastal submergence of the Maritime Provinces. Nova Scotian Institute of Science, Proceedings, 27 (3); p. 83-102.

Hale, W. J. 1992. Sand dunes of Nova Scotia; Unpubl. MSc. Thesis, Geography Department McMaster University, Hamilton Ontario; 271 p.

Honig, C.A. 1987. Estuarine sedimentation on a glaciated coast: Lawrencetown Lake, Eastern Shore, Nova Scotia. Centre for Marine Geology, Technical Report 9, Dalhousie University, Halifax, 132 p.

Jacques Whitford Environmental Limited and Canadian Seabed Research Limited 1994. An ecological study of Kingsburg beach, Lunenburg County. Draft contract report to Nova Scotia Department of Natural Resources, 35 p.

Kromer, B. and Becker, B.; Linick, T.W., Long, A., Damon, P.E. and Ferguson, C.W.; Stuiver, M. and Pearson, G.W. 1993. Composed high-precision bidecadal calibration of radiocarbon time scale, AD 1950 to 9440 BC; Radiocarbon 35.

Laidler, R.B. 1990. Testate rhizopods from the sediments of a maritime/freshwater transitional lake: their distribution and paleoenvironmental significance. MSc. dissertation, Dalhousie University, Halifax, 38 p.

LRIS (Land Registry and Information Service) 1982. Topographic Map Series, Lower Rose Bay, Nova Scotia, Map Sheet 10 44 2500 64 200, 1:10,000 scale.

Munroe, H.D. 1982. Regional variability, physical shoreline types and morphodynamic units of the Atlantic coast of mainland Nova Scotia. In: R.B. Taylor, D.J.W. Piper and C.F. M. Lewis (eds); Geological Survey of Canada Open File Report 725, 25 p.

Piper, D.J.W., Mudie, P.J., Letson, J.R.J., Barnes, N.E. and Iuliucii, R.J. 1986. The marine geology of the inner Scotian Shelf off the South Shore, Nova Scotia; Geological Survey of Canada Paper 85-19, 65p.

Shaw, J., Taylor, R.B. and Forbes, D.L. 1990. Coarse clastic barriers in eastern Canada: patterns of glaciogenic sediment dispersal with rising sea levels. Proceedings of the Skagen Symposium, 2-5 September 1990. Journal of Coastal Research, Special issue 9, p. 160-200.

Shaw, J., Taylor, R.B. and Forbes, D.L. 1993. Impact of the Holocene transgression on the Atlantic coastline of Nova Scotia; Géographie physique et Quaternaire, Vol. 47, No. 2; 221-238.

Stea, R.R., Forbes, D.L. and Mott, R.J. 1992. Quaternary Geology and Coastal Evolution of Nova Scotia; Geological Association of Canada, Mineralogical Association of Canada, Joint Annual meeting, Wolfville'92; Field Excursion A-6; Guidebook; 125 p.

Taylor, R. B. 1993. Recent morphological changes and future management of Crescent Beach, Lunenburg County, Nova Scotia, Geological Survey of Canada Open File Report 2675; 20 p.

Taylor, R.B. and Frobel, D. 1990. Approaches and results of a coastal dune restoration program on Sable Island, Nova Scotia. In: proceedings Canadian Symposium on Coastal Sand Dunes National Research Council of Canada, Ottawa, p.405-431.

Taylor, R.B.and Shaw J., 1994. Recent geological evolution of Kingsburg Beach, Kingsburg, Lunenburg County, Nova Scotia, Unpublished contract report submitted to the Nova Scotia Department of Natural Resources, Parks and Recreation Division, Belmont, Nova Scotia, 43 p.

Taylor, R.B., Wittmann, S.L., Milne, M.J. and Kober, S.M. 1985. Beach morphology and coastal changes at selected sites, mainland Nova Scotia; Geological Survey of Canada Paper 85-12, 59 p.

Taylor, R.B., Forbes, D.L., and Shaw, J. 1991. Surficial geology and physical properties 9: coastal geology, case studies. In: East Coast Basin Atlas Series: Scotian Shelf; Atlantic Geoscience Centre, Geological Survey of Canada; p. 127.

Urquhart, E.F., 1977. Holocene history of Kings and Hartling Bays, Atlantic coast of Nova Scotia, Unpub. BSc. thesis, Dalhousie University, 113 p.

World Meteorological Organization 1992. Global climate change and the rising challenge of the sea, Report of the Coastal Zone Management Subgroup to the Intergovernmental Panel on Climate Change Response Strategies Working Group.

APPENDIX A

MARINE INFLUENCE IN KINGSBURG POND

by

James A. Ceman

Contract Report
Prepared for

J. Shaw
Geological Survey of Canada
Atlantic Geoscience Centre

September 1994

Kingsburg Pond

A total of 6 samples from core 94-304-006 were processed for foraminiferal analysis. The samples, which consisted of 9 to 15 cm^3 of sediment, were wet-sieved through 0.5 mm and 63 μm sieves to separate the coarse organics from the foraminifera. The foraminifera in the fractions >63 μm were picked from the dried residues.

Core 94-304-006

In general, the number of foraminiferal tests in the samples is relatively low, ranging from 0 to 119 tests per 10cc of sediment. Only two of the six samples yielded >100 tests, but, the influence of marine water in the study area could be resolved. The two major species present are *Eggerella advena* and *Trochammina ochracea* . *Eggerella advena* is found in modern sediments from the lower estuary at Miramichi Bay (Scott et al. 1977) and the upper bay estuarine environment of Chaleur Bay (Schafer and Cole, 1978). Both *Eggerella advena* and *Trochammina ochracea* have been reported in modern sediments from the lower estuary of Chezzetcook Bay (Scott et al., 1980) and the intertidal mudflats in the Cumberland Basin (Ceman, 1994).

The total number of foraminiferal tests in the samples is likely the best indicator of marine influence in Kingsburg Pond. Therefore, the core has been zoned according to the number or trends in the number of tests in the samples. It is important to note that the number of foraminiferal tests in a sample is dependent on environmental conditions as well as sedimentation rate. A high sedimentation rate decreases or 'dilutes' the number of tests present in a sample. Thus, a sample containing <100 tests per 10cc of sediment may indicate either an increase in sedimentation rate and/or degradation of the local marine environment. The absence of calcareous species in the samples may be an accurate depiction of the fossil record or the result of dissolution of the tests after burial (Scott, 1976).

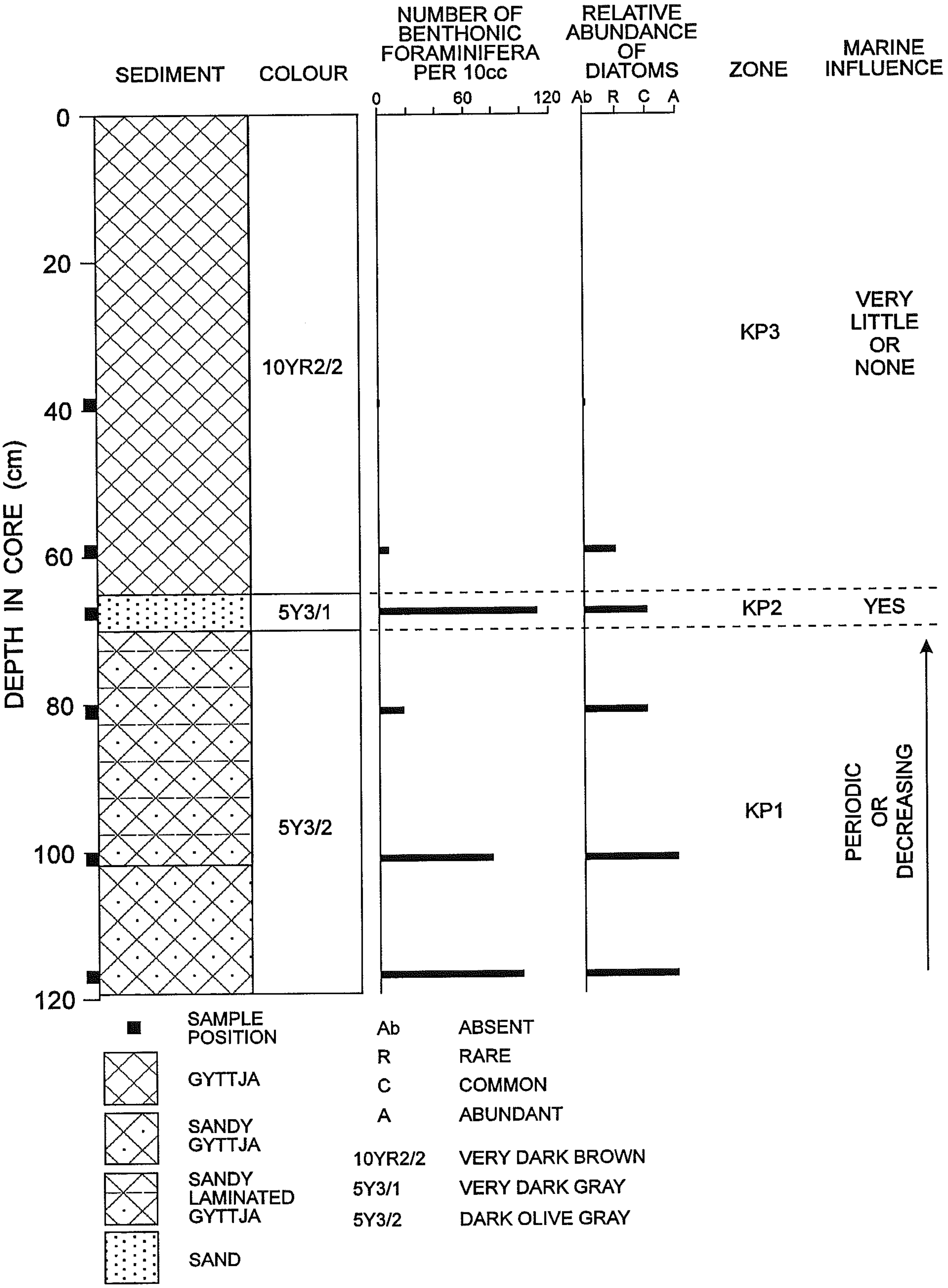


Figure 1. Sediment, microfossil numbers and zones for core 94-304-006.

Zone KP1: The lower part of the core consists of massive sandy gyttja (Fig. 1). The number of foraminiferal tests is relatively high in the lower part of the zone and low in the upper part of the zone (Figs 1 and 2). It appears that the marine influence during this zone was either periodic or decreased from the lower to the upper part of the zone. The laminated sediments in the upper part of the zone may suggest a periodic invasion of marine water into the pond. A detailed analysis is required to determine whether the marine influence oscillated or decreased in the upper part of this zone.

Zone KP2: The sediment in this zone is a well sorted sand which consists of approximately equal parts of quartz and a mafic mineral or rock fragment. The number of foraminiferal tests in the one sample from this zone is high and the abundance of *Eggerella advena* is about 68 per cent. This indicates a marine influence in the pond during zone KP2.

Zone KP3: The sediment in this zone consists of massive gyttja. One of the samples from this zone yielded only 6 foraminiferal tests and the other sample was barren of tests. This indicates that there has been very little or no marine water present in the pond during the deposition of sediments in this zone. In an adjacent core, the lower part of this zone was dated at 580 ± 60 years BP. Therefore there has been virtually no marine influence in Kingsburg Pond since that time. The numbers and percent abundance of foraminiferal species for core 94-304-006 are listed in Table 1.

Summary and Conclusions

The total number of foraminiferal tests in samples from core 94-304-006 were used to determine the extent of a marine influence in Kingsburg Pond. The two main species present in the samples are *Eggerella advena* and *Trochammina ochracea.* Three zones are recognized in the core. The oldest zone, KP1, contains relatively high numbers of foraminiferal tests in the lower part of the zone and low numbers in the upper part of the zone. The marine influence thus was either periodic or decreased from the lower to the upper part of the zone. The middle zone, KP2, contains relatively high numbers of foraminiferal tests in a sandy horizon which indicates a marine

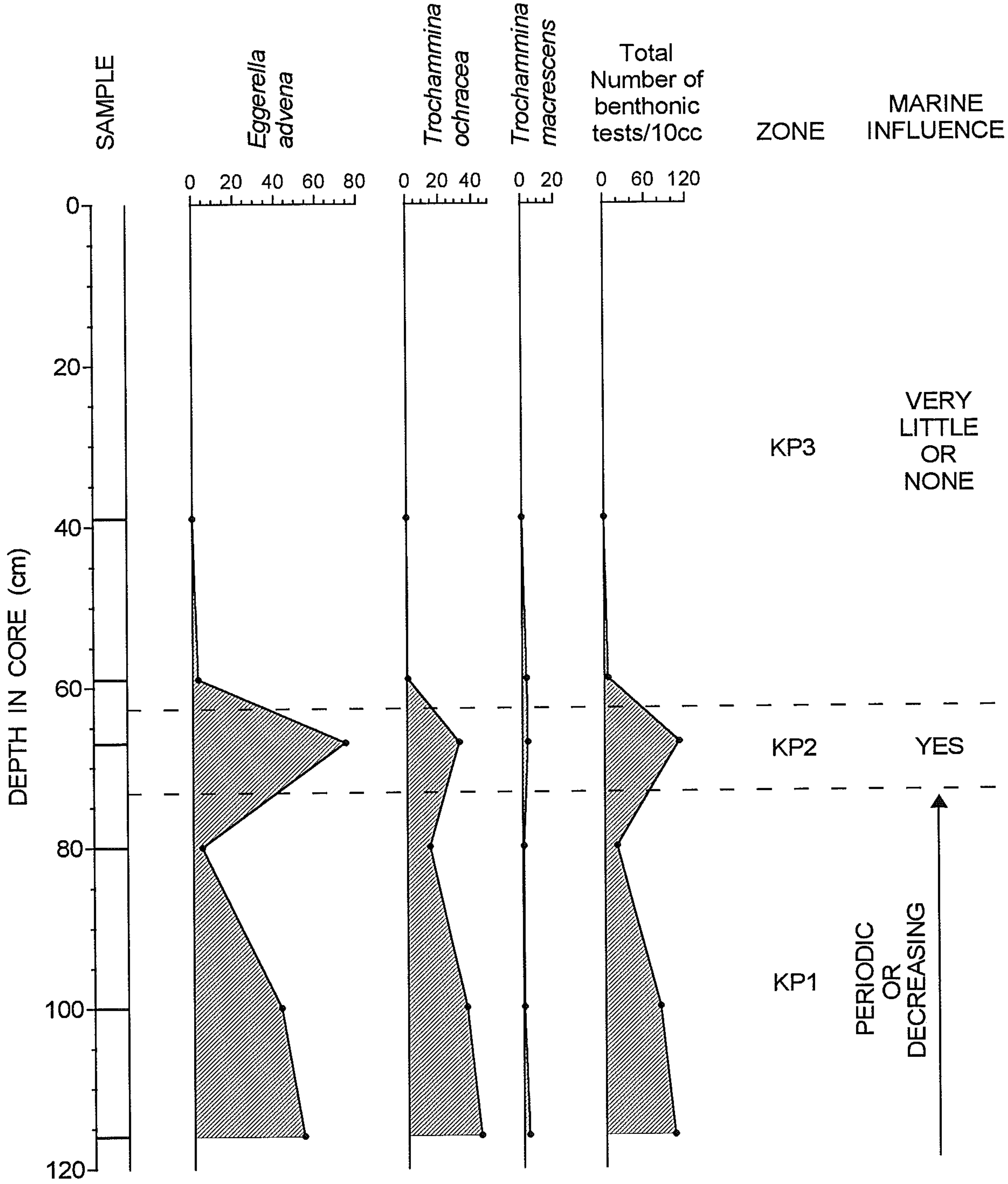


Figure 2. Number of tests (per 10cc) of major benthonic foraminiferal species and zones for core 94-304-006.

Table 1. Number and percent abundance of foraminiferal species in samples from core 94-304-006.

KINGSBURG POND

Raw Data

Interval (cm)	**39-40**	**59-60**	**67-68**	**80-81**	**100-101**	**116-117**
Volume (cc)	10	15	12	14	12	9
Bathysiphon sp.		1				
Eggerella advena		4	89	6	51	48
Spiroplectammina biformis					1	
Trochammina ochracea		1	38	19	43	40
Trochammina macrescens		4	4	1	1	3
Neogloboquadrina pachyderma (D)		1				

Percent Abundance

Interval (cm)	**39-40**	**59-60**	**67-68**	**80-81**	**100-101**	**116-117**
Volume (cc)	10	15	12	14	12	9
Number of tests (B - Total)	0	10	131	26	96	91
Number of tests (B - Calc)	0	0	0	0	0	0
Number of tests (B - Aggl)	0	10	131	26	96	91
Number of tests (B/10 cc)	0	6	109	18	80	101
Number of species (B - Total)	0	4	3	3	4	3
Number of species (B - Calc)	0	0	0	0	0	0
Number of species (B - Aggl)	0	4	3	3	4	3
Number of tests (P)	0	1	0	0	0	0
Number of tests (P/10 cc)	0	0	0	0	0	0
Number of species (P)	0	1	0	0	0	0
Planktonic/Benthonic	0	0.1	0	0	0	0
Sediment type	MUD	MUD	SAND	SM/MS	SM/MS	SM/MS
Bathysiphon sp.	0	10	0	0	0	0
Eggerella advena	0	40	67.94	23.08	53.13	52.75
Spiroplectammina biformis	0	0	0	0	1.04	0
Trochammina macrescens	0	40	3.05	3.85	1.04	3.3
Trochammina ochracea	0	10	29.01	73.08	44.79	43.96
Neogloboquadrina pachyderma (D)	0	100	0	0	0	0
Relative abundance of diatoms	absent	rare	present	present	abundant	abundant

SM/MS..Sandy mud/Muddy sand
Calc......Calcareous
Aggl......Agglutinated
⬭.... <100 tests per 10cc of sediment

influence in this part of the core. Samples from the youngest zone, KP3, contain very few or no foraminiferal tests which suggests that there has been very little or no marine influence in Kingsburg Pond during the deposition of sediments in this zone.

References

Ceman, J.A., 1994. Marine influence in Kingsburg Pond and distribution of modern foraminifera at John Luzby Marsh. Report prepared for Dr. John Shaw under DSS contract number 23420-4-M090/01-OSC., 24 p.

Schafer, C. T. and Cole, F. E., 1978. Distribution of foraminifera in Chaleur Bay, Gulf of St Lawrence. Geological Survey of Canada, Paper 77-30, 55 p.

Scott, D.B. 1976. Quantitative studies of marsh foraminifera patterns in southern California and their application to Holocene stratigraphic problems. First International Symposium on Benthonic Foraminifera of Continental Margins, Part A, Ecology and Biology, Maritime Sediments, Special Publication 1, pp. 153-170.

Scott, D.B., Medioli, F.S. and Schafer, C.T. 1977. Temporal changes in foraminiferal distributions in Miramichi River estuary, New Brunswick. Canadian Journal of Earth Sciences, 14, pp. 1566-1587.

Scott, D.B., Schafer, C.T. and Medioli, F.S. 1980. Eastern Canadian estuarine foraminifera: a framework for comparison. Journal of Foraminiferal Research, 10, pp. 205-234.

APPENDIX B

SEDIMENT SAMPLES AND CORE DESCRIPTIONS

Kingsburg Pond

Sample No:	94304-001	Water Depth:	2.64 m.
Corer:	Push Corer		
Latitude:	44° 16.50	Longitude:	64° 15.86
Julian Day:	159	Time (UTC):	15:34

Comments: Using the push corer with a 196 cm long barrel, mud covered 136 cm of the barrel. However, the coring failed-the barrel contained only a few tens of cm of sediment. It is believed that the sediment was being pushed aside as the core barrel was forced downward. The retained sediment consisted of dark olive brown silty mud with disseminated fine sand and some granules, organic fibres, and disseminated shell fragments.
A total of three sediment samples were retained: from the barrel, the cutter and the catcher.

Sample No:	94304-002	Water Depth:	2.64 m
Corer:	Eijkelkamp auger.		
Latitude:	44°16.50	Longitude:	64°15.86
Julian Day:	159	Time (UTC):	17:00

Core description:

Depth (cm)	Stratigraphy
0-40	Missing - probably soft, soupy gyttja with macroscopic plant remains including Typha stems.
40-105	Soft, dark brown gyttja, scattered plant fibres.
105-107	Gray, well-sorted sand with some mud.
107-316	Dark olive brown gyttja with disseminated, poorly sorted medium and fine sand, scattered small shell fragments and a few platy granules. Becoming stiffer with increasing depth. Shell fragments at 154 cm. Broken purplish shell at 160-170 cm. Small shell fragments at 228-230 cm. Broken purplish shell fragments at 285 cm. Platy granules at 180-190 cm, and at 242 cm (10x10x1 mm), 284 cm (15x10x1 mm) Pod of muddy sand at 260 cm. The sample is contaminated from 290-300 cm and 310-316 cm.

Thirty-one subsamples were retained from 94304-002. Ten centimetre increments of sediment were bagged, as were the increments 105-107 cm, 107-110 cm, and 310-316 cm. Shell fragments were collected from 223-226 cm.

<u>Sample No:</u>	<u>94304-003</u>	Water Depth:	1.6 m
Corer:	Eijkelkamp auger.		
Latitude:	44°16.43	Longitude:	64°15.81
Julian Day:	159	Time (UTC):	18:48

<u>Core description:</u>

First attempt:

<u>Depth (cm)</u>	<u>Stratigraphy</u>
0-35	missing -washed out -probably soft gyttja
35-70	moderately well sorted medium gray sand.
70-100	missing -washed out.

No samples were retained.

Second attempt:

<u>Depth (cm)</u>	<u>Stratigraphy</u>
0-30	missing -probably soft gyttja
30-35	soupy organic-rich mud
35-110	grey, well-sorted medium sand, with scattered shell fragments. Small (1 cm) wood chip at 110 cm.
110-130	lost-washed out

Two samples were retained one from 100-110 cm (wood) and the other from 70-80 cm (sand).

<u>Sample No:</u>	<u>94304-004</u>	Water Depth:	2.4 m
Corer:	Eijkelkamp auger.		
Latitude:	44°16.49	Longitude:	64°15.82
Julian Day:	159	Time (UTC):	19:22

<u>Core description:</u>

<u>Depth (cm)</u>	<u>Stratigraphy</u>
0-55	Soft, soupy dark brown gyttja with numerous plant fibres, more compact with depth. The lower contact is sharp (1-2 mm).
55-200	Moderate to well-sorted medium sand, gray, a few scattered organic fragments, some finely comminuted shell fragments.

Only one sample was retained from the mud/ sand interface at 50-55 cm.

Sample No: 94304-005 Water Depth: 2.74 m

Corer: Eijkelkamp auger.

Latitude: 44°16.50 Longitude: 64°15.82

Julian Day: 160 Time (UTC): 16:06

Core description:

Depth (cm)	Stratigraphy
0-14	Missing - probably soupy gyttja.
14-102	Soft dark brown gyttja with plant fibres, soupy to 90 cm becoming firmer towards the base. Sharp lower contact (over 2 mm).
102-106	Well sorted gray medium to fine sand with a few granules.
106-300	Dark grayish brown organic rich mud (or gyttja) with plant fibres, disseminated medium to fine sand, scattered granules and a few small, platy pebbles. Interval 190-200 was probably contaminated. Platy pebble measuring 15 x 10 x 2 mm at 260 cm. Refusal was reached at 300 cm.

Thirty-one subsamples were retained. Samples collected at 10 cm increments.

Sample No: 94304-006 Water Depth: 2.7 m

Corer: Push Corer

Latitude: 44°16.50 Longitude: 64°15.82

Julian Day: 160 Time (UTC): 16:06

Core description:

Depth(cm)	Stratigraphy
0-65	soft very dark (10 YR 2/2) brown gyttja,small twigs and plant fibres, upper 36 cm more watery sharp lower boundary (over 2 mm); rounded pebble 28x20x10mm at 65 cm.
65-70	very dark gray (5Y 3/1) well sorted fine to med. sand with trace organics
70-104	dark olive gray (5Y 3/2) sandy gyttja; laminated med to fine sand up to 5 mm thick organic rich layers at 72,73.5,74.5, 75.5 79,86 cm; twig at 78 cm; more massive from 86to 94 cm.
104-119	massive sandy gyttja, (5 Y 3/2) disseminated fine-med sand, scattered granules shell sample insitu bivalve at 11.5 cm, broken shell at 115 cm, and alder wood frag. 25x22x10 at 111-114 cm.

Sediment compaction occurred during coring - total penetration of the lake bed was 196 cm but only 113 cm of core was retained. After opening the core liner there was sediment movement in the upper core when it was laid horizontal, total core length was logged as 120 cm . Water and soupy gyttja at top of core was poured away. In the laboratory six samples were taken for foram analysis, eight for organic carbon analysis and a half bivalve of a freshwater mussel was sampled from 111. 5 cm and a wood (*Alnus sp.* alder) fragment (25x22x10 mm) from 111-114 cm (Appendix C).

Backshore Beach Ridges and wetlands

Sample No: 94304-007

Corer:	Eijkelkamp auger.		
Latitude:	44°16.24	Longitude:	64°15.71
Julian Day:	160	Time (UTC):	19:09

Core description:

Depth (cm)	Stratigraphy
0-30	poorly humified reddish brown peat with a few fibres and with woody roots or stems (up to 10 cm long, 1.5 cm diameter) at the base.
30-60+	well-sorted gray medium sand (speckled appearance) with a few pebbles.

Sample retained included 10 plugs of peat collected by repeated augering of the basal 2 cm of peat.

Sample No: 94304-008

Same location as 94304-007. Sample consisted of a small piece of wood from the base of the peat.

APPENDIX C

WOOD IDENTIFICATION REPORT NO. 94.70

Date: August 12,1994

Locality: Kingsburg, Nova Scotia

Latitude: 44° 16.50 **Longitude:** 64° 15.82

NTS: 21A/8

Sample Submitted By:
J. Shaw,
Atlantic Geoscience Centre
Dartmouth, Nova Scotia

Field No.: 94304-006

C-14 Lab No:

Age: gyttja sampled at 102 cm depth in an adjacent core was 580±60 yrs BP Beta-73537 (Table 1 this report)

Paleoecology Laboratory Number: PL-94.82

Description of Sample: Contained in a sandy gyttja at 111-114 cm depthin a lake core. Water depth at site of core 006 was 2.7 m.

Identification: Alnus sp. (alder) Three different alder species live in the area according to distribution maps could not identify the species.

by H. Jetté
Quaternary Paleoecology Laboratory
Geological Survey of Canada
Ottawa, Ontario

APPENDIX D

RADIOCARBON SAMPLES
FIELD LOG SHEETS

Sample Number: 94304-004 (50 to 55 cm)

Geographic Location: Kingsburg, Lunenburg Co. Nova Scotia

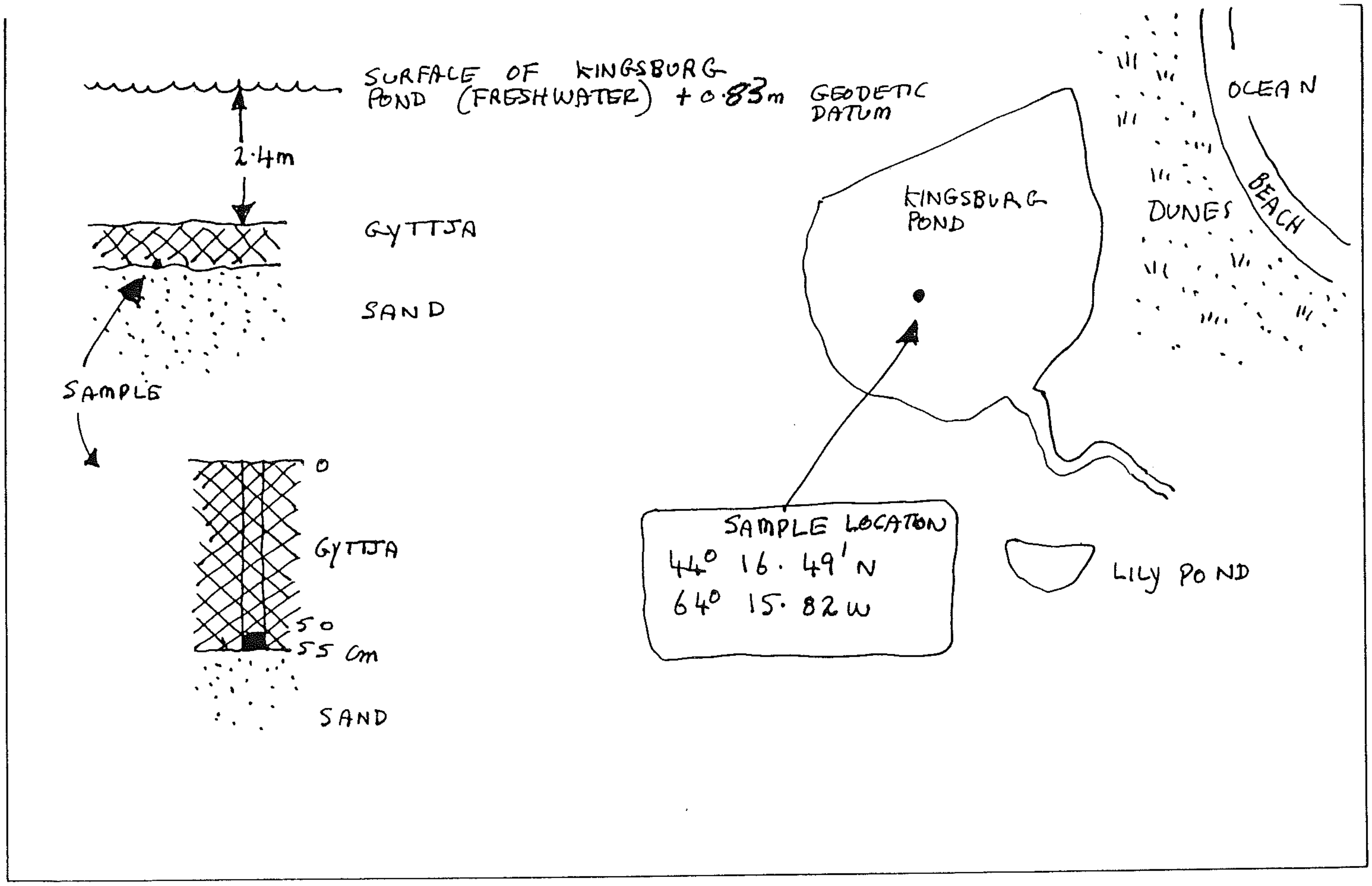
Latitude: 44° 16.49 N **Longtitude**: 64° 15.82 W

Type of Material: gyttja with some disseminated sand

Weight of Material: 16.68 g (wet)

Collection Treatment and Storage: Collected June 8,1994, put in plastic bag and kept at 4°C until June 16,1994 when shipped to Beta Analytic Inc. for dating.

Stratigraphic and Environmental Details:



RADIOCARBON SAMPLES
FIELD LOG SHEET

Sample Number: 94304-005 (100 to 102 cm)

Geographic Location: Kingsburg, Lunenburg Co. Nova Scotia

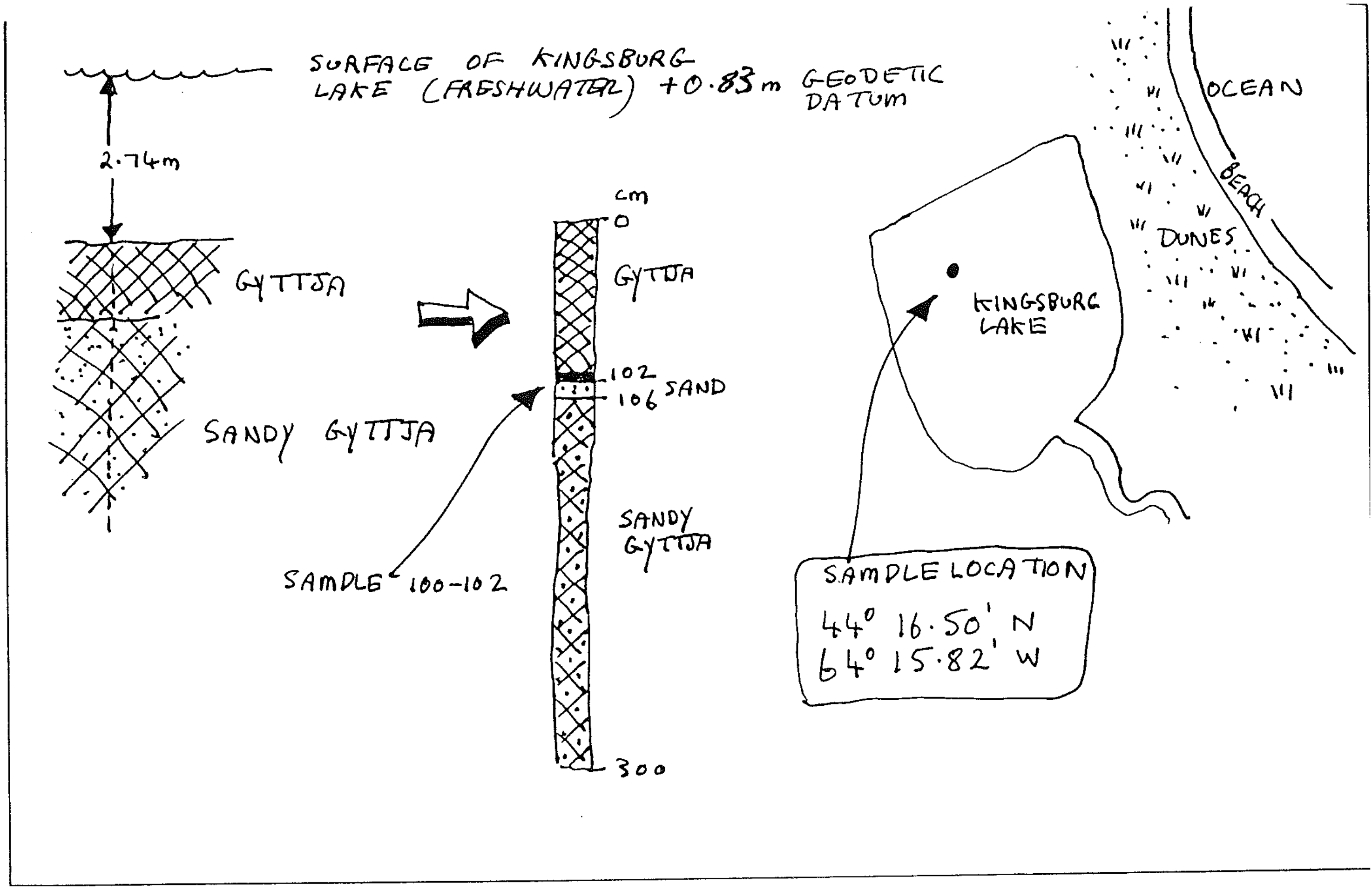
Latitude: 44° 16.50 N **Longtitude**: 64° 15.82 W

Type of Material: gyttja

Weight of Material: 4.54 g (wet)

Collection Treatment and Storage: Collected June 9,1994, using Eijkelkamp auger, put in plastic bag and kept at 4°C until June 16,1994 when shipped to Beta Analytic Inc. for dating.

Stratigraphic and Environmental Details:



RADIOCARBON SAMPLES
FIELD LOG SHEET

Sample Number: 94304-005 (270 to 280 cm)

Geographic Location: Kingsburg, Lunenburg Co. Nova Scotia

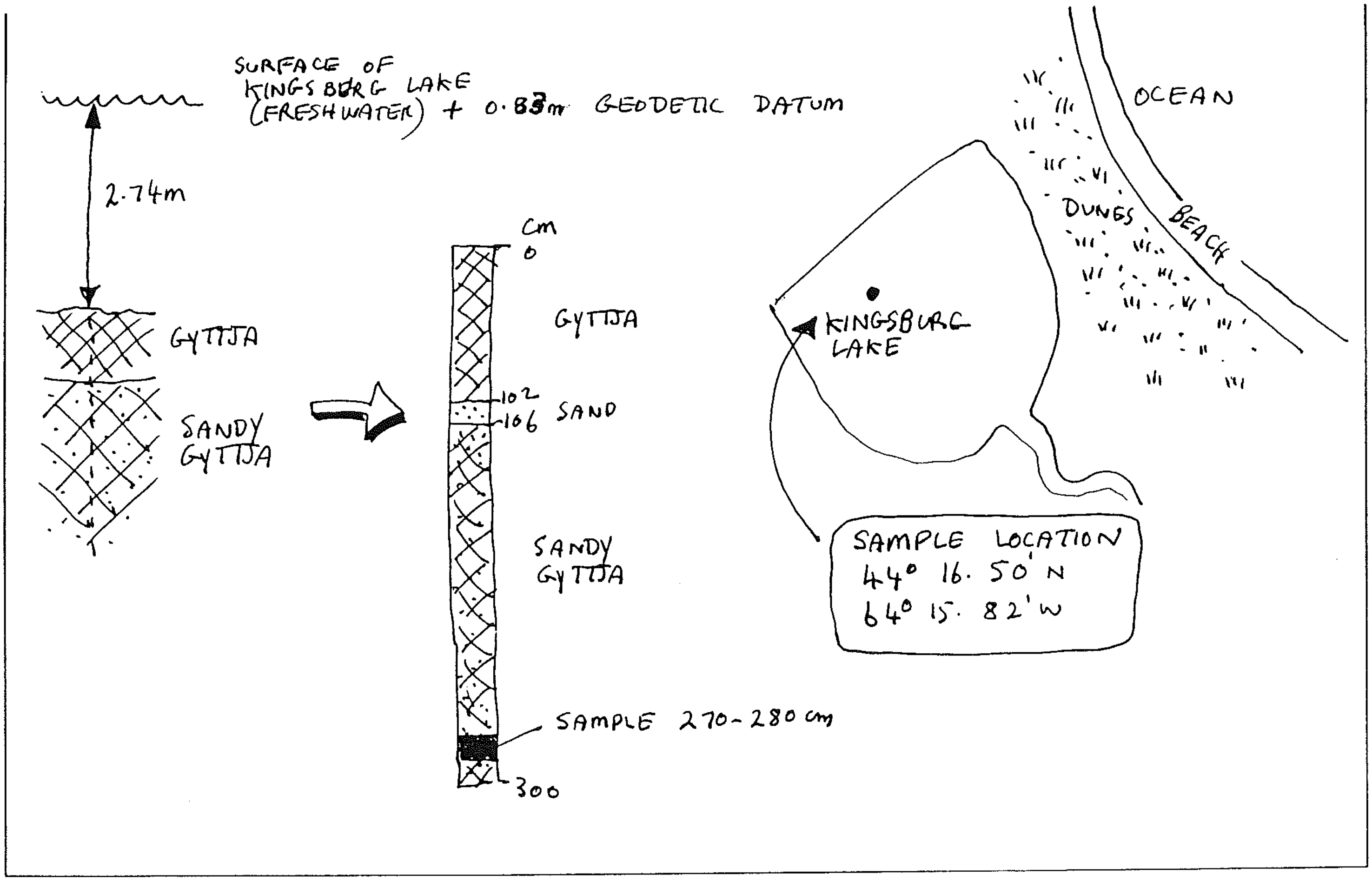
Latitude: 44° 16.50 N **Longtitude**: 64° 15.82 W

Type of Material: gyttja with disseminated sand

Weight of Material: 49.5 g (wet)

Collection Treatment and Storage: Collected June 9,1994, using Eijkelkamp auger, put in plastic bag and kept at 4°C until June 16,1994 when shipped to Beta Analytic Inc. for dating.

Stratigraphic and Environmental Details:



RADIOCARBON SAMPLES
FIELD LOG SHEET

Sample Number: 94304-007 (28 to 30 cm)

Geographic Location: Kingsburg, Lunenburg Co. Nova Scotia

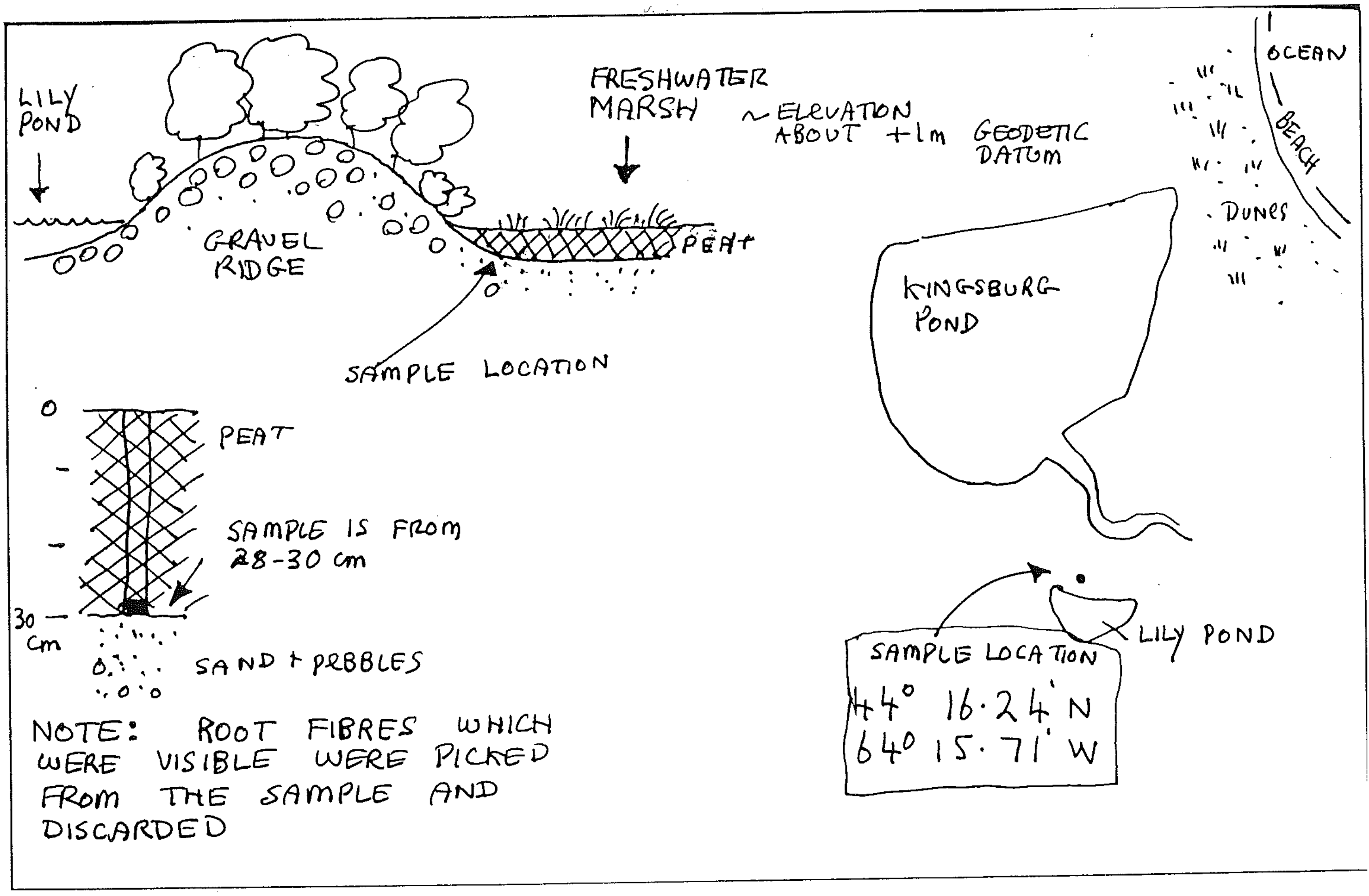
Latitude: 44° 16.24 N **Longtitude**: 64° 15.71 W

Type of Material: freshwater peat

Weight of Material: 87.3 g (wet)

Collection Treatment and Storage: Collected June 9,1994, using Eijkelkamp auger, amalgamated 10 samples collected at same depth, put in plastic bag and kept at 4°C until June 16,1994 when visible root fibres were removed and sample was shipped to Beta Analytic Inc. for dating.

Stratigraphic and Environmental Details:



NOTE: ROOT FIBRES WHICH WERE VISIBLE WERE PICKED FROM THE SAMPLE AND DISCARDED

APPENDIX E

CRUISE 94-304

FIELD OPERATIONS

GENERAL INFORMATION

Cruise:	94304 -Coring Program Kingsburg Pond and adjacent coastal lowlands.
Dates:	June 6 to 10, 1994 October 19, 1994
Area of Operations	Kingsburg, Lunenburg County, Nova Scotia.
Agency:	Geological Survey of Canada (GSC), Atlantic Geoscience Centre (AGC)
Funding:	Nova Scotia Department of Natural Resources (Parks and Recreation Division, Mr. C. Trider, contact) and Natural Resources Canada, Geological Survey of Canada.
Senior Scientist:	R.B. Taylor AGC
Field Staff:	J. Shaw AGC D. Frobel AGC F. Jodrey AGC
Vessel:	One 14 foot aluminum and one 14 foot fibreglass boat

SCIENTIFIC OBJECTIVES

To develop a chronology of the physical evolution of Kingsburg Beach over the past few thousand years and to evaluate its pattern of development relative to other coastal systems in Nova Scotia (Taylor and Shaw, 1994).

BACKGROUND INFORMATION

Kingburg Beach was given protected beach status in April of 1993 under the Nova Scotia Beaches Protection Act. Information collected during this study will provide information to the Minister of Natural Resources, Nova Scotia who is responsible for the management of lands designated under the Beaches Protection Act. Kingsburg Beach is subdivided into many small narrow lots extending perpendicular to shore. Ownership of some parts of the coastal lowland and rights to use the access road along the back of the beach are hotly debated. There are also very emotional debates between permanent residents and seasonal residents of how the coastal area should be managed. Some private land owners of the beach want to develop housing units in the primary dune and have taken the province to court because of their restrictions to develop the beach.

SUMMARY OF FIELD OPERATIONS

(all times are Atlantic Daylight Time unless otherwise stated)

Initial plans were to core the bottom sediment in Kingsburg Pond from the ice surface in February 1994 but conflicting information about the depths of the pond (residents reported the depths could be anywhere from 10-40 feet deep) required a more detailed sounding survey of the pond before core sites could be selected. It was also hoped that an echosounding survey would provide better definition of the submerged portion of the backbarrier beach ridges adjacent to the pond. Cores from the pond sediment would provide a stratigraphic sequence and possible dateable material that could be used in determining when the pond was linked to or shut off from the sea. To determine the relative age and near surface stratigraphy of the beach ridges that lie between Kingsburg Pond and Lily Pond, an Eijkelkamp auger was to be used for exploratory work. More detailed coring and/or trenching would be completed if required.

Monday 6 June, 1994 (Day 157). Departed Dartmouth at 10:30 and arrived at Kingsburg, Nova Scotia at 11:40 ADT. Seven sounding lines were surveyed across Kingsburg Pond between 13:50 and 15:05. The survey was completed using an aluminum boat and motor rented from Mr. Steven Mosher. The boat was outfitted with a Raytheon DE-719B sounder with a 200 kHz transducer and a pole mounted prism which was part of the Geodimeter 140 H electronic total station surveying instrument used to track the path of the boat. The Geodimeter was located at the picnic park on the north side of the pond adjacent to the main highway. Exploratory sampling of the pond sediment was completed using an Eijkelkamp auger and acoring site was selected, surveyed and marked with a surface buoy. The crew departed Kingsburg at 17:15 and arrived at the Bedford Institute of Oceanography (BIO) at 18:45.

Weather: fog lifted by early afternoon; sunny day with brisk winds out of the southwest.

Wednesday 8 June, 1994 (Day 159). Departed Dartmouth at 09:30 and arrive at Kingsburg at 11:00 ADT. The aluminum boat was used to transport the crew and tow a fibreglass boat to the coring sites. The boats were anchored at 4 points and lashed together to provide a better platform for coring. The second boat also provided additional space for examining and sampling the cores. The first core (94304-001was taken at the site marked by the surface buoy on June 6). The water depth was 2.64 m. The first core was collected using a modified Livingstone corer with 7.7 cm

(3") diameter aluminum core tube, cutter and catcher. Mud on the outside of the tube suggested 1.36 m of total penetration but when the core barrel was transported to shore and examined, it only contained about 40 cm of sediment. Three samples were retained. A second core was collected at core site 1 using an Eijkelkamp auger. Sediment was collected at 1 m increments and each section was sampled in 10 cm increments and where the stratigraphy was distinctive, e.g. shell sample at 223 cm. The total penetration of core 94304-002 was 316 cm but the upper 40 cm of soupy organic-rich mud (gyttja) was lost.

Following the successful coring at site 1, the boats were moved over onto on the submerged platform at the southwest end of the pond where water depths of 1.6 m were recorded. Core 94304-003 was collected with the Eijkelkamp auger. The first attempt failed. On the second attempt the auger penetrated to 130 cm but the upper 30 cm and lower 20 cm were lost. The sounder did not show a second bottom reflector but the core contained 55 cm of soupy dark brown gyttja over well sorted medium sand. Fine shell fragments extended to 130 cm depth and a wood chip was sampled at 110 cm. The core was logged but only two samples were retained, one was the wood chip, and the other was from the mud/sand interface at 70-80 cm depth in the core. At 16:00 the boats were moved eastward and northward off the platform to a water depth of 2.4 m. A second bottom reflector occurred at a depth of 2.9 m. The Eijkelkamp auger penetrated 200 cm of sediment but the only sample retained from core 94304-004 was from 50-55 cm where the sharp contact between gyttja and sand was observed. Core sites were positioned by a portable GPS receiver and surface water buoys were left at the core sites for later positioning with the geodimeter. The crew departed Kingsburg at 17:00 and arrived back at BIO at 18:30.

Weather: patchy fog, light to moderate breeze from the southwest, broken cloud. During the day the winds switched from calm to brisk northwest winds and then blew from the east.

Thursday 9 June, 1994 (Day 160). Departed BIO and Dartmouth at 09:00 and arrived at Kingsburg Beach at 10:30. The Geodimeter was re-established at the picnic park to position the core sites while the two boats were taken back out on the pond to sample a site roughly 30 m northeast of core 94304-004. The water depth was 2.65 m (2.74 m by lead line-deeper because of inability to detect surface of soupy mud) and a second bottom reflector occurred at 3.4 m depth. Core 94304-005 was collected with the Eijkelkamp auger. Total penetration was 300 cm but the upper 14 cm was lost. A well defined sand layer with a few granules existed at 102 to 106 cm. It separated the soupy gyttja above from the organic rich mud and disseminated medium to fine sand below. Our surveyor was asked to leave the picnic area by a local resident, so the surface buoys at all core sites were surveyed in from shore before the instrument was dismantled.

Another core 94304-006 was collected at the same site as 94304-005 with a push corer. The 196 cm long aluminum tube was slowly pushed into the sediment until it reached full capacity. However the total length of core recovered was only 120 cm (due to compaction). The upper few centimetres of core was water and soupy gyttja, which was drained away. Some additional sounding was completed along the north side of the pond and across the pond near the pump house (line 8). The boats were cleaned and stored onshore at the pump house. The instrument site at the picnic park, the pond water level, and the pump house were surveyed and all tied into sea level (14:10) at Kingsburg beach. Frobel and Jodrey left Kingsburg at 15:15 and returned to Dartmouth.

Shaw and Taylor began sampling the backbarrier wetlands and beach ridges located between Lily and Kingsburg Ponds. A transect was run across the most prominent beach ridges. The shallow stratigraphy was documented using an Eijkelkamp auger. The elevation of the ridges could not be surveyed but the ridge crests are estimated to be 0.5 m above the surface of Kingsburg Pond. The highest ridge is along the east flank of Lily Pond where sample 94304-007, a peat deposit ,was collected from the eastern base of the ridge by repeated augering. Sample 94304-008 was a small piece of wood collected from the base of the peat.

Sampling and reconnaissance surveys were terminated abruptly because of interference by two individuals who accused us of trespassing and demanded that we leave. To avoid further conflict we packed up. We briefly examined Kingsburg beach and checked on the AGC benchmarks at Hirtles beach before returning to Dartmouth at 21:00 hours.

Weather: clear and sunny, with a brisk northwest breeze which increased in strength throughout the day.

Wednesday 19 October, 1994 (Day 292). During beach and cliff surveys in Hartling Bay, which is located just southwest of Kings Bay, the instrument site (at the Kingsburg picnic park) and bench marks used on Kingsburg Beach during the June surveys were tied into the Hirtles beach and cliff surveys. Also, ground observations were made along the southwest shores of Kingsburg Pond, the area south of Lily Pond and the barrier beach fronting Dry Spitz Pond to map the occurrence of bedrock and relict beach ridges.

Weather: clear and sunny

TECHNICAL SUMMARY

Navigation

A Geodimeter 140H infrared electronic total station surveying instrument was used for tracking the boat during the sounding survey and coring operations. Global positioning of the instrument site and core sites was provided by a Magellan GPS NAV 5000 Pro portable receiver. Vertical control for the surveys was difficult because of the absence of Geodetic or Land Registry benchmarks. The elevation of the instrument site and water level of the pond were tied into mean sea level and two property survey markers (L.A. Berrigan, Bridgewater, N.S.) on Kingsburg Beach.

Bathymetry

Soundings were obtained using a Raytheon DE 719B sounder with a 200 kHz transducer clamped to the transom (stern) of the boat. The soundings were recorded on paper using a graphic recorder and the depths were corrected for transducer depth. Vertical air photos were used to plan the survey lines and man-made structures were used for directional guidance. A mast mounted reflector prism was used to link the boat position with the Geodimeter. Survey lines 1 to 7 were surveyed using the Geodimeter. Sounding positions collected along line 8 were scaled off the echo gram using the distance measured on air photos between known points at the ends of the survey line. Sounding lines began and ended at 5 to 15 m from shore. Water depths were manually picked off the sounding record at intervals of roughly 10 m distance and entered into a computer file for plotting.

Coring

Eijkelkamp Auger: The auger consists of a one metre stainless steel semi-enclosed core barrel which is manually pushed into the sediment to the required depth and then turned to retain the sediment. One metre rods are attached to the corer to extend the depth of coring. The auger is lowered to the pond bottom, pushed in a metre, turned and then brought back to the water surface and boat, where the sediment is sampled at 10 cm intervals and bagged. The auger is cleaned and then pushed back into the pond sediment but this time it is not turned until the core barrel has penetrated an additional metre into the pond sediment, so that sediment from 1 to 2 m depth is sampled. The auger is brought back to the surface for examination and subsampling. The process continues for as long as the corer can be pushed into the sediment, or you run out of extension rods. The maximum penetration at Kingsburg Pond was 3.1 m. The same auger was also used to obtain cores of the peat deposits and surfical sediment on the beach ridge complex adjacent to Kingsburg Pond.

Wide Diameter corer: The coring device was essentially a push corer. The corer consisted of 7.7 cm (3 inch) diameter aluminum tube with an adaptor at one end to attach smaller diameter barrel for holding onto when pushing the corer into the sediment. The adaptor contained several holes to allow water to escape as the core penetrated the sediment. A catcher and cutter were attached to the other end of the tubing. Maximum core recovery in Kingsburg Pond was only 1.2 m.

Latitude and Longitude, Easting's and Northing's for survey instrument and pond core sites using a Magellan GPS NAV 5000 Pro portable receiver.

SITE	POINT	LAT	LONG	ZONE	EASTING	NORTHING	s	ALT	#PTS	DATUM	DATE	PDOP
KINGSBURG	INST AT PICNIC PARK	44°16.5661	064°15.9673	20	398959	4903103	3.6	0M	32	NAD27	9-Jun-94	1.2
NOVA SCOTIA	INST AT PICNIC PARK	44°16.5895	064°15.9841	20	398937	4903146	3.4	2M	32	NAD27	6-Jun-94	1.4
	PUMP HOUSE (CORNER NEAR RD	44°16.5962	064°15.6103	20	399435	4903151	4.3	2M	32	NAD27	6-Jun-94	1.5
	POND CORE 94304-001 &-002	44°16.5057	064°15.8610	20	399098	4902989	5.5	5M	32	NAD27	8-Jun-94	1.3
	POND CORE 94304-003	44°16.4383	064°15.8122	20	399162	4902863	6.1	5M	32	NAD27	8-Jun-94	1.3
	POND CORE 94304-004	44°16.4901	064°15.8226	20	399149	4902959	2.3	5M	32	NAD27	8-Jun-94	1.5
	POND CORE 94304-005 &-006	44°16.5029	064°15.8285	20	399142	4902983	3.2	2M	32	NAD27	9-Jun-94	1.4
	MARSH SAMPLE 94304-007 &-008	44°16.2445	064°15.7167	20	399283	4902502	8.1	2M	32	NAD27	9-Jun-94	1.4
	INST KINGSBURG BCH CREST	44°16.5854	064°15.4803	20	399607	4903128	4.6	0M	32	NAD27	9-Jun-94	1.5
	LEGAL SURV CAP IN MARSH	44°16.2602	064°15.7977	20	399175	4902533	31.1	25 M	32	NAD27	19-Oct-94	2.6
NOTE:	ALT NOT SET BEFORE LAST READING											

Navigation for the echosounding surveys in Kingsburg Pond, Nova Scotia.

Survey instument was located at the Kingsburg Picnic site.

INFO	FIX#	H ANG	V ANG	S DIST	H DIST	DIST BTWN	CUM DIST	EAST'G	NORTH'G
JUNE6.94 KNGSBURG POND									
KNGSPICNCPRK I.H.=1.63				NOTE:					
ECHOSOUNDING SURVEYS									
EAST'G INST=									
398959									
NORTH'G INST=									
4903103									
SURVEY LINE 1	100	243.0439	90.8361	444.018	443.971		0.000	399402.45	4903124.53
	101	246.7811	91.0072	375.981	375.923	73.078	73.078	399334.87	4903096.72
	102	253.6006	91.3033	289.376	289.301	95.090	168.168	399245.64	4903063.85
	103	274.7756	92.0722	182.254	182.135	136.382	304.550	399118.37	4903014.83
	105	326.4756	92.4200	157.806	157.665	149.786	454.336	398984.61	4902947.43
	106	327.6072	92.4200	158.306	158.165	3.159	457.494	398981.60	4902946.46
LINE 2	110	311.1283	91.8161	209.609	209.504	73.197	0.000	399046.53	4902912.66
	111	291.4767	91.7161	227.153	227.051	76.480	76.480	399117.71	4902940.63
	112	275.3961	91.4356	272.598	272.512	83.118	159.598	399196.01	4902968.51
	113	266.7389	91.2100	323.253	323.181	67.633	227.230	399260.89	4902987.63
	114	259.8856	90.9722	396.313	396.256	84.676	311.906	399343.38	4903006.72
	115	257.6978	90.8550	452.583	452.533	58.553	370.459	399401.85	4903009.89
LINE 3	120	257.2278	90.8639	437.555	437.505	15.464	0.000	399387.87	4903016.49
	121	262.5311	90.9633	397.475	397.419	55.637	55.637	399339.64	4902988.75
	122	268.8022	91.0244	370.583	370.524	49.856	105.493	399300.12	4902958.35
	123	283.2017	91.1094	343.210	343.146	93.476	198.970	399231.68	4902894.69
	124	290.5567	91.1044	340.265	340.202	43.929	242.898	399200.68	4902863.57
	125	302.8883	91.0989	351.139	351.074	75.030	317.929	399149.88	4902808.35
	126	311.9583	91.0361	375.907	375.846	62.556	380.485	399111.06	4902759.29
	127	320.0772	90.9433	421.728	421.671	72.642	453.127	399073.43	4902697.15
LINE 4	130	316.8506	90.8639	434.374	434.325	27.218	0.000	399100.21	4902692.27
	131	306.3511	90.9050	417.005	416.953	79.787	79.787	399164.15	4902740.01
	132	296.1739	90.9172	420.644	420.590	74.375	154.162	399227.38	4902779.16
	133	285.2872	90.8400	448.703	448.655	87.062	241.224	399305.38	4902817.84
	134	279.6339	90.7672	473.470	473.428	51.768	292.992	399352.37	4902839.57
LINE 5	140	280.2811	90.8517	464.209	464.158	10.676	0.000	399341.72	4902840.38
	141	278.3289	90.9356	413.902	413.847	52.480	52.480	399308.02	4902880.61
	142	275.4811	91.0789	357.100	357.037	59.936	112.416	399269.27	4902926.33
	143	272.3994	91.2817	302.530	302.454	57.372	169.788	399229.50	4902967.69
	144	268.9239	91.4967	250.107	250.022	55.021	224.810	399188.98	4903004.91
	145	263.2411	91.9117	199.610	199.499	55.162	279.972	399149.35	4903043.28
	146	257.0117	92.5450	150.027	149.879	53.059	333.030	399106.03	4903073.92
	147	249.8817	93.4644	111.136	110.933	42.118	375.149	399069.65	4903095.15
LINE 6	150	269.8683	94.4367	87.952	87.688	41.377	0.000	399039.08	4903067.27
	151	282.9994	92.6961	143.482	143.323	61.257	61.257	399073.20	4903016.40
	152	287.6183	92.0511	184.540	184.422	43.137	104.394	399096.49	4902980.09
	153	293.1328	91.6228	243.428	243.330	62.335	166.728	399123.99	4902924.15
	154	296.8339	91.3272	296.660	296.580	56.005	222.734	399145.60	4902872.48
	155	300.2811	91.1283	348.119	348.051	54.980	277.714	399161.33	4902819.80
	156	303.3933	90.9694	397.921	397.864	53.757	331.471	399172.37	4902767.19
	157	305.2111	90.8861	447.706	447.652	51.557	383.028	399186.96	4902717.74
	158	305.9922	90.8150	474.241	474.193	27.274	410.301	399194.89	4902691.64
LINE 7	160	292.3622	90.6911	555.253	555.213	146.264	0.000	399340.91	4902700.01
	161	292.7550	90.7883	499.678	499.631	55.699	55.699	399300.19	4902738.00
	162	292.8772	90.8478	449.038	448.989	50.652	106.351	399264.90	4902774.35
	163	292.5528	90.9878	394.976	394.917	54.124	160.475	399229.70	4902815.45
	164	292.0017	91.0800	343.721	343.660	51.380	211.855	399196.96	4902855.05
	165	290.2356	91.3944	271.536	271.456	72.816	284.670	399152.91	4902913.03
	166	288.1561	91.6933	216.935	216.840	55.321	339.991	399119.30	4902956.97
	167	284.9544	92.6122	147.564	147.411	70.145	410.135	399073.35	4903009.97
	168	283.0111	94.8117	80.301	80.018	67.493	477.629	399022.75	4903054.64
BUOY CORE SITE 1		283.3589	91.7106	224.743	224.643	144.627	144.627	399137.14	4902966.14

KINGSBURG INST TIE-IN JUNE6/94√

INFO	DESCRIPTION	PT NO	SIG HT	H ANG	V ANG	S DIST	H DIST	ELEV (GEOD)	DIST BTWN	CUM DIST	ELEV INST	G ANG	EAST'G	NORTH'G
KINGSBURG POND JUNE 6,1994											**7.578**			
PICNIC PARK I.H.=1.63											GEODETIC DATUM			
EAST'G INST=	**STOPSIGN**	1	1.60	65.1383	86.1594	37.340	37.256	**10.109**				269.3144	398921.75	4903102.55
398959	EDGE PAVEMENT ROAD	1	1.90	77.3450	85.8267	52.471	52.332	11.127	17.761			281.5211	398907.72	4903113.45
NORTH'G INST=	EDGE PAVEMENT ROAD	2	1.90	83.3033	86.1000	39.969	39.876	10.027	13.330			287.4794	398920.96	4903114.98
4903103	EDGE PAVEMENT ROAD	3	1.90	115.7150	86.7872	25.833	25.792	8.756	22.777			319.8911	398942.38	4903122.73
EAST'G PUMP HOUSE=	EDGE PAVEMENT ROAD	4	1.90	155.8950	88.9200	28.325	28.320	7.842	18.738			0.0711	398959.04	4903131.32
399435	EDGE PAVEMENT ROAD	5	1.90	161.4500	88.7972	23.809	23.804	7.808	5.170			5.6261	398961.33	4903126.69
NORTH'G PUMP HOUSE=	EDGE PAVEMENT ROAD	6	1.90	113.4472	85.8644	20.844	20.790	8.811	18.347			317.6233	398944.99	4903118.36
4903151	EDGE PAVEMENT ROAD	7	1.90	76.9078	85.3589	33.788	33.677	10.042	21.008			281.0839	398925.95	4903109.47
G ANG INST TO PMP HSE CRNR	EDGE PVMNT HIRTLES RD	8	1.90	61.4606	85.5350	40.672	40.549	10.474	12.078			265.6367	398918.57	4903099.92
84.2417	EDG PVMNT HIRTLES RD	9	1.90	41.5350	87.5367	52.066	52.018	9.546	19.598			245.7111	398911.59	4903081.60
	EDG PVMNT HIRTLES RD	10	1.90	44.7611	87.5733	55.882	55.832	9.674	4.874			248.9372	398906.90	4903082.93
	EDG PVMNT HIRTLES RD	11	1.90	60.8844	86.0700	48.283	48.169	10.617	16.440			265.0605	398911.01	4903098.85
	EDGE PAVEMENT CORNER	12	1.90	70.9506	85.4717	52.394	52.230	11.445	9.693			275.1267	398906.98	4903107.67
	EDGE PAVEMENT RD	13	1.90	70.4633	85.2944	65.292	65.072	12.664	12.851			274.6394	398894.14	4903108.26
	BARN SW CORNER	14	1.90	95.5367	86.0117	38.404	38.311	9.979	34.438			299.7128	398925.73	4903121.99
	BARN NW CORNER	15	1.90	91.1017	85.9039	46.955	46.835	10.662	9.132			295.2778	398916.65	4903123.00
	PUMPHOUSE CORNER	16	1.90	240.0656	90.6589	469.892	469.861	**1.904**	510.563			84.2417	399426.49	4903150.14
	WL POND (16:19 ADT)	17	1.90	240.4650	90.8161	464.081	464.034	**0.698**	6.675			84.6411	399421.01	4903146.34

Position of Instrument site at the picnic area relative to: the paved road leading to Rose Bay, the pumphouse in Kingsburg and the water level of Kingsburg Pond.

TIE-IN SURVEY OF SEA LEVEL JUNE 9 1994 (14:11 ADT) TO KINGSBURG POND LEVEL.

INFO	DESCRIPTION	PT NO	SIG HT	H ANG	V ANG	S DIST	H DIST	ELEV (GEOD)	DIST BTWN	CUM DIST	ELEV INST	G ANG	EAST'G	NORTH'G
KINGSBURG JUNE9.94														
BCH CREST I.H.=1.60	INST AT BCH CRST													
INST SWD OF CEMETERY	HIGH TIDE LEVEL, SAND, SEAWEE	20	2.14	339.5267	97.8100	14.784	14.647	1.409				93.4027	399621.62	4903127.13
EAST'G INST=	WL OCEAN (14:11ADT) SAND	21	2.14	338.9822	95.7450	36.739	36.554	**-0.260**	21.909	21.909	5.008	92.8582	399643.51	4903126.18
399607	BERRIGAN BM 409	22	2.14	256.3461	88.3050	19.204	19.196	3.986	39.049	60.958		10.2221	399610.41	4903146.89
NORTH'G INST=	BERRIGAN BM 409	23	2.14	254.6444	83.3950	5.660	5.622	4.069	13.577	74.535		8.5204	399607.83	4903133.56
4903128	PUMP HOUSE CORNER	24	2.14	158.0722	90.4489	175.824	175.819	2.040	176.550	251.085		271.9482	399431.28	4903133.98
G ANG INST TO PMPHSE CRN	WL KINGSBURG POND (14:22 ADT)	25	2.14	158.1378	90.7928	187.533	187.515	**0.823**	11.698	262.783		272.0138	399419.60	4903134.59
269.2925	INST SITE AT PICNIC PARK	26	2.14	153.9033	89.6306	645.241	645.228	7.578	458.434	721.217		267.7793	398962.26	4903103.00
EAST'G PUMPHOUSE CRNR=														
399435														
NORTH'G PUMPHOUS CRNR=														
4903151														
EAST'G PARK PIN=														
398959														
NORTH'G PARK PIN=														
4903103														
1411 ADT=1311AST														
TIDE FOR LUNENBURG 1311AST														
JUNE 9, 1994=														
0.79M														
PRES GEOD ZERO = 1.05 M														
ABOVE CHART DATUM														
MSL=1.28 M ABOVE CH DATUM														