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Killbear Provincial Park: The beach and dunes, their use and the implications for management (Ontario)

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KILLBEAR PROVINCIAL PARK: THE BEACH AND DUNES, THEIR USE AND THE IMPLICATIONS FOR MANAGEMENT

by

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THESIS

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Abstract

Beaches, and in particular sand dunes, are extremely fragile environments, easily altered by human activities. Intensive use of the beach/dune complex at Killbear Provincial Park near Parry Sound, Ontario may have led to the severe degradation of its dune system within Kilcoursie Bay. At present the dunes have been degraded back to an embryonic state, and as a result it is necessary to consider the development of management strategies before the system is completely destroyed.

In order to develop effective management strategies however, it is necessary to understand how the natural process of the system work and the specific effects human activities are having. Unfortunately no information is currently available on the coastal processes active within Kilcoursie Bay. It will therefore be necessary to conduct studies to determine these processes, and to observe human activities on the beach to establish patterns of movement through the dunes and areas of particularly intense use. Once this has been accomplished several management techniques, to repair and reduce the human impacts on the system, will be developed and presented to park managers.

Acknowledgements

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Chapter 1 - Introduction

1.1 Introduction

According to the United Nations, an estimated 66% of the world's population lives within a few kilometres of the coast, an area which constitutes only a small percentage of the Earth's total land surface (Pethick 1988). In addition to providing living space for the majority of the Earth's population, this area is also relied on for its valuable natural resources which support such activities as fisheries, agriculture, forestry, sand and mineral extraction and recreation (Ranwell et al. 1986, Brooks 1991). Unfortunately many coastal environments, and in particular beaches and sand dunes, are extremely fragile and easily altered by human activities (Hindson 1989, Carter 1988). This means, that even with only minor use, significant damage and drastic changes can result. With the recognition of the vulnerability of beach and dune systems to human activities, many of the more obviously destructive practices, such as sand and mineral extraction, have declined or ceased (Ranwell et al 1986). However, coastal environments still endure intense human pressures, and as world population increases, it is expected that the demands and pressures on the coastal region will also increase. Carter (1988) suggested recreational activities now pose the single greatest threat for damage. In fact, in many areas of the world the present level of recreational use has had extremely negative impacts on the environment and many beach and dune systems are now in advanced stages of degradation.

Bird (1996) suggested that the space currently available for coastal recreational use is declining, and that the quality of the remaining areas is deteriorating. As a result, he defined coastal recreational areas as a diminishing resource. The destruction and loss of these beach and dune systems can have serious physical and ecological repercussions, in addition to detrimental economic and cultural implications.

As a natural system, coastlines act as a method of coastal defence, protecting the shoreline by absorbing the energy of wind and wave attack, particularly those generated by storm events. Dunes may also serve as a source of fresh water for local residents and, particularly along marine coasts, prevent the intrusion of saltwater into the water table (Carter 1988, Ranwell et al. 1986). The loss of this natural physical system can therefore leave coastal communities vulnerable to flooding and salinization of water supplies. The destruction of the natural system can also lead to the deterioration in the quality of tourism or recreational opportunities along the coast, threatening the financial basis of economies dependant on coastal tourism.

Although rigid structures are still frequently used to solve problems associated with coastal degradation, more recently views have begun to shift toward developing 'soft' approaches to coastal management. These 'soft' solutions involve attempting to work with, or utilize, natural coastal processes in preventing or repairing damage to the system (Brooks 1991, Carter 1988, Ranwell et al. 1986). Part of this approach requires determining a reasonable balance between use of the beach and dune system and its protection, and creating adequate management strategies that ensure sustainable use of the coastal environment. Davidson (1990) suggested the need for the rehabilitation of previously damaged coastal environments, and the restoration of the natural ecosystem. However, in order to successively achieve such goals it is necessary to understand the nature of the coastal area in question, including both the natural and human altered processes active within the system. Davidson (1990) also emphasised that the key to achieving this goal, and the proper management of such environments, is knowledge. More specifically he noted that the inventories of coastal dune systems in Ontario were insufficient, and that more detailed information is required so scientists and managers have a better understanding of how the systems work and are capable of making more informed decisions on management issues.

1.2 Objective of the Study

This thesis presents research undertaken to determine the physical processes active within the coastal system of Killbear Provincial Park, Ontario, and the impact of human use on the beach and dune system within the park. Ultimately, the goal of this study is to provide management strategies to park managers in an attempt to prevent the destruction of the beach and dune system. For the purpose of achieving this goal, four more specific objectives have been outlined, which include: (1) determining and documenting the natural and human-altered beach and coastal processes active within Kilcoursie Bay, (2) determining the impacts of intensive human use on the beach, with particular emphasis on the dunes, (3) supplying park managers with the information collected, thereby providing them with a better understanding of the beach/dune environment within the Park, and finally (4) providing recommendations on possible management strategies for the beach/dune complex.

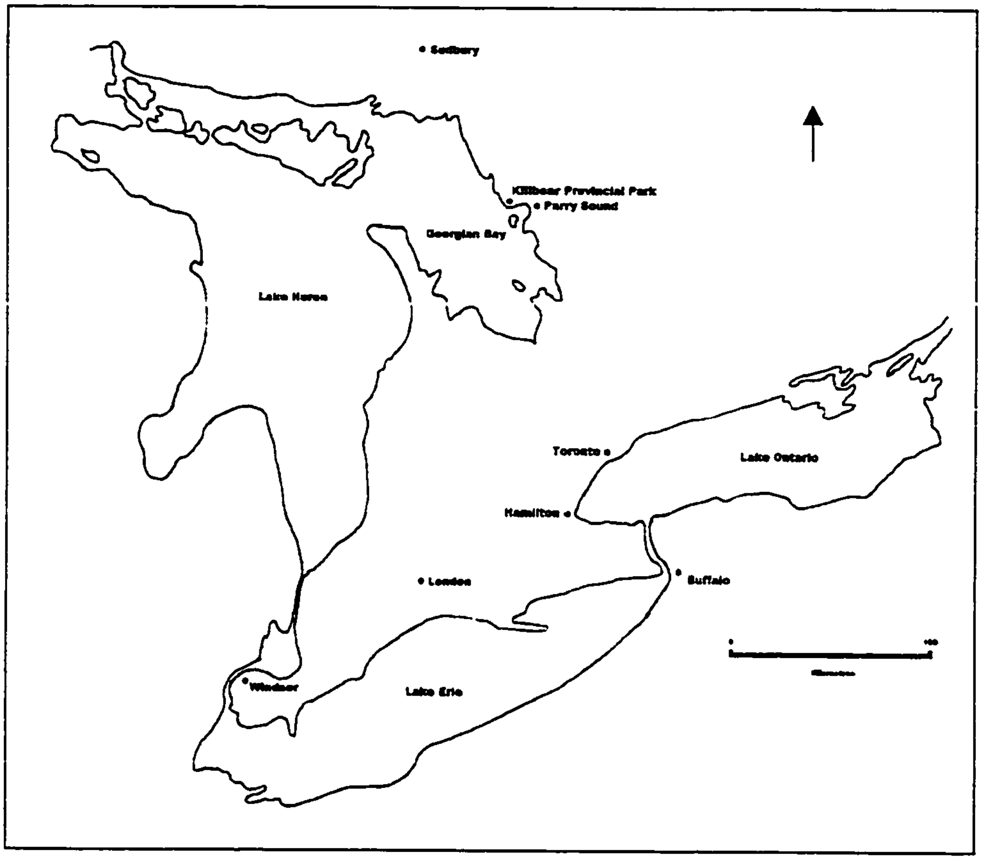
1.3 Location of Study Area

Killbear Provincial Park is a 1756-hectare Natural Environment Park located along the shores of Georgian Bay near the town of Parry Sound (Figure 1.1). The park is situated within the rugged and scenic Canadian Shield, and encompasses a variety of forest communities, bogs, marshes, swamps, rocky shorelines and sandy beaches. The Park provides users with over 850 campsites divided among 7 campgrounds, as well as 2 group campgrounds (Figure 1.2). In addition, it offers users a wide variety of recreational opportunities, including numerous water sport activities such as swimming, fishing and boating (MNR 1991).

As outlined in the MNR Ontario Provincial Parks Policy (1993), the goal of the provincial park system is to provide users with a variety of outdoor recreational opportunities, and to protect significant natural, cultural and recreational landscapes. Parks Ontario achieves this goal by utilizing a system of categories which arranges the parks into different classes, each with specific purposes and characteristics. The purpose of a Natural Environment Park, such as Killbear, is to combine exceptional landscapes with striking natural features and significant historic characteristics, while providing park users with recreational and educational opportunities.

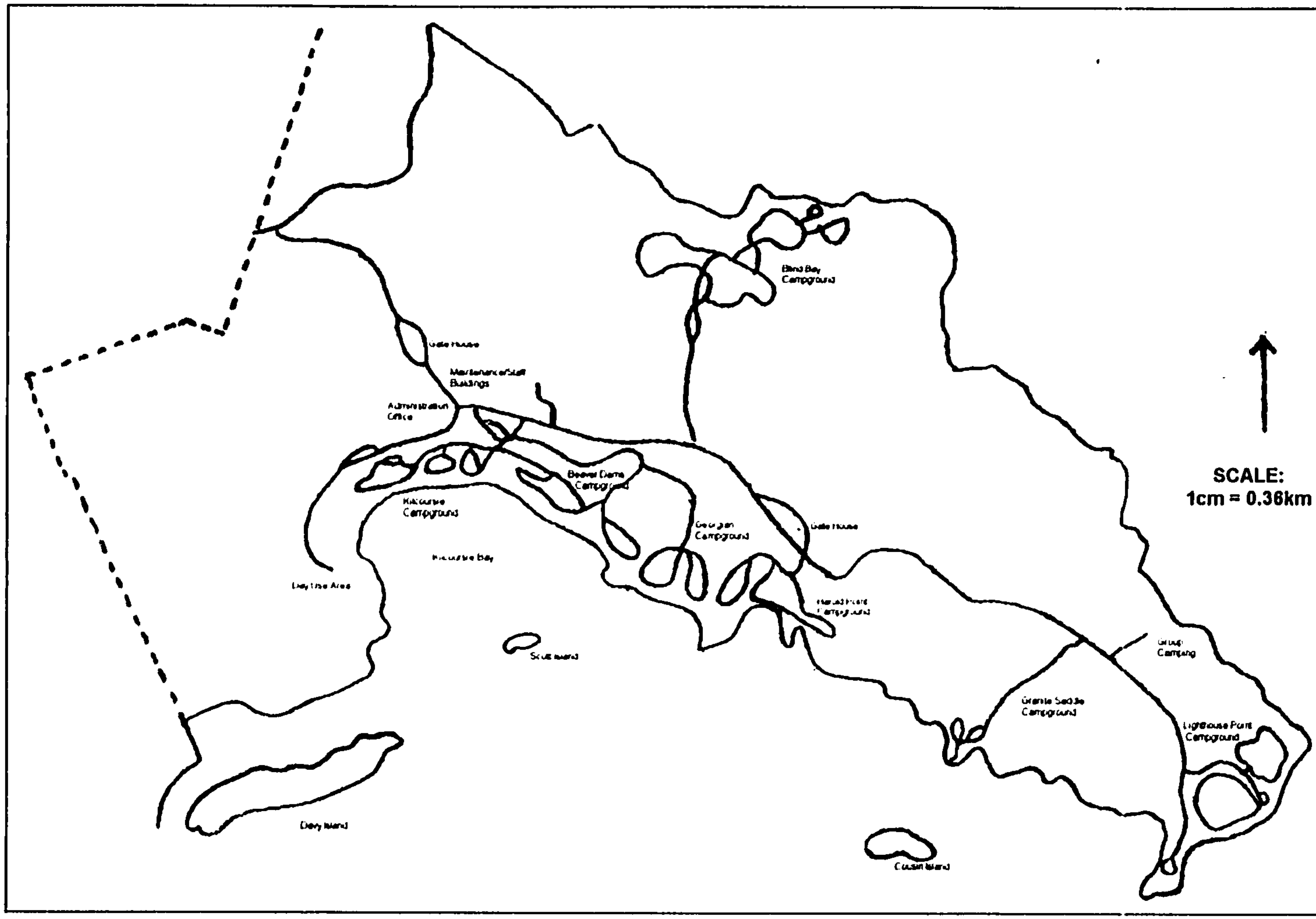
The picturesque setting , as well as its close proximity to the major urban areas of Southern Ontario, has resulted in the park's popularity as a summer camping retreat. According to Walsh (Personal Communication), the Park Superintendent, many campers have developed a strong loyalty to the Park and even

Figure 1.1: Location of Killbear Provincial Park



Source: Killbear Provincial Park Master Plan (1977)

Figure 1.2: Layout of Killbear Provincial Park



Source: Killbear Provincial Park Master Plan, 1978

to specific campsites and have been returning each summer for 10 years or more. Killbear is currently Ontario's third largest provincial campground, and as such is capable of accommodating well over 100,000 people during a summer season. In the 1970's, park managers at Killbear recognized that the present level of use within the Park threatened to cause severe damage to its environment resulting in a decreased recreational experience for its users. Therefore, in the Killbear Provincial Park Master Plan (1978), recommendations were made for the development of management strategies that took precautions against such threats, however in the case of the beaches, little was actually done.

Killbear has just over 3 km of sand beaches, the majority of which lie within Kilcoursie Bay, adjacent to Kilcoursie and Beaver Dams campgrounds. These campgrounds contain approximately 300 campsites, they are extremely popular with campers and are heavily used each season (Walsh, personal communication). Beach environments, and in particular sand dunes, are very fragile features which can easily be disturbed or damaged by human activities. Only limited information is available on the ancient dune systems within the park, and little is available on the current coastal processes affecting the beaches and the present day dune system. In fact, the existence of the dune system is only briefly acknowledged in any of the literature. The Master Plan (1978) developed to assist in the management of Killbear, recognized the presence of several sandy beaches within the park and suggested that these beaches are among the finest located along the eastern shoreline of Georgian Bay. The Plan also recognized the importance of the beaches as a resource for the park and recommended that they be maintained and managed to ensure their preservation. Unfortunately, the intensive use of the campgrounds and the beach/dune complex appears to have resulted in severe degradation to the system. At present, the dunes have degraded back to an embryonic state, however one can visualize that the dunes along Kilcoursie Bay should form a relatively continuous ridge.

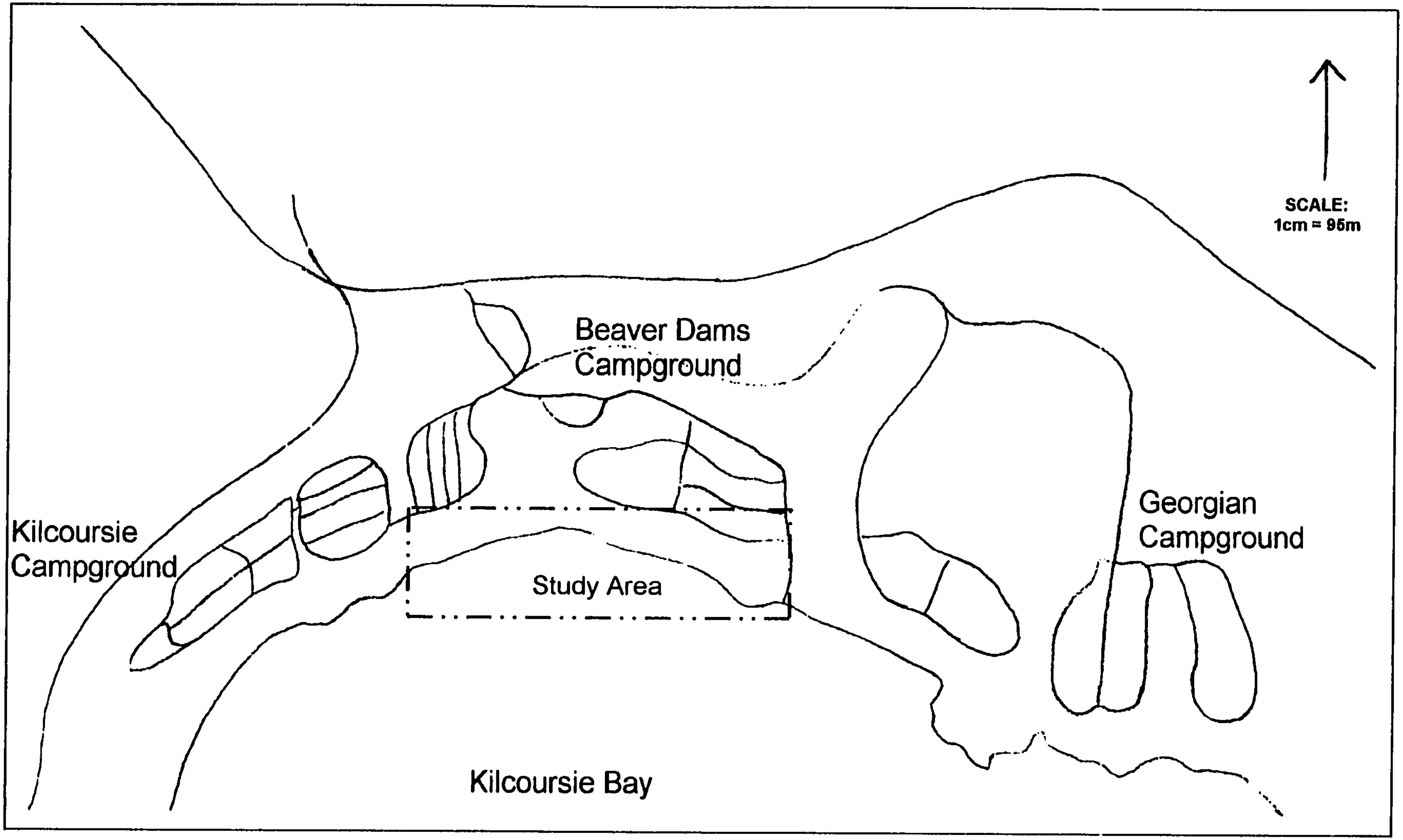
1.4 Methods

The most significant physical processes responsible for the development and maintenance of the beach and dune systems at Killbear Provincial Park involve wind, waves and currents. These processes in turn drive sediment transport and determine the extent of beach accumulations and the level of dune development. Part of the proposed research for this project was to quantify these processes. Coastal processes and beach development can be altered by human use. Determining and documenting the influence of human use on the beach and dune environment at Killbear make up the remainder of the proposed research for this project. In order to complete these tasks, several field studies were conducted. In addition, a number of data sources were utilized including historical maps, photographs, personal communications with park users, and meteorological data.

Killbear has just over 3 km of sandy beaches, the majority of which are located within Kilcoursie Bay (MNR 1991). The largest aerial extent of beach, and the only substantial present day dune development, occurs adjacent to Kilcoursie and Beaver Dams campgrounds, the field study site was therefore established between the 'staff beach' at Kilcoursie campground and the Beaver Dams boat launch (Figure 1.3).

Field research was conducted between May 1996 and May 1997 in an attempt to document and measure the coastal processes and human impacts. A full year field program was designed to avoid seasonal patterns or variations in processes, as well as to view the beach and dune system prior to, during and after the heavy summer season. Field research was not conducted over the winter due to heavy snow accumulations and lake freeze up which reduced active processes to a minimum, as well as restricted access to the research site. Unfortunately due to the limits in funding and personnel, as well as the high visitor traffic within the study site, few permanent measuring techniques could be established and the majority of measurements and studies were conducted on a periodic and often random basis.

Figure 1.3: Location of Study Area



Source: Killbear Provincial Park Master Plan, 1978

Survey lines were established within the study site to determine beach profiles and to monitor changes in profile and to provide information on sediment transport. Sediment samples were also collected from the study site to determine size and composition of beach material. Due to the request of park managers to avoid establishing potentially obtrusive structures on the beach, profiling and sediment sampling were the primary methods of measuring aeolian sediment transport during the busy camping season. However after the park closed, several groups of sand traps were established at each beach site. Field measurements of wave and current action were completed using simple observation and tracer techniques. Wave development within the study area was relatively negligible during the summer so only wave type and swash width were recorded. Nearshore currents were measure using tracer techniques and patterns of geomorphic features along the shore. Human use of the beach and it impacts were documented in a series of photographs taken throughout the field season. In addition, three 'human' exclosures were erected within the study area. These exclosures were erected to eliminate the effects of human activity within the area so the extent of human induced damage could be observed and dune regeneration potential studied. An inventory of the beach and dune vegetation was also conducted during the season. In addition, information on park use and changes to the beach and dune system over the Park's history were recorded from interviews with long term park users and employees.

After the field season analysis of the data began. Additional data were also obtained from several outside sources to assist in the quantification and interpretation process. These data sources included wind data from Environment Canada, bathymetric data from Georgian Bay Small Craft Route Charts and historical documents and photographs from the Killbear Interpretative Office and Ontario Provincial Archives.

1.5 Summary

The following chapter will present a review of pertinent literature. Specifically, the literature will discuss information on coastal processes, human use of beaches and dunes, and techniques for the effective management of these systems. Chapter 3 will provide a more detailed description of the studies conducted for this research project. The results compiled for these studies will also be presented in this chapter. An interpretation of the results will be presented in Chapter 4. This chapter will also discuss the results of these studies in the development and maintenance of the beach and dune system within Kilcoursie Bay. Finally, Chapter 5 will summarize the information presented in this report, provide information on the state of the beach and dune system at Killbear, and make recommendations on potential management strategies.

Chapter 2 - Literature Review

2.1 Introduction

Part of the mandate of a Natural Environment Park, such as Killbear Provincial Park, is to provide users with excellent recreational and educational opportunities within an exceptional natural landscape (MNR 1993). In the 1970s, park managers at Killbear recognized that if recreational use within the Park was allowed to continue at such intense levels, it threatened to cause significant damage to the environment, and result in a deterioration of the experience for park users. Therefore, in 1978 a Master Plan was published by park managers, which recommended the development of management strategies to create a more sustainable balance between recreational use and the preservation of the natural environment (MNR 1978).

Although park managers at Killbear have since made efforts to understand and preserve different aspects of their natural environment, little has been accomplished in terms of the beach and dune system. The need to improve the management of coastal resources along Ontario's Great Lakes and to develop a balance between their recreational use and protection was stressed to park managers by Davidson (1990). However, Hindson (1989) suggested that before effective management plans could be developed it was necessary to understand how the system works.

Although no specific information is available on the current coastal processes active within Killbear's beach and dune system, the literature explaining coastal processes and the development of beach and dune environments is quite extensive. The literature ranges from a summary of basic concepts and processes, such as King (1972), Komar (1976) and Pethick (1984), to complex detailed explanations of specific processes such as Bagnold (1941), Thorton (1970) and Pye (1994). As well, there is an abundance of literature discussing the impacts of human activity within such systems and methods or techniques of coastal management including Ranwell et al. (1986), Carter (1988) and Brooks (1991).

This chapter will focus on providing readers with a basic background on coastal processes, beach and dune development and the concepts behind coastal management. The following provides a definition of a beach, then outlines the factors involved in beach development. Beach morphology and classification are then discussed, as well as dune development. Finally the chapter concludes with an explanation of the potential impacts of human use in the beach and dune environment, and suggests methods for reducing such impacts and creating successful management plans.

2.2 Defining the Beach

Probably the most commonly recognized coastal landform is the beach. However there are many different types of beaches, other than the wide white sand beach many people envision. Beaches may be composed of various different materials and formed under a variety of different conditions. Pethick (1984) suggested that the precise morphological definition of a beach is often difficult. At the most basic level, a beach is defined as an accumulation of unconsolidated sediment along a shore (Bird 1996, Davis 1985, King 1972). Although sand is the most common type of sediment accumulation, beaches may also consist of gravel and cobble, or less frequently silt and clay (Bird 1996, Pethick 1984, King 1972). Complications begin to arise as attempts are made to develop more precise definitions. Defining the landward and seaward limits of a beach are one of the major complicating factors. Komar (1976), Hardisty (1990) and Bird (1996) all delimit the boundaries of a beach differently. From a purely process, or geomorphological context, these definitions may prove satisfactory, however from a management perspective it is important to look at the system as a whole. In fact, Carter (1988) believed it was not responsible to define absolute boundaries of a beach at all because each area is unique and boundaries may be defined on the basis of several different factors including physical, biological and cultural criteria, many of which do not coincide. However, for the purpose of this study it is necessary to delimit some sort of boundaries and therefore I have chosen to utilize boundaries as defined by Bird (1996). Instead of simply using a single term (ie: beach) to delimit the landward and seaward boundaries, Bird (1996) divides the coastal region into three smaller, yet interacting zones: the nearshore, the foreshore and the backshore. According to Bird (1996), the nearshore is the zone extending shoreward to the water line, the foreshore as the zone between tidal extremes and the backshore as the zone landward of the highest tide line, which, where conditions permit, may include the dune system. However, when dealing with beach systems along the Great Lakes, where tidal influence is negligible, water level changes associated with swash and backwash are used for delimiting appropriate boundaries. For example, in the absence of tides, Komar (1976) defined the foreshore as the zone between the upper limit of swash and the lower limit of backwash.

2.3 Beach Development

2.3.1 Introduction

The sediment supply, in addition to the wind and wave regime, help to determine the development of beaches and influence their physical characteristics. The sediment supply determines the amount of material along a shoreline available for deposition and accumulation and therefore determines the extent and level of beach development. The wind and wave regime are primarily responsible for sediment transport and the shaping or altering of beach systems through a variety of erosional and depositional processes. On marine coasts, tides also play a significant role in beach morphology, as they can expose a wide portion of the sediment bed to numerous different processes as water level rises and falls. In lake environments, the effects of tidal action are generally negligible and fluctuations in water level often play a similar role as tides. However, it should be noted that the effects of water level fluctuations occur on different time scales than those produced by tides. (Carter 1988, King 1972, Komar 1976, Pethick 1984)

2.3.2 Sediment Supply

The amount of sediment supplied to a beach determines the extent of accumulation and the level of dune development. The sediment can come from a variety of sources including fluvial outwash, erosion of other coastal landforms along the shore, or from the shoreward movement of sediment which is stored offshore

(Carter 1988, Komar 1976, King 1972). As mentioned previously, most beaches are accumulations of sand, however they may also be composed of gravel and cobble, or less commonly silt and clay (Bird 1996, Pethick 1984, King 1972). It also should be noted that some beaches no longer receive a fresh, or new, sediment supply because the source which once supplied them no longer exists (Bird 1996). These beaches are termed relict beaches, and they are maintained by a continual reworking of the *in situ* material (Bird 1996).

2.3.3 Waves

Waves are a significant factor in the generation of subaqueous processes. Waves produce a variety of conditions in the nearshore and control current development, in turn influencing the morphology of coastal landforms. For this research project, wave activity occurring landward of wave base is of primary interest. It is in this zone where the majority of subaqueous water movement and sediment transport occurs. However in order to understand these processes a basic knowledge of waves must be obtained.

The wind regime is the primary force behind the generation of waves and currents. As the wind blows across a body of water it creates a stress on the surface and as a result transfers energy to the water mass. This stress and transfer of energy creates a distortion on the water surface which is visible as undulations or waves (Brown et al. 1990, Carter 1988, Pye 1994). These waves consist of water particles which are moving in a circular orbit. The velocity of the water particles and the radius of its orbit depend on the amount of energy within the wave. The influence of wave energy on the water particles is most significant near the water surface and diminishes rapidly with depth until the particle motion becomes very slight. The point where the water particles are no longer influenced by the energy from the wave is called wave base (Bird 1996, Pethick 1984).

The amount of energy within the wave, and hence the amount of wave development, depends primarily on the speed of the wind blowing over the water surface at the time of formation, the length of time the surface is exposed to the wind and the fetch, or the distance of the surface over which the wind blows (Viles et al 1994, Pethick 1984 and Komar 1983). For example, the stronger the wind, the greater the duration of exposure to the wind and the larger the fetch, the more energy that can be transformed to the surface of the water. However these factors can vary considerably resulting in the development of a wide variety of different wave forms. Although wave forms may differ significantly, all waves have the same basic characteristics. These characteristics include wave height (H), or the difference in height between the crest and trough of the wave, wave length (L), or the distance between successive crests, wave period (T), or the time required for successive crests to pass a given point and wave speed (C), or how fast the wave is moving across the surface (Carter 1988, Pethick 1984, Komar 1983).

Although the characteristics of waves may vary, wave forms are primarily divided into two distinct types: sea waves and swell waves. Sea waves are those that are generated within the storm area and are still receiving energy from the wind (Carter 1988, Komar 1983). According to Komar (1983), these waves are complex and have a broad range of heights and periods. As these waves move away from the area of generation, they no longer receive energy from the storm wind, and they begin to disperse. This dispersion causes a sorting of the wave forms into groups with similar wave periods, and results in the transformation of the complex spectrum of sea waves into a more regular and uniform wave pattern. Waves consisting of this more regular pattern are called swell waves (Carter 1988, Komar 1983).

Waves generated by distant storm events are typically responsible for much of the energy reaching the shore, however waves can also be generated near the shore by local winds. These locally generated waves generally are not affected by dispersion and therefore tend to reach the shore in approximately the same form and pattern as they were formed. This pattern tends to be less regular than that of swell waves, with wave forms of shorter height and period. The irregular wave pattern caused by the local waves will exist simultaneously, and often interfere with, the regular swell waves. Depending on the direction and strength of the local winds, the interactions between the different wave patterns may serve to accentuate or diminish the overall wave heights at the shore. (Bird 1996, Army Corps of Engineers 1973)

Swell waves continue to propagate landward with little change in wave form and power until they begin to enter shallow water. As the wave enter shallow water, they undergo numerous changes, however it is not until the point where wave base interacts with the bottom that significant changes occur. Wave base is generally considered to first contact the bottom at depth/wavelength=0.25 but significant interactions do not occur until much later, at approximately depth/wavelength=0.50 (Carter 1988, Davis 1985, Komar 1976, King 1972). The interaction of wave base with the bottom creates a frictional force, as the orbital movements of the water particles near the bottom drag across the sediment surface. As waves enter shallowing water, this drag or frictional force results in a decrease in the speed of the wave. The decrease in wave speed is accompanied by a decrease in wavelength and an increase in wave height. The increase in wave height and the corresponding decrease in wave length results in a subsequent steepening of the wave form. As the wave steepens, the water particle orbitals become more elliptical in shape and cause the velocity of the wave crest to increase, while the overall wave form slows. As the water progressively shallows, these processes continue until eventually the velocity of the wave crest exceeds that of the rest of the wave, and wave steepness becomes such that the wave is over steepened and unstable. At this stage the wave form is compromised and collapses, forming a breaking wave (Bird 1996, Viles et al. 1995, Davis 1985, Pethick 1984).

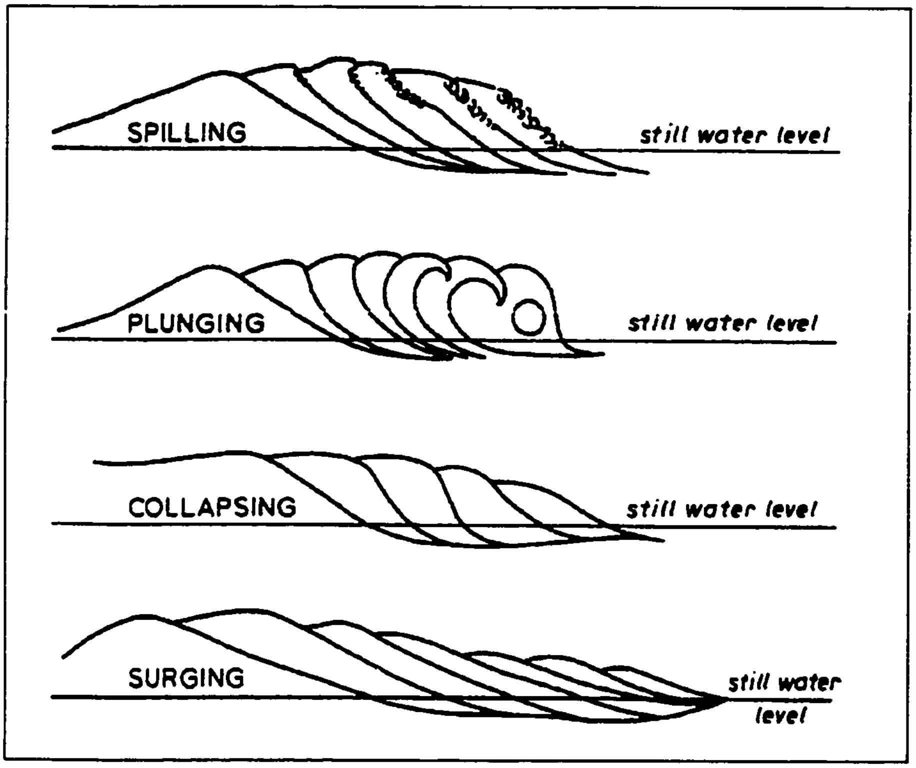
As waves enter shallowing water they may also be affected by a process known as wave refraction. This process causes wave crests to bend or alter their original direction of wave approach. The amount of wave refraction depends on the initial direction of wave approach, and the change in wave speed upon entering shallow water. Generally, the difference between the angle of wave approach and the depth contour progressively decreases as waves move shoreward (Viles et al. 1995, Pethick 1984, Komar 1976). For example, along a shoreline with parallel depth contours waves approaching the shore obliquely will undergo refraction as the more shoreward portion of the wave enters the shallow water before the portion farther offshore. In this situation, the speed of the more shoreward portion of the wave slows because of the drag, or friction, associated with the interaction of wave base and the bottom sediment, while the more offshore portion of the wave maintains the original speed. These lateral differences in wave speed subsequently result in a bending of the wave crest (Komar 1983).

Wave refraction may also produce a variation in wave height and the distribution of wave energy along the shore (Viles et al. 1995, Komar 1976). Where wave refraction causes a divergence, or spreading out, of the wave crests, there will be both a decrease in wave height and wave energy reaching the shore. This is because the amount of wave energy remains constant and as it is redistributed over a now longer wave crest a resulting decrease in height occurs. The opposite is true for areas where wave refraction results in convergence. (Komar 1976)

The point where waves break is greatly influenced by wave height, however the nearshore beach slope also plays a significant role. Due to the interference of local winds in the patterns of swell waves, and the redistribution of wave energy along the shore resulting from wave refraction, there may be a broad spectrum of wave heights reaching the shoreline. As well, not all depth contours are parallel to the shore, and in many situations submarine topography is quite irregular. The irregular offshore topography further complicates the process of wave refraction and creates numerous variations in nearshore slope along the shore. Therefore, not all waves will break at the same point. (Viles et al. 1996, Pethick 1984, Komar 1976). Galvin (1968, 1972) used the variables associated with wave height and beach slope to calculate a value he termed the breaker coefficient, which would determine the point where waves begin to break.

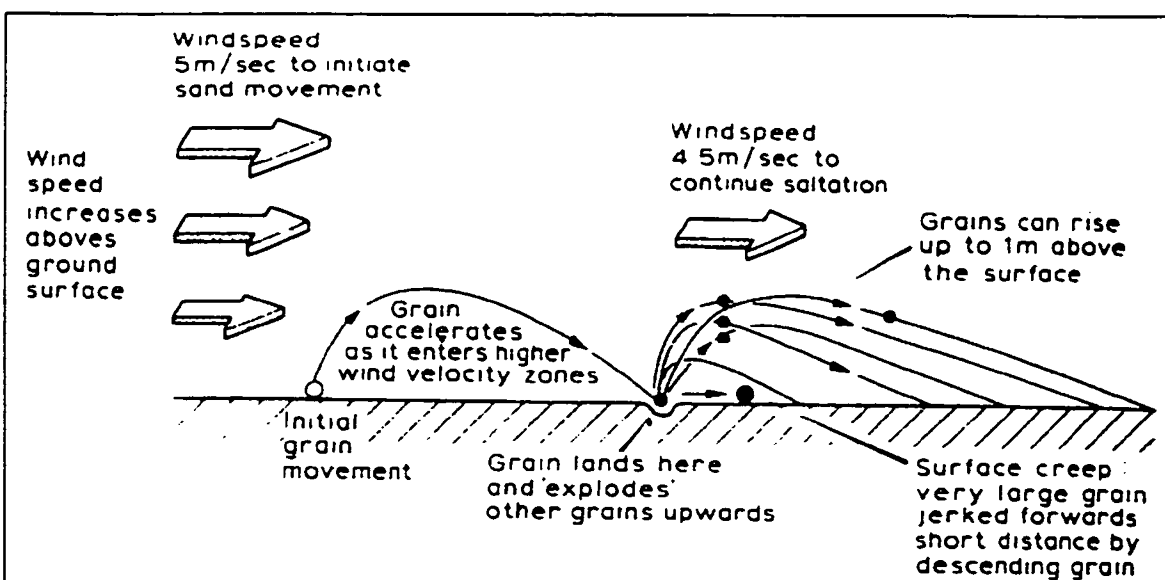
Galvin's breaker coefficient was not only used to determine the breaking point of a wave but it also proved useful in determining the type of breaker (Viles et al. 1996, Pethick 1984). Based on this breaker coefficient Galvin (1968) identified four basic breaker types: surging, collapsing, plunging and spilling (Figure 2.1). What follows is a general description of the characteristics for each breaker classification as defined by Galvin (1968) and summarized by authors such as Fredsoe et al. (1994), Hardisty (1990), Carter (1988),

Figure 2.1: The Four Basic Breaker Types



Source: Pethick (1984)

Figure 2.2: Diagram of Sediment Transport Theory



Source: Pethick (1984)

Pethick (1984), and Komar (1976). Surging breakers are typically formed from low flat waves and most commonly occur on beaches with a steep gradient. As a result the break-point for these waves is relatively close to shore. During the breaking process, the wave crest remains moderately stable while the base rather calmly rushes up the beach face with little white water or foam being produced. Conversely, spilling breakers are generally the result of larger and steeper waves, and are primarily associated with more gently sloping beach profiles. These waves therefore begin to break some distance from shore, curling slightly near the crest and producing a thin line of white water. This white water slowly flows or spills down the front of the wave gradually increasing in size as the wave nears the shore. Between these two extremes are the collapsing and plunging breakers which develop from wave conditions and beach slopes intermediate to those fro surging and spilling breakers. In a collapsing breaker the front of the wave steepens as it moves shoreward until it is nearly vertical. At this point, the wave form becomes unstable and the lower portion of the wave front bulges and begins to break. As a result the wave crest slowly subsides while the lower portion of the wave front continues to advance up the beach face in front of it. In a plunging breaker the crest curls out over the front of the wave and falls, as a complete mass of water, to the base of the wave. The impact of the water creates a large splash which disrupts the wave form and the remainder of the wave rushes up the beach as a turbulent mass of water and foam.

Once a wave has broken the resulting bore-like mass of water, or surf, continues to travel shoreward. It is within this zone, which Komar (1976) defines as the surf zone, that remaining wave energy is dissipated. The forces of gravity and friction, as well as the loss of water volume due to its percolation into the beach face are the primary dissipative forces (King 1972, Komar 1976, Pethick 1984). At the shoreline, the last of the wave energy is dispersed, and the remaining water rushers up the beach eventually coming to a stop. This final uprush of water is referred to as the swash. The ensuing retreat of water, or backwash, is the result of gravitational forces pulling any leftover water back down the beach. (Davis 1985, Pethick 1984)

2.3.4 Currents

Water motions, created as waves enter shallow water and break, often result in the generation of currents. The nature of these nearshore currents depends on the amount of wave energy reaching the shore, as well as on the angle of wave approach (Pethick 1984, Bird 1996, Davis 1985, Komar 1983). However, wave conditions in the nearshore are constantly changing, therefore, these wave induced currents can be quite complex (Pethick 1984, Davis 1985). To simplify the potential complexity of these currents, and to understand their significance in the nearshore, it is common practice by researchers to divide nearshore current flow into two basic categories: shore-normal currents and longshore currents (Pethick 1984, Carter 1988, Army Corps of Engineers 1973).

Shore normal currents, which move water either onshore or offshore, are created by waves that break parallel to the shore (Bird 1996, Pethick 1984, Davis 1985). However, not all waves break parallel to the shore and those which break at an angle generate longshore currents (Pethick 1984, Bird 1996, Komar 1976, Carter 1988). These currents move along the shore, parallel to the shoreline, away from the direction of wave approach (Carter 1988, Army Corps of Engineers 1973). These currents receive their energy from breaking waves and therefore have greatest strength within the surf zone. Although longshore currents are not confined to the surf zone, their energy outside of this area rapidly decreases and their significance becomes negligible (Komar 1976, Davis 1985, Komar 1983, Thorton 1970). Oblique wave approach is not the only mechanism for generating longshore currents, variations in water level or wave set up, along the shore can also lead to the development of such currents (Pethick 1984, Bird 1996, Komar in Hails 1975, Komar 1976, Carter 1988, Komar 1983). Bird (1996) and King (1972) also suggested that longshore currents can be driven by local winds blowing along the coast. Of the other possible mechanisms for longshore current development the generation of currents by local, winds is probably the most significant at Killbear Provincial Park. Although wind is indirectly responsible for the generation of currents via wave development, local winds can also directly move surface waters in the direction of the prevailing wind. In many cases, these mechanisms for generating longshore currents occur simultaneously and are often cumulative (Komar in Hails 1975, Komar 1976, Carter 1988, Davis 1985, Komar 1983).

The discussion to this point has focused primarily on currents which produce shoreward movement of water, however in general, there is no significant increase in the water level at the shoreline, therefore, in order to maintain a balance in the water level there must also be a movement of water offshore (Pethick 1984, Bird 1996, Komar 1976, Zenkovich 1976). Two types of offshore water movement are recognized: undertow and rip currents. Undertow is an expansive flow of slow moving water over the surface of the sediment bed, while rip currents are narrow, rapidly moving currents occurring at the water surface and moving out across the breaker zone (Davis 1985, Zenkovich 1976, Bird 1996, Carter 1988).

The onshore mass transport of water, the development of longshore currents and the subsequent movement of water seaward in rip currents has become known as circulation cell. The process of cell circulation was first recognized by Shepard, Emery and LaFond (1941). Since that time extensive studies have been conducted to understand this phenomena, and it is now one of the major theories of coastal geomorphology.

2.3.5 Water Level Fluctuations

As previously mentioned, on marine coasts tides also play a significant role in beach morphology. However, since the effects of tidal action within lake environments, such as Georgian Bay, is negligible, their influence on coastal processes will not be discussed here. Information on tides and the effects they have on coastal processes and beach morphology can be found in any text explaining the basics of coastal geomorphology or sediment transport, such as King (1972), Komar (1976), and Pethick (1984). Within lake environments changes in water level often play a similar role as tides however these changes do not occur on a regular basis and often occur over much longer time periods (Sly in Pye 1994, Carter 1988). These fluctuating water levels are primarily the result of three different factors: wind stress or seiche, annual variations in catchment storage, and long term climate change (Cain 1988, Carter 1988, Fisheries and Oceans 1993).

Seiche is produced by the stress of strong winds blowing over the surface of the lake. If the wind blows over the lake surface, in the same direction for extended periods of time, the water tends to pile up on downwind end of the lake. When the wind ceases or declines this piled up water then begins to oscillate back and forth within the lake basin with decreasing magnitude until it disappears entirely (Cain 1988, Carter 1988, Fisheries and Oceans 1993). Annual fluctuations in lake levels result from seasonal variations in the hydrological cycle. Typically these variations are the result of changes the rates of precipitation and evaporation, and the seasonal variation in the storage of water (Cain 1988, Carter 1988, Changnon 1997). For example, during the winter, precipitation usually falls as snow and water is stored as ice, however in the spring when this snow and ice melts the water level of lakes begins to rise. Over the summer, precipitation rates generally decrease but evaporation rates increase which in turn lowers lake levels. Finally lake levels can be altered by long term patterns in temperatures and precipitation rates or climate change (Cain 1988, Carter 1988, Changnon 1997). In North America, weather conditions have only been recorded for a short period of time climatologically speaking so long term climate cycles or patterns are not fully recognized. According to Carter (1988), the Great Lakes have long term water level fluctuations which occur on a 30-40 year cycle.

2.3.6 Subaqueous Sediment Transport

Waves and currents in the nearshore act as a mechanism for sediment transport. However, in order to understand the significance of these processes in moving sediment, one must first understand the basic principles of sediment transport. Sediment is moved by force which exerts pressure on the grains or grain bed. The force is provided by a fluid, which in this case is water. The amount of force depends largely on the velocity and turbulence of the water. As water flows over the surface of the sediment bed, gravity and friction create a resistance to force of the water. This resistance is called shear stress. Seaward of the point where wave base initially interacts with the sediment bed, little sediment transport occurs. Landward of wave base, the wave orbitals begin to interact with sediment bed and exert a force on the grains. Eventually, the force exerted by the flow of the water becomes significant enough to exceed the stabilizing forces of the sediment bed. This point is called the critical flow. (Bagnold 1941, Carter 1988, Fredsoe et al. 1994, Hardisty 1990, Pethick 1984)

Once the critical flow has been achieved the sediment grains begin to initiate movement. Initial movement is not necessarily very significant, usually starting only as a simple rocking back and forth of individual grains. This point however is referred to as the threshold of movement. If the flow remains the same grains will show no net movement, but simply just move back and forth. More energy is required to initiate grain movement than is required to maintain a grain already in motion because initiating forces must overcome stabilizing forces before a grain will move. Once the critical threshold and threshold of movement have been exceeded grains are in motion (Figure 2.2), however if the flow falls below these values grain movement will cease and deposition will occur. If the flow continues to increase grains will begin to move in a downflow direction. Once grain movement has been initiated, in addition to the fluid-sediment interactions described above, the sediment bed also experiences a sediment-sediment interaction. This means that grains in motion will collide with other grains, both those already in motion and those lying stationary on the sediment bed. For collisions with grains on the sediment bed, a significant force is created which often exceeds the critical threshold values and dislodges, or ejects, grains from the surface. Eventually these collision may result in flurries of grains, or even entire sediment surfaces, move in a downflow direction. It should also be noted that waves passing over the sediment bed may only create temporary sediment transport. The force on the sediment may not be significant enough to maintain grain movement after the wave passes, therefore the grain will settle back to the surface until the next wave. (Bagnold 1941, Carter 1988, Fredsoe et al. 1994, Hardisty 1990, Pethick 1984)

Sediment transport under these circumstances takes place as either bed load or suspended load. Bed load is the movement of sediment that occurs more or less in continuous contact with the sediment bed. This type of movement also includes saltation, where sediment bounces or rolls along the bottom. Suspended load occurs when sediment is moved within the water column and little contact occurs with the bottom. The method of transport is usually determined by the amount of force exerted on the bed, the sediment grain size and by how much the critical flow and threshold of movement is exceeded. For example, higher flow velocities acting on smaller grains usually result in suspended sediment transport. However in many cases, larger grains move only as bed load because flow velocity cannot reach levels required to transport them as suspended load. (Carter 1988, Komar 1976, Fredsoe et al. 1994, Pethick 1984)

Sediment can also be moved by direct action of breakers on the sediment bed. As waves break within the surf zone, the shallow water results in the intense turbulence directly interacting with the sediment bed. This interaction agitates the surface of the sediment bed and stirs it up the grains, making the initial dislodgement of sediment from the surface easy. Again, the force may not be significant enough to maintain movement of the material, and the grains will settle back to the bottom. (Carter 1988, Komar 1976)

Once a grain has been dislodged from the sediment surface, even if only for a short period, it is available for transport by any local currents. The surf zone is therefore the area with the most significant sediment transport, because not only is it the area where the greatest amount of sediment is loosened from the bed, it is also the area where the majority of nearshore currents exist. Such is the case with longshore currents, which move large quantities of sediment loosened by breaker action along the shoreline. Currents can also directly move sediment, but their velocity much be significant enough to exceed the shear stress and the threshold of movement values. (Carter 1988, Komar 1976)

Once sediment is in motion, it will move downstream until the velocity of the water falls below the critical flow and the sediment is deposited. If wave approach or currents occur as frequently in one direction as another, the net sediment transport over time will be negligible (Bagnold 1941, Carter 1988, Pethick 1984). However in most cases, a predominant long term current and net sediment drift occurs in a particular direction, producing coastal features such as spits, bars, and other features which provide evidence of this flow direction. Jacobsen and Schwartz (1981) explained the use of such landforms as indicators of net shore drift direction.

2.4 Beach Morphology and Classification

The overall morphology of a beach, and in particular the beach profile, is closely related to the local wave regime. Since wave characteristics, such as height and steepness, are used to determine breaker type and the amount of energy reaching the shore, several authors including Pethick (1984), Komar (1976) and King (1972), point to a link between wave characteristics and profile gradient. King (1972) suggested that the most important wave characteristic in determining beach slope is wave steepness. She also demonstrated that with an increase in wave steepness there was a corresponding decrease in profile gradient because steep waves have a tendency to remove sediment from the upper beach and surf zone and transport it to the breaker zone. The net shoreward movement of sediment therefore results in a decrease of the mean beach slope. Conversely, flatter or less steep waves promote a more shoreward movement of sediment which tends to accumulated on the upper beach increasing the mean beach slope. However, Komar (1976) and King (1972) both suggested that in addition to steepness, wave height also influences the profile gradient. In general, it was determined that an increase in wave height was also accompanied by a decrease in beach slope. Since wave characteristics, such as steepness and height, determine breaker type it is therefore possible to see how breaker type and beach gradients relate (Bird 1996, Pethick 1984).

Another important factor influencing the beach profile is the relationship between grain size of the beach material and beach slope. However, it has been suggested by many authors that the relationship between grain size and slope is actually a function of percolation rates of particular grain sizes (Pethick 1984, Davis 1985, Komar 1976, King 1972). Percolation rates are significantly higher on coarse beaches, as compared to beaches composed of finer material. As swash rushes up a coarse beach a large portion of the flow volume is lost to percolation into the beach sediment, leaving a considerably reduced volume of water for backwash. The significant difference between swash and backwash volume means there will be an overall net shoreward movement of water and sediment, which will increase the overall mean beach gradient (Bird 1996, Pethick 1984, Davis 1985, Komar 1976, King 1972). In contrast, because percolation rates on beaches composed of fine material are much lower, the swash and backwash volumes remain relatively equal. The backwash, under the influence of gravity, will have an increased energy, which enables it to remove sediment from the upper beach and transport it offshore. This net seaward movement of sediment results in a decrease in the mean beach slope (Bird 1996, Pethick 1984, Davis 1985, Komar 1976, King 1972).

2.5 Dune Development

2.5.1 Introduction

Coastal dunes are accumulations of sand usually occurring as vegetated ridges with a flat to undulating outline. Dunes may form continuous ridges, but in many cases are interrupted by erosional features or occur as fragmented mounds. The development of dunes depends on a number of local conditions such as climate and topography, however the major controlling factors are an abundant sand supply (both onshore and offshore supplies), strong onshore winds to transport the sediment, and the presence of stabilizing vegetation (Carter 1988, Davis 1978, Pethick 1984).

The natural physical function of sand dunes is to act as a method of coastal defense. Dunes act as a storage device in the process of coastal sediment cycling and form a protective barrier for the shoreline by absorbing the energy of wind and waves, particularly those generated by storm events. During periods of fair weather, when wave energy is generally lower, sediment tends to show a net shoreward movement accumulating as berms, just above mean water level, and in the dunes. During periods of higher wave energy, the berm is eroded and its sediment moved back offshore. This 'combing' of the upper beach creates a more gradual beach profile and results in the larger, higher energy waves breaking farther offshore and dissipating much of their energy before reaching the actual shoreline. The dissipation of the wave energy in turn decreases the erosive power of the waves therefore reducing the potential for substantial shoreline erosion and coastal flooding. Typically, erosion or combing of the dune system occurs only during extreme storm events or periods of particularly high wave energy. Sand dunes may also serve as a source of freshwater to local residents and prevent the intrusion of saltwater into the water table. Ecologically, sand dunes provide important habitats for a wide variety of flora and fauna, especially coastal shorebirds. As well, they provide critical breeding grounds for a number of migratory animal species (Brooks 1991, Carter 1988, Trider 1990).

2.5.2 Criteria for Dune Development

As previously mentioned, dune development depends primarily on the local physiographic setting, the availability of a sediment supply, winds to transport the sediment onshore and the presence of vegetation to stabilize accumulating sediment. These criteria for dune development are reviewed more thoroughly by Goldsmith (1985) and Pye (1994). Where abundant offshore sediment supplies exist, currents, waves and/or tides can transport the material onshore. Sediment deposited by high tides or high water levels is then exposed to the drying properties of the air. Once the sediment is dry, and if the onshore winds are strong enough, it is possible that the sand can be picked up by the wind and transported across the beach. However Goldsmith (1985) suggested that no simple relationship existed between wind and dune development. High winds may move more sand per unit time than lower velocity winds that occur more frequently, but because prevailing winds occur for a greater period of time, they are more important. The orientation of the shoreline to the winds is also very important. The most efficient dune forming environments are typically those in which the shoreline is normal to the prevailing winds. In addition, a number of local factors, such as soil moisture, salt crusting, temperature and beach slope, also affect the winds ability to transport sand, but the major determining factors are wind speed and sediment grain size (Carter 1988, Davis 1978, Pethick 1984, Smith 1988). The role of the vegetation is then to act as a disruption to windflow, trapping and accumulating sand, while the roots anchor the sand securely in place (Brooks 1991, Carter 1988, Davis 1978, Pethick 1984, Ranwell et al. 1986).

2.5.3 Aeolian Sediment Transport

As discussed in Section 2.3.6 (Subaqueous Sediment Transport) sediment is moved by a force which exerts pressure on individual grains or the grain bed. The force is provided by a fluid, which in this case is the wind. Again, the amount of force acting on the grains depends largely on the velocity of the fluid (ie: the wind). The principles of aeolian sediment transport therefore parallel those for subaqueous transport, the only difference being a change of the fluid medium. Bagnold (1941), Carter (1990), Pye (1990) and Pye (1994) however provide references with in depth explanation and discussion of aeolian sediment transport.

Sand grains have a critical or threshold value at which the wind is strong enough to start them in motion, below that value the grains will remain stationary (Figure 2.2). Once the 'critical' value for a particular grain size has been exceeded, the grains will move by either a process of saltation or surface creep. A mobile grain will move downwind until it collides with another grain, if the second grain is larger than the initial grain, the force of the impact will cause the second grain to roll slightly forward. This process is called surface creep. If the initial grain collides with a grain that is equal or smaller in size, the force of the impact will cause the second grain to be ejected into the air. This grain will then begin to accelerate under the influence of the wind, however, because sand has a significantly higher density than the surrounding air, the grain will begin to fall back towards the ground as it continues to move forward. The grain will finally strike the surface, at some distance from its initial position, and the resulting impact will throw several new sand grains up into the air. The cycle continues until eventually the entire beach surface, downwind of the initial grain, is in motion. This process is saltation, and it is the most significant method of sand transport in dune formation, moving approximately three quarters of all sediment transported on the beach (Carter 1988, Davis 1978, Pethick 1984, Smith 1988).

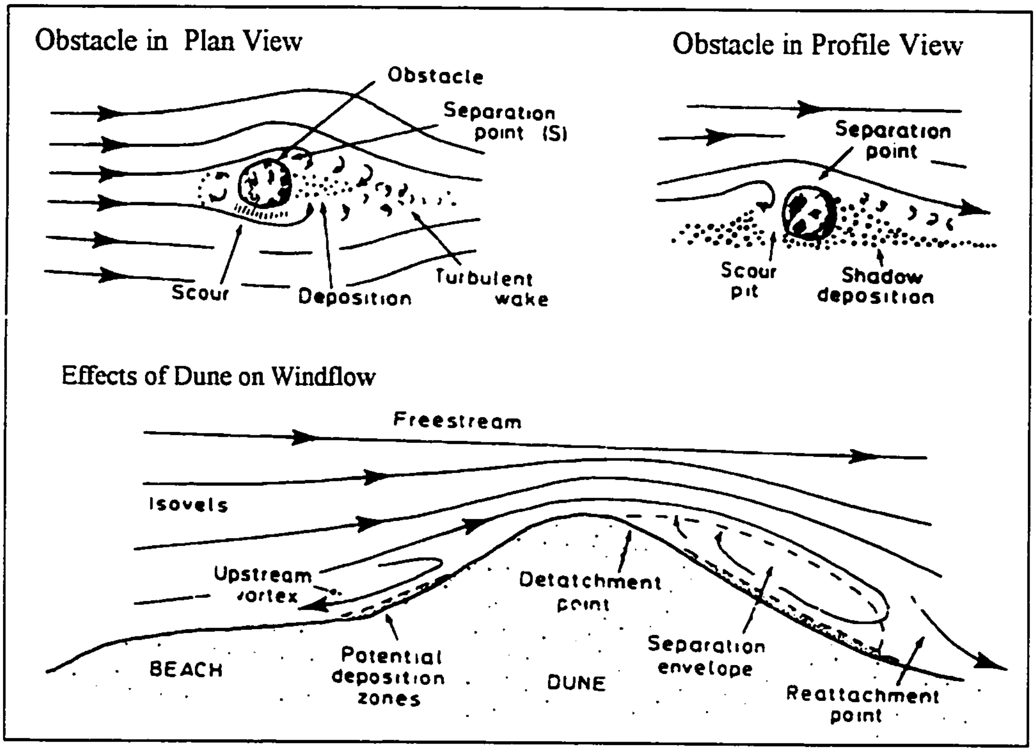
Sediment transport will continue over a flat surface until the wind speed decreases, and it is no longer capable of exceeding the critical entrainment value, or until the windflow is disrupted by some obstacle. The obstacle can take the form of tidal litter, vegetation, or rocks, all of which serve to deflect and decrease the overall windflow resulting in sediment deposition. As the wind approaches an obstacle it is deflected around the sides and may cause a slight increase in wind speed and some scouring at the edges of the obstacle (Figure 2.3). However overall the obstacle causes a significant decrease in wind speed, on both the up- and downwind sides, resulting in sand deposition. The net result is the accumulation of sand until the obstacle is buried. Once completely buried, the obstacle no longer acts to disrupt the windflow so deposition ceases. In order for accumulation to continue the presence of some new obstacle is necessary (Carter 1988, Davis 1978, Pethick 1984, Smith 1988).

2.5.4 Vegetation

Vegetation plays an intrinsic role in the development of coastal dunes and dune systems. The presence of vegetation acts as an obstacle to the wind and serves to slow or disrupt the wind flow, thereby trapping and accumulating any windblown sand. The roots of the vegetation also serve to anchor trapped sediment securely in place (Carter 1988, Pethick 1984, Ranwell 1972).

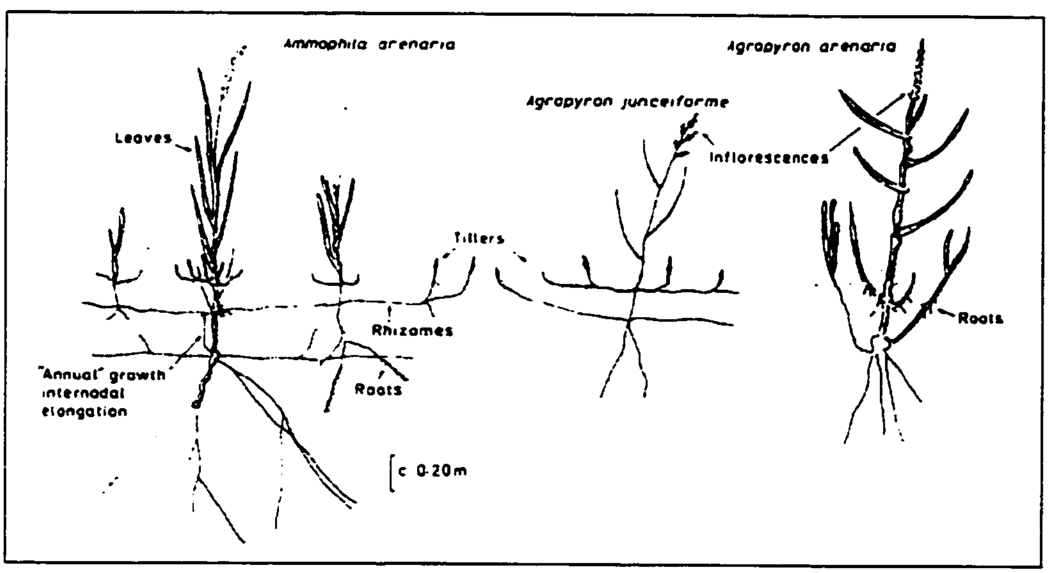
The first plants to colonize a dune are referred to as pioneer vegetation. Plant fragments, or seeds, wash up on the beach during high water events, accumulating just above the mean high water level in the tidal litter, also referred to as the strandline. This strandline vegetation, typically consisting of annual plants, begins to germinate and grow (Brooks 1991, Carter 1988, Davis 1985, Pethick 1984). As sand is accumulated, perennial plants begin to become established and eventually replace the annual plants as the dominant dune vegetation. Ranwell (1972) stated that it is unclear whether the annual vegetation is overwhelmed by accretion

Figure 2.3: Windflow Disruption By An Obstacle



Source: Carter (1988)

Figure 2.4: Rooting System of Typical Dune Vegetation



Source: Carter (1988)

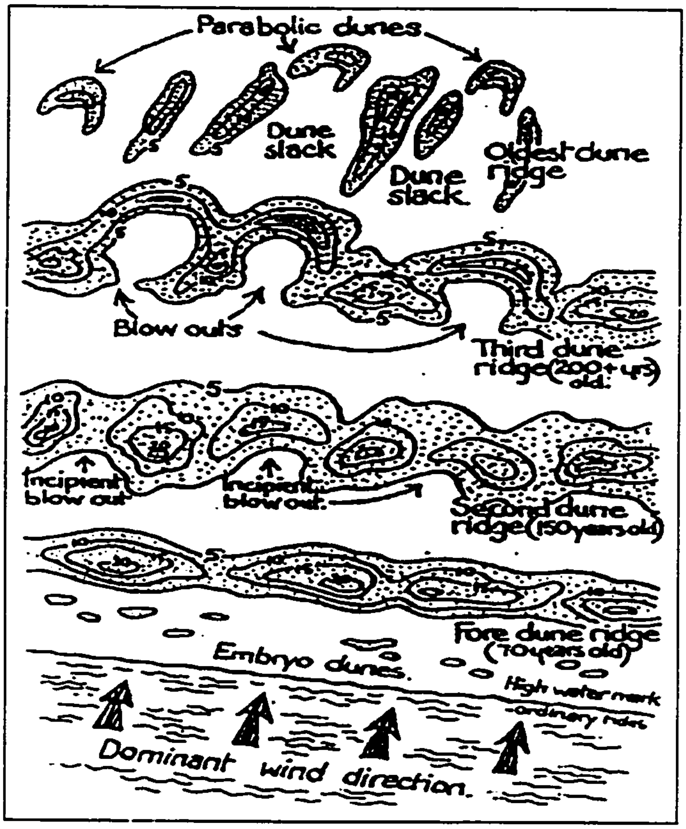
rates, or whether nutrient requirements are no longer met, or whether the presence of perennial plants simply shades out them out.

The environment in which these plants colonize is particularly inhospitable, with continual wind and/or salt spray, low soil nutrient and organic content, and a low soil moisture holding capacity, so the plants must be extremely hardy and resilient. The majority of these plants propagate either by seed or by rhizomes, and develop elaborate root systems that extend both vertically and horizontally through the sand. This elaborate root system securely anchors the plants, as well as the accumulated sand (Figure 2.4). In addition, the root system provides the plants with an extensive area to gather essential nutrients and moisture. Many of the perennial plants, such as Ammophila breviligulata, have root systems extending vertically for 1-2 metres and even further horizontally, and are often capable of withstanding sand burial of up to 1 metre per year (Brooks 1991, Carter 1988, Davis 1985, Pethick 1984). According to Maun (1985), species such as Cakile edentula, Ammophila breviligulata and Calamovilfa longifolia are among the most common types of dune vegetation on the Great Lakes shorelines.

2.5.5 Dune Evolution

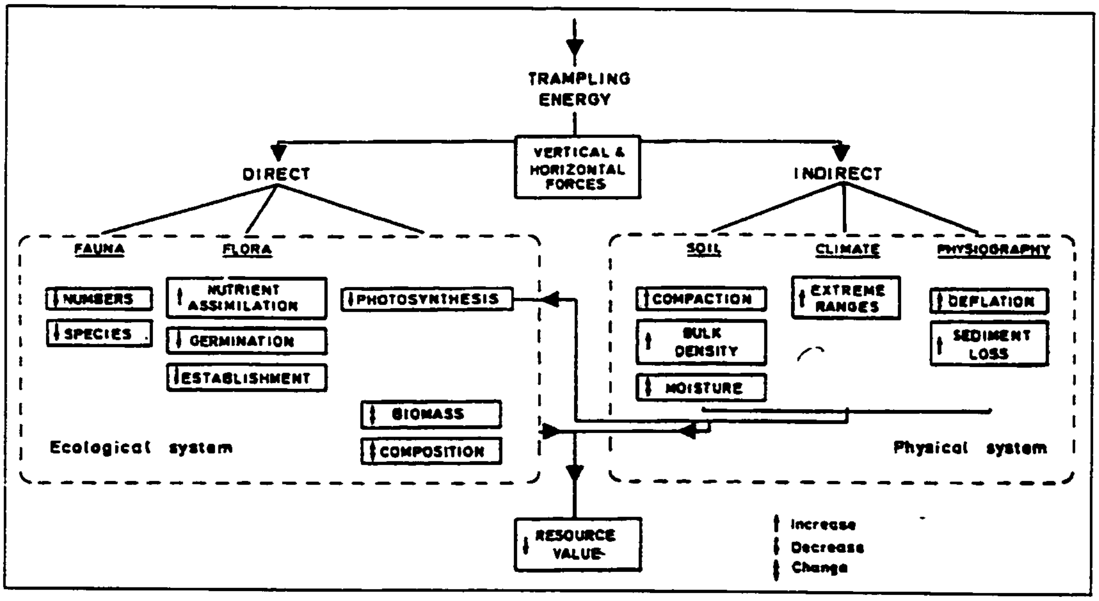
The initial stage of dune development consists of small, isolated mounds or hummocks of vegetated sand called embryo dunes (Figure 2.5). Pioneer vegetation is primarily responsible for accumulation of these dunes. The plants trap and accumulate sand while their roots anchor the sand securely in place. The continual growth of the vegetation and accumulation of sand eventually causes the hummocks to grow both laterally and vertically coalescing into larger ridges. These ridges called foredunes constitute the second stage of dune development (Figure 2.5). In this stage there is almost a complete vegetation cover and the resulting disruption in windflow causes rapid deposition of sediment. In fact, foredunes can grow up to 1 metre in height during a single growing season, if adequate sand supplies exist.

Figure 2.5: The Evolutionary Stages of Dune Development



Source: Brooks (1991)

Figure 2.6: Impacts of Trampling on Dune Environments



Source: Carter (1988)

The next stage of dune development is the primary dune (Figure 2.5). This dune ridge is the highest and most coherent of all the ridges. The overall height of this dune is controlled by natural factors such as sand supply, climate, wind regime and local topography. The location of the primary dune landward of the embryo dunes and foredune means a less exposed environment, and the presence of vegetation cover for a number of years adds to the organic, nutrient and moisture content of the soil. This enables less hardy vegetation, such as shrubs and trees, to establish and increase the stability of the dune. The primary dune ridge continues to accumulate sand but since the majority of wind blown sand was captured in the foredune, accumulation rates are much lower (Brooks 1991, Carter 1988, Davis 1978, Pethick 1984).

It should be noted that dune development occurs both temporally and spatially, that is, as the foredune grows and accumulates sand, developing into the primary dune, the embryo dunes are developing into a foredune, and new embryo dune should be forming. As well, depending on the abundance of sand supply, a series of older ridges may exist landward of the primary dune. These ridges are referred to as the secondary, tertiary, etc... dunes respectively. These dunes are lower and less stable than the primary dune, and due to a lack of fresh sand supply, frequently lose their continuous ridge formation and become fragmented. Damage to vegetation, caused by either natural and/or anthropogenic factors, is believed to contribute to the increase in instability. The loss of vegetation cover allows the initiation of wind erosion and the creation of large hollows or blow-outs in the dune ridge. The lack of new sand supply to these landward dunes prevents their restabilization. As well, it should be noted that changing sand supply, differing climatic conditions, or alterations in topography may limit the development of the dunes to any of the above stages. For example, some areas never progress beyond the embryo dune stage (Brooks 1991, Carter 1988, Davis 1978, Pethick 1984).

2.6 Human Use and Its Impacts

2.6.1 Introduction

Sand dune systems have historically been used for a number of different human activities including agriculture, sand and mineral extraction, afforestation, coastal defence. and recreation (Brooks 1991, Ranwell et al. 1986). However, beaches, and in particular dunes, are extremely sensitive ecosystems and only minimal amounts of human use can create significant damage. With increases in population, developments in technology and machinery, and a general overuse, the beach system has suffered severe degradation and even complete destruction in some areas.

Of the traditional uses, sand and mineral extraction provided possibly the greatest risk to the stability of beach and dune systems. More recently, with the realization of the serious detrimental effects of such activities, many extraction operations have been restricted or are conducted under careful regulation and monitoring (Ranwell et al. 1986). However recovery for areas damaged by such practices is often slow, and in many cases, the damage was so severe that the system was totally destroyed and will never recover. More recently, the increased development of houses, resorts and cottages, as well as the significant increase in recreational use along the shoreline has posed the greatest threat to the coastal environment. At present, human pressure on beach and dune systems is at an all time high. The human pressure has resulted in a continual increase in the degradation of the systems, and erosion of the coastlines. This damage and destruction of the coast's natural defence mechanism has also resulted in an overall increase in shoreline erosion and coastal flooding (Brooks 1991, Carter 1988, Ranwell et al. 1986).

Only the impacts of recreational use within the coastal environment are of interest here, therefore other impacts will not be discussed. However abundant literature is available on the impacts of the more traditional uses mentioned above, and references such as Ranwell et al.(1986), Brooks (1991) Carter (1988), Viles et al

(1995), Doody (1989), Skarregaard (1989) and Hewitt (1989) provide good starting place for those who are interested.

2.6.2 Recreational Impacts

In the past 50 years recreational use of the coast has increased dramatically: hotels, resorts and cottages now litter coastlines around the world and the value of shorefront property has soared; during the summer, beaches are crowded and the coastal waters packed with swimmers, boaters, surfers and jet skiis. The intensive use of the coast has had severe impacts on the stability of beach/dune systems, and many have suffered tremendous damage.

Unfortunately, in most cases, people do not realize the damage they are inflicting on the beach/dune system, and they perceive the system as being resilient and capable of withstanding their use. As Trider (1990) suggested, this perception is often supported by media and advertising, which show people using the systems in destructive manners. For example, television ads featuring images of cars racing along a beach engulfed in a spray of water, or friends gathering around a bonfire on the beach or within the dunes are not unfamiliar to us. The shear number of users may also make it difficult for the individual to comprehend their overall impact. That is, someone walking over a dune and trampling the vegetation may realize the damage they are causing, but justify and dismiss it as the act of only one, not considering that perhaps hundreds of others have walked over the same dune having thought the same thing. Also when discussing recreational use of the beaches most people visualize sunbathing, swimming, or surfing, but very few consider that cottages, hotel and resorts also contribute in the recreational use of the shores. However, this project deals only with the potential impacts caused by mass use of public beaches therefore the impacts of cottages, resort development and other aspects of commercial tourism will not be discussed here.

Beach and dune systems are very fragile and easily damaged, besides the actual removal or destruction of the dunes, the most serious threat to their stability is the trampling and destruction of vegetation (Brooks

1991, Carter 1988, Ranwell et al. 1986, Vogt 1979). This is where public beaches and mass beach use have the most significant impact. The use of public beaches has increased dramatically over the last few decades, and activities such as horseback riding, hiking and off-roading are commonly a problem (Godfrey et al. 1980, Ranwell et al. 1986, Trider 1990). As discussed in Section 2.5.4 (Vegetation), vegetation is one of the key components in dune development. Plants that colonize a dune system are generally very hardy and resilient, but these plants are also very vulnerable to trampling and crushing, and only a few passes over the same plants can destroy them. Beach users typically gain access to the shoreline by walking through the dunes, and free-ranging activities such as off-roading have unrestricted access to the entire beach/dune system. Thus vegetation is at extreme risk of being damaged or destroyed. Even an activity as simple as drying a sailboard in the dunes can cause damage to the vegetation (Carter 1988, Godfrey et al. 1980, Ranwell et al. 1986, Vogt 1979).

Carter (1988) noted that low levels of pressure may seem to improve the system, as damage to the vegetation creates more organic matter in the soil, and some vegetation is actually encouraged to grow more rapidly if trampled. However, at slightly higher levels of pressure other types of vegetation are completely destroyed. The problem arises in defining the different levels of pressure, and determining when the pressure is significant enough to cause degradation to the system. Hindson (1989) suggested that just one family picnicking on a dune could create enough pressure to damage the vegetation, and Godfrey et al. (1980) suggested that even a single pass of an All-Terrain-Vehicle (ATV) could have the same effect. One relatively easy method of determining the extent of pressure and degradation is to notice the development of paths, tracks or blow-outs, as a decrease in stability of a system and its increased degradation usually coincide with the occurrence of these features (Carter 1988, Godfrey et al. 1980, Vogt 1979).

Trampling (and crushing) has both direct and indirect impacts on the vegetation and the stability of the dune system (Figure 2.6). The direct effect of trampling is to kill the vegetation, however, because different plant species have different levels of trampling tolerance, the indirect effect of this damage is to cause a change in the overall species diversity and populations (Carter 1988, Godfrey et al. 1980, Vogt 1979). In other words, the plant species that are more susceptible to trampling damage will be destroyed, but those more resistant plant species will continue to grow. Therefore, the overall vegetation cover should remain about the same but species diversity will decrease. As trampling increases, the diversity of species continues to decrease, and this will eventually be reflected in changes in the physical and chemical properties of the soil, as well as in the moisture regime. That is, the bulk density of the soil begins to increase as trampling causes compaction, the organic, nutrient and phosphorus levels of the soil begin to increase with the increase of biodegrading plant material, but oxygen levels drop significantly because of compaction, and finally the soil moisture decreases because of the penetration resistance of the soil and the loss of moisture trapping plant species (Carter 1988, Vogt 1979).

Eventually the pressure of tramping will begin to destroy even the most resistant species, and paths, tracks or bare patches will begin to develop. Continued trampling along these paths will increase their width, and finally the paths, devoid of vegetation, are no longer able to stabilize the underlying sand and wind erosion begins. As erosion continues, small depressions develop along the paths and eventually larger blow-outs may form. If the paths are orientated at right angles to the prevailing winds, they may actually funnel the winds and the erosional effect will be concentrated. These blow-outs significantly decrease the stability of the dune systems and eventually can lead to the fragmentation of its dune ridges (Carter 1988, Hindson 1989, Vogt 1979).

2.7 Management: Reducing Impacts

With the global increase in shoreline erosion and coastal flooding, demands to preserve coastal systems and develop new methods of protection have increased dramatically. Ultimately, the best method for ensuring coastal protection is to preserve and maintain the system in its natural state. However, the only way to ensure that these systems can be left in their natural state is to exclude human activity entirely, but unfortunately in most cases this is not a viable option. Alternatives therefore have been developed which range from the construction of rigid engineering structures which armour the shoreline, to more natural techniques that attempt to utilize the coastal processes and cycles to restabilize or regenerate damaged parts of the system.

2.7.1 Engineering Techniques

Artificial or engineering solutions to coastal defence usually involve the construction of permanent rigid structures such as breakwaters, seawalls, groynes or jetties, that 'armour' the shore against wave attack and erosion. Examples of this type of defence can frequently be seen along the Great Lakes and the eastern coast of the United States. These structures attempt to prevent erosion and flooding by removing the natural erosional processes along a shoreline. Unfortunately, the structures also interfere with natural sediment cycling and the processes of beach and dune development, which in turn may actually increase the erosion problem.

In addition to disrupting natural cycles and processes along a shoreline, these rigid structures are also unsightly and very expensive to build and maintain. However, they provide land owners and investors with a quick and temporary solution to their erosion problems. Other less rigid and unsightly engineering techniques have also been developed, such as contouring or beach nourishment. Although these techniques are somewhat less destructive to the natural environment, in the long run they still alter the natural cycles and may be no more successful at protecting the coast from erosion.

2.7.2 Working with Nature

With todays knowledge and understanding of the natural physical and ecological processes active within a beach and dune system, it is possible to develop planning and management strategies that attempt to utilize the natural processes and cycles within the system to restabilize or regenerate damaged areas. A bonus to such management techniques is that they seek to preserve and restore the natural state of the system while still taking into consideration human use. In other words, recreational use of the beach is still permitted, but only in a manner that attempts to ensure the minimal possible damage (Carter 1988, Van der Malawian 1990).

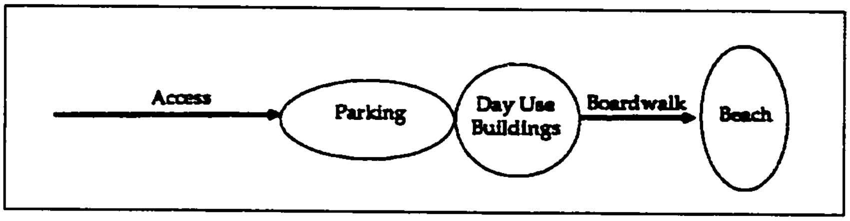
Although the basic principles behind the natural processes and the typical activities on a beach are the same, each site is unique with its own variety of different influencing factors therefore management projects are very site specific. The first step in developing an effective management plan is in depth research and study of the particular area (Van der Meulen 1990). This includes determining the physical processes (ie: level and stage of dune development, predominant wind and wave climate, sediment characteristics, level of degradation), the ecology (ie: wildlife and vegetation identification and populations) and the human activities (ie: type, extent and distribution) within the system. However, in order to ensure the system is adequately understood research may need to be conducted over a number of years as short term study may only provide information on small scale trends rather than on the actual long term changes or cycles.

Once the initial research is completed, the system can be divided and classified into different categories based on physical, ecological and land use criteria (Carter, 1988). For example, areas most heavily used by visitors, suffering greatest degradation, significant for some particular plant or animal, most sensitive to damage or priorities for restoration can be designated. The principle of zoning can then be applied to create areas where recreation, protection and restoration would be most suited. Areas chosen for recreation are usually more stable and at less risk of damage from human activities, they should also already be in use by visitors (Carter 1988, Vogt 1979). These areas will now facilitate all recreational activity, but the use and impact within this zone is still monitored, and some activities may need to be regulated, or others, determined to be too destructive to the system (ie: off-roading), restricted altogether. Protected zones are designated so because they are the most sensitive to human pressure, or they provide critical habitats for important plant or animal species (ie: piping plovers). These zones can withstand very little human use so access is strictly regulated and everyone, except authorized scientific researchers, is normally restricted from the area. Areas designated for restoration are usually those that have suffered the most significant damage from recreational activities, and are in need of time to recover. These areas can be left to regenerate naturally, or a restoration program designed by the beach managers can be implemented to aid in the recovery process (Carter 1988, Vogt 1979).

In order to ensure human activity remains within the areas designated for recreation, a program of access management must be implemented (Brooks 1991, Carter 1988, Gribbin 1990, Vogt 1979). This involves designing facilities with the intent of subtly controlling and restricting access to the dune system and channelling users through designated routes to the beach (Figure 2.7a). The key to the success of these techniques is the siting of the facilities. Parking lots should be located well back from the main dune ridges and be oblong or tear dropped in shape so visitors are directed toward a common access route. Parking lots that are oriented parallel to the main dune ridges encourage visitors to just walk from their cars directly through the dunes to the beach causing extensive damage to the vegetation and creating a network of paths (Figure 2.7b). Once channelled out of the parking lot, specially designed routes should guide the visitors over the dunes and down to the beach (Figure 2.7c). These routes can be widened sandy paths, boardwalks or paths surfaced with some soft material. The paths must be easy to use and comfortable to walk on, even in bare feet, so visitors do not stray from them. Fences or the intentional siting of vegetation such as wild rose bushes (should be native vegetation) along the edges of designated paths may also be necessary to discourage visitors from venturing off into the dunes. The paths should also zig-zag over the dune to prevent onshore winds from being concentrated in the paths and causing erosion (Brooks 1991, Carter 1988, Gribbin 1990, Ranwell et al. 1986).

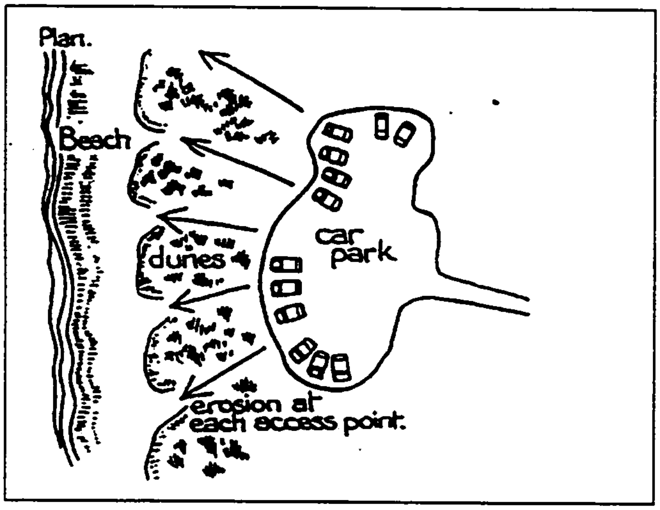
Public education and awareness should also be conducted in conjunction with access management. It is important to inform visitors of the significance of sand dunes and their vegetation, how easily they can be damaged by human activity, and the consequences of such damage. If restoration activities are also being conducted at the site, visitors should be informed and brief explanations provided of the processes involved and the success of the project given. Most people are not destructive by nature so once informed, it is likely they will try to avoid these damaging activities, however, it may be necessary to employ the use of signs as friendly

Figure 2.7a: Effective Access Management Design



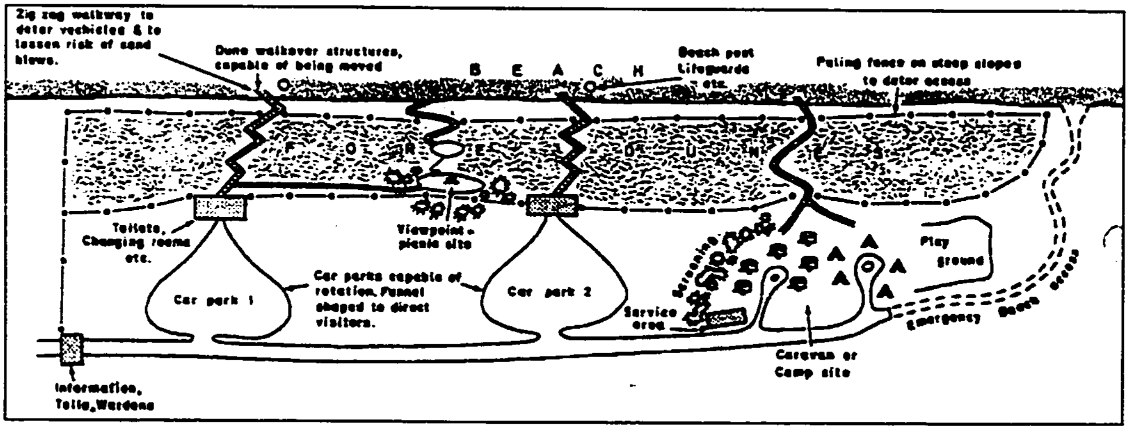
Source: Gribbons (1990)

Figure 2.7b: Destructive Access Design



(Source: Brooks 1991)

Figure 2.7c: Minimal Impact Access



Source: Carter (1988)

reminders. Signs should be posted at major access routes and at areas where visitors may be tempted to stray off the designated paths. The signs should be very positive in their message but stress the importance of staying out of the dunes (Brooks 1991, Ranwell et al. 1986).

Once visitor activities have been controlled and limited to a special recreational zone, restoration of badly damaged dunes can begin. As mentioned earlier, dunes can be left to regenerate naturally or managers can implement a human assisted restoration program. Dunes that are more severely degraded will likely require this human intervention. To restabilize dunes, a process of artificial sand trapping and transplanting of vegetation is used (Brooks 1991, Carter 1988, Ranwell et al. 1986).

With artificial sand trapping, obstacles, usually fences, are used to disrupt the natural windflow across a beach and accumulate sand being transported via saltation. The fences are usually established in blow-outs, or on the windward side of damaged dunes, to replace the sand lost by erosion resulting from overuse of the system. However, they can also be used to laterally extend dunes or to initiate the development of new embryo dunes and foredunes (Brooks 1991, Carter 1988, Ranwell et al. 1986). Unfortunately this process is of little use in the older dune ridges (ie: secondary and tertiary dunes) because sediment supply to these areas is minimal.

The fences are usually made of small wooden slats held together with heavy wire (same as snow fences), but can be constructed of other material as well. They can range in length depending on the size of the area to be restored, and are rarely higher that 1.5 m. Sand accumulation is most efficient if the fences are placed at right angle to the predominant wind direction, however, if wind directions are variable in a site, a zig-zag fencing pattern may be more effective. Studies have also shown that a fence porosity (number of holes or spaces in the fence compared to solid material) of between 30% and 50% will result in maximum deposition of sand. In fact, if an ample sediment supply exists, these sand fences can accumulate on average 0.9-1.8 m of sand per year. If multiple rows of fencing are to be used it should also be noted that sand accumulation usually occurs horizontally for a distance up to twice the height of the fence itself (Brooks 1991, Carter 1988, Ranwell et al. 1986).

Transplanting of vegetation should occur concurrently with sand accumulation, as the vegetation will stabilize existing deposits and help to promote accumulation. Plants for transplanting are usually gathered from stable areas within the system, where vegetation is rapidly growing, to ensure the use of native vegetation. In these areas, up to a third of the new plant growth can be removed. The best time for planting the transplants is in late winter or early spring, just before the end of their winter dormancy period. There are many suggestions concerning the best methods of gathering the plants and techniques for transplanting, including information on costs, equipment that should be used and standard productivity levels (ie: transplants per day) for workers (Brooks 1991, Ranwell et al. 1986). Several suggestion are also made about plant spacing, however the most common method involved a pattern of offset rows, with plants spaced at approximately 45 cm intervals. Although random planting of vegetation would seem to be the most natural approach, the references suggest actual pattern planting is more effective, and less likely to result in an uneven surface cover. It is also recommended that the new planting sites be periodically fertilized, to ensure the vegetation survives the transplanting process, and is able to establish a healthy root system in a relatively short period of time (Brooks 1991, Carter 1988, Ranwell et al. 1986).

This method of dune management has generally proven very successful. By using methods of zoning and access management pressures on particularly sensitive areas have been reduced with little inconvenience to the user. Restabilization of degraded dunes by sand trapping and re-vegetation has also proved successful; in fact this method is believed to be the cheapest and most effective method. However, such management techniques are not a 'quick-fix' solution to the impacts of recreation but an ongoing process. Monitoring, maintenance and evaluation of the system will be a continual part of its future.

2.8 Summary

Numerous factors and processes interact to form beach and dune systems. Wind regime, wave climate and sediment supply are the primary factors influencing beach development, while wind regime, sediment supply and vegetation are the key factors influencing dune development.

Sediment supply determines the availability of material for accumulation and therefore influences the extent and level of beach development. Sediment can come from a variety of sources, however, typically beaches are composed of sand. Some beaches no longer receive a fresh new supply of sediment and are maintained by a continual reworking of in situ material. The wind regime drives the generation of waves and currents and in turn influences subaqueous sediment transport. Direct interaction of waves with the sediment bed can cause sediment transport. Generally this interaction results in an onshore/offshore movement of sediment. Waves also are responsible for the generations of nearshore currents. Depending on the direction of wave approach, currents can be onshore/offshore, alongshore or a combination of the two. If these currents are strong enough sediment transport may occur.

Waves and currents move sediment subaqueously and are ultimately responsible for providing material to the beach. Sediment accumulated on the beach is then exposed to the influence of the wind regime and potential aeolian transport. These processes influence the extent of dune development. The presence of vegetation also plays a significant role in determining the extent of dune development. Vegetation traps and accumulates aeolian transported sediment and also holds the material in place. Therefore vegetation acts as a stabilizing mechanism in dune development.

The beach and dune environment is a relatively inhospitable setting for vegetation growth, therefore plants that colonize this environment must be very hardy and resilient. These plants may be capable of withstanding the harsh shoreline environment but unfortunately they are vulnerable to trampling and crushing associated with human activity. These activities quite frequently destroy dune vegetation and expose the once stabilized sediment to erosion by the wind.

Many beach and dune systems have suffered extensive damage from human activity. In many cases, the impact of human activity has resulted in severe degradation or the complete destruction of beach environments. The impacts of such human activities can be reduced however, with the development of effective management strategies. Access management provides a natural approach to preventing human impacts and promoting sustainable use of the beach and dune environment. Such a management technique involves designing and siting facilities which subtly control and restrict access to particularly vulnerable beach areas. In addition, access management involves a process of zoning which divides the system into different categories. These zones permit the designation of areas for recreation, protection and restoration. The most important step in developing such an effective management approach is to conduct in depth research and study of the area in question, and to determine the active physical processes, level and stage of dune development and the impact of human activities.

To understand the natural physical environment of the beach and dune system within Kilcoursie Bay studies were conducted in an attempt to quantify each of the processes discussed in this chapter. The results of these individual studies are presented in Chapter 3.

Chapter 3 - Results

3.1 Introduction

One of the primary objectives of this project was to develop an understanding of the beach and dune system at Killbear Provincial Park. In order to develop such an understanding it is necessary to quantify the natural physical processes active within Kilcourise Bay, as well as determine the current state of the system and identify the impacts of human use. To achieve such goals a series of field studies were conducted. In addition, a number of data sources were utilized including meteorological data from Environment Canada; maps, charts, and photographs from the Killbear Interpretative Office and Ontario Provincial Archives; and personal communications with park staff and users.

Field research was conducted between May 1996 and May 1997. Field work was conducted over a one year period in an attempt to avoid seasonal variations in processes, as well as to observe and document the nature of the beach and dune system prior to, during and after the peak visitor season. During the winter, field research was not conducted because the weather and climatic conditions minimized active processes and significantly restricted access to the study area. Extensive laboratory analysis and comparative studies of maps, charts and photographs were also conducted after the completion of the field season.

This chapter presents field study results. In addition, the results of the laboratory analysis and comparative studies are also presented here.

3.2 Bathymetric Data (Sediment Availability)

Georgian Bay Small Craft Route charts were used to determine the depth of Kilcoursie Bay. In addition, several chart editions were compared to determine any changes in bathymetry within Kilcoursie Bay over time. The charts used spanned from mid 1960's to late 1980's and included Chart 2203 Sheet 1: Parry Sound to Carling Rock (1966), Chart 2202 Sheet 4: Amanda Island to Parry sound (1970) and Chart 2203 Sheet 3: Parry Sound to Twin Sister Island (1988).

According to the Small Craft Route charts (Figure 3.1) the depth of Kilcoursie Bay ranges from approximately 6.7 m just off the Day-Use portion of the beach to approximately 12.2 m off of Beaver Dams beach. The depth increases off the research site area to a maximum of approximately 22.6 m just north of Scott Island. The maximum depth within Kilcoursie Bay occurs just to the east of Scott Island and just south of Harold Point with values ranging between 30.5 m and 33.9 m.

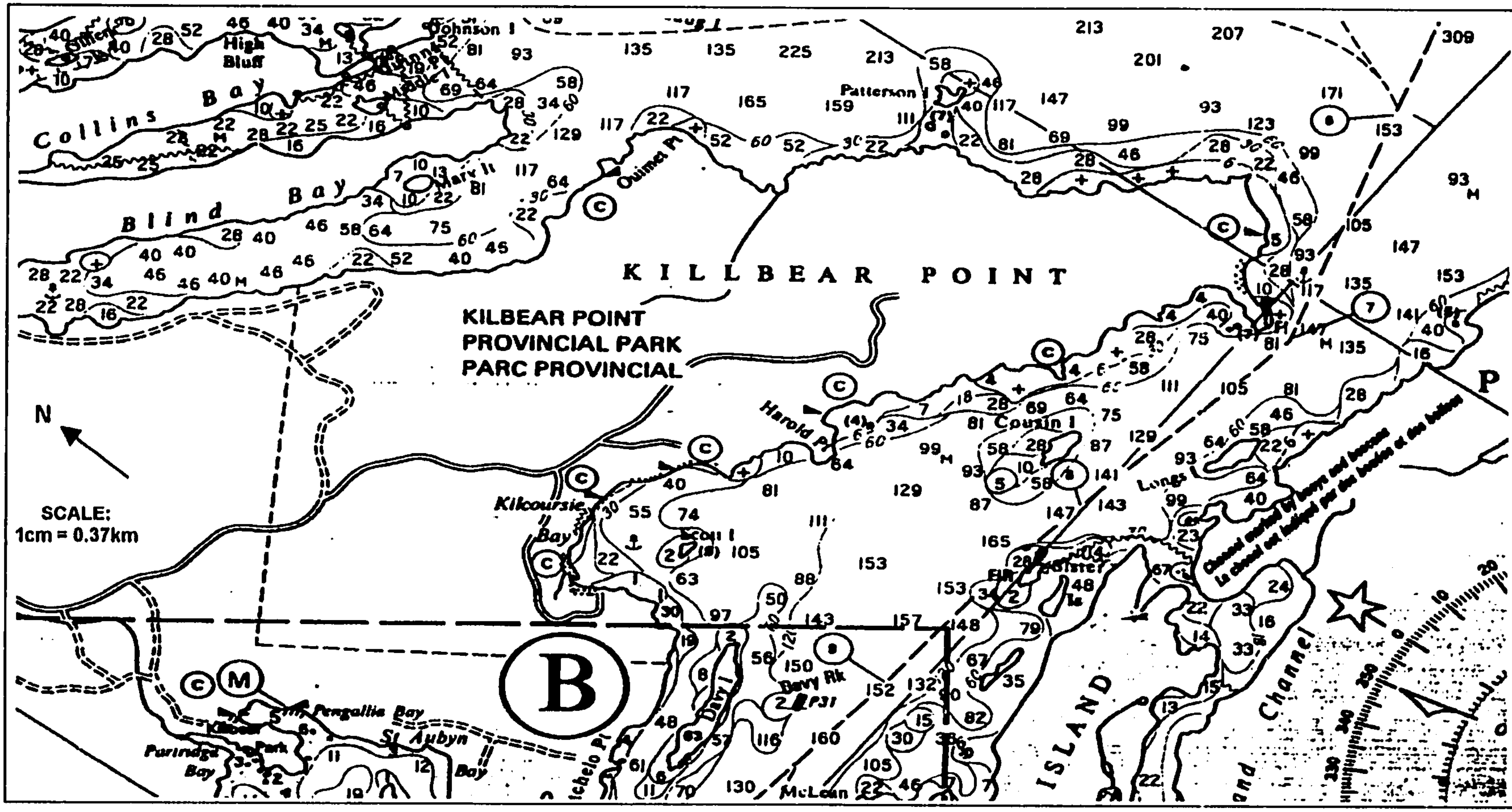
Comparison of the different Small Craft Route charts (Figure 3.2) also indicate little to no change in the bathymetric contours within Kilcoursie Bay between 1966 and 1988. However, it should be noted that large quantities of sediment were reportedly dredged from just offshore of the Day-Use beach sometime during the 1960's (Park Maintenance Staff, personal communication). The sediment was believed to be removed for use in road construction. Unfortunately no formal documentation of this sediment extraction could be located.

3.3 Wave Data

At the request of park officials, studies requiring the establishment of permanent surveying equipment were not conducted during the camping season. As a result, wave data were gathered through direct personal observation and documentation. Several attempts were also made to obtain wave gauge data from the Canadian Hydrographic Service but they were unable to provide the information. The observations recorded consisted of wave height and swash width (Table 3.1). Wave heights were classified into three categories: calm, minimal and small. Flat wave conditions were classified as calm, while wave development with heights less than 0.5 m were considered to be minimal and waves with a height of 0.5 m to 1 m were considered to be small. Swash widths were classified based the distance between the point where waves began to break and the upper landward limit of swash. Values recorded for swash width were an estimation or range of this distance.

Ice cover appears to retard wave activity within Kilcoursie Bay from approximately December to April. In the spring and early summer, wave development is minimal except during occasional storm

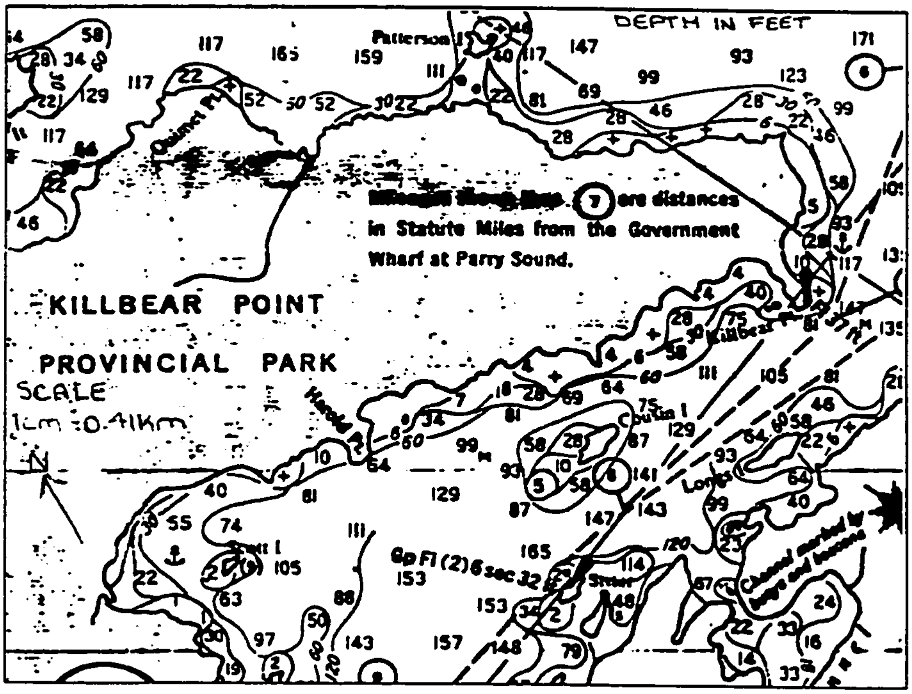
Figure 3.1: Bathymetry of Kilcoursie Bay



Source: Georgian Bay Small Craft Route (1988)

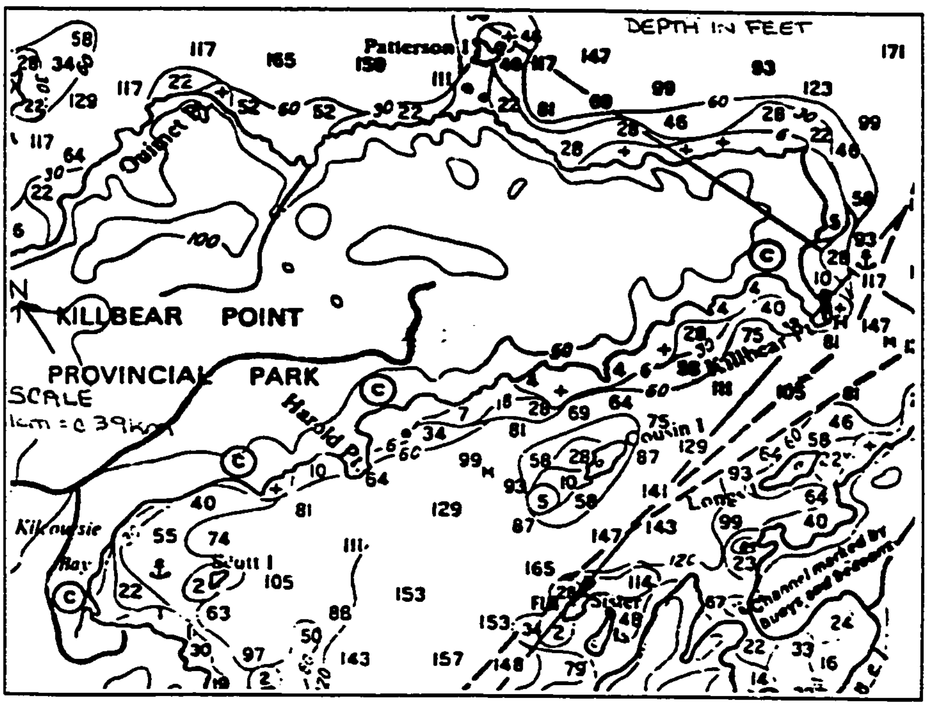
Figure 3.2: Bathymetric Changes in Kilcoursie Bay Over Time

a) Bathymetry of Kilcoursie Bay (1966)



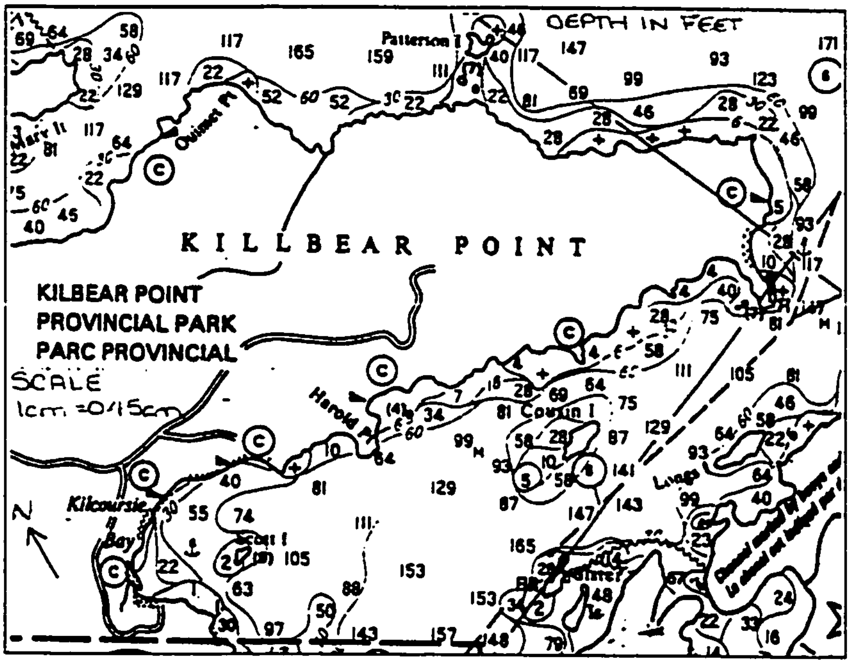
Source: Georgian Bay Small Craft Route Chart (1966)

b) Bathymetry of Kilcoursie Bay (1970)



Source: Georgian Bay Small Craft Route Chart (1970)

c) Bathymetry of Kilcoursie Bay (1988)



Source: Georgian Bay Small Craft Route Chart (1988)

Table 3.1: Observations of Wave Characteristics

Date	Wave Height	Swash Width
May 18, 1996	Minimal	WL to 0.5 metre
June 1, 1996	Minimal to Small	0.5 to 1 metre
June 2, 1996	Minimal to Small	0.5 to 1 metre
June 8, 1996	Calm to Minimal	N/A
June 23, 1996	Minimal to Small	WL to 0.5 metre
June 25, 1996	Minimal to Small	1 metre
June 26, 1996	Minimal	WL
July 20, 1996	Minimal to Small	0.5 metre
July 21, 1996	Minimal to Small	1 metre
July 22, 1996	Small	N/A
July 31, 1996	Minimal to Small	0.5 metre
August 3, 1996	Calm	N/A
August 4, 1996	Minimal	N/A
August 5, 1996	Calm to Minimal	N/A
August 17, 1996	Small	1 to 3 metre
August 18, 1996	Minimal to Small	1 to 2 metre
August 30, 1996	Minimal	WL to 0.5 metre
September 1, 1996	Minimal to Small	1.5 to 2 metre
September 2, 1996	Small (largest yet)	N/A
September 3, 1996	Minimal	N/A
September 14, 1996	Minimal to Small	N/A
September 15, 1996	Minimal	N/A
October 5, 1996	Small	1 to 2 metre
November 8, 1996	Minimal to Small	N/A
November 5, 1996	Calm	N/A

events. Typically the swash zone created by these waves is less that 1 m and often the waves break directly at the shore line. Due to the minimal wave heights (typically less than 0.5 m) wave type is difficult to determine. Later in the summer, wave development becomes more significant and wave height increases. The swash zone for these waves also increases ranging from 0.5 m to 3 m. Wave types vary significantly and include spilling, plunging and surging. Although throughout the study period wave heights observed never exceeded 0.5 m, debris lines up to 6 m above the typical water level suggest more significant wave conditions. In addition, according to several personal communications, extreme storm event which are accompanied by severe winds and waves are not uncommon for the area.

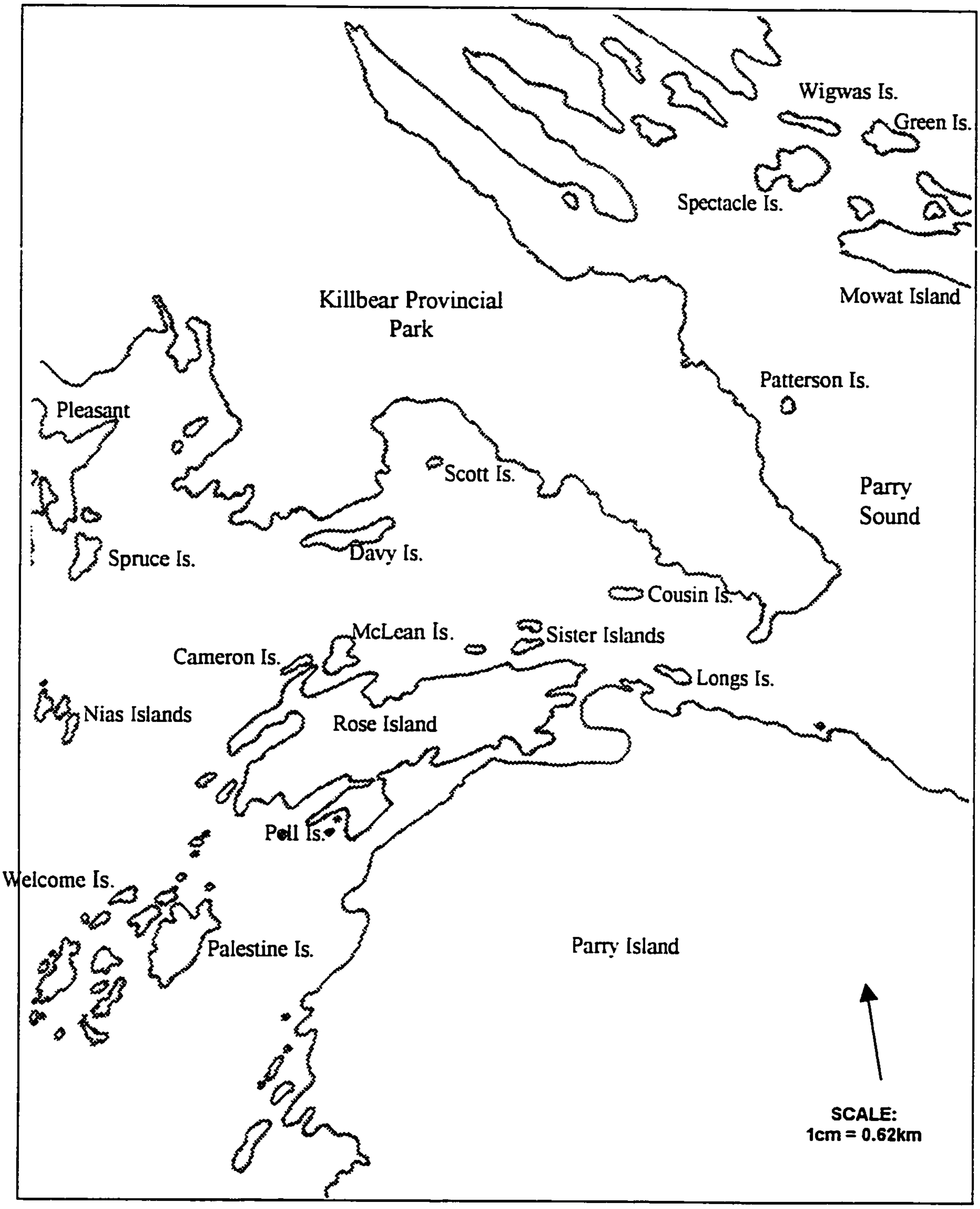
The regional geography and the presence of the large number of islands in the Parry Sound area (Figure 3.3), fetch for waves reaching Kilcoursie Bay is limited. Although the periodic extreme storm event may influence the wave and current activity within Kilcoursie Bay, wave conditions within the Bay appear to be more directly influenced by local wind conditions. The shallow depth of Kilcoursie Bay also suggests that local winds probably play a significant role influence on the wave regime.

Waves have been observed approaching th shoreline of the research area at a variety of angles. The orientation of wave approach appears to be related to local wind conditions. The topography of Kilcoursie Bay also appears to influence wave orientation as some waves seem to undergo a process of refraction as they approach the shoreline. In cases where refraction has resulted in waves approaching the shoreline at oblique angles to the wind direction, small ripples parallel to wind direction can be observed forming on the waves.

3.4 Wind Data

Wind data was obtained from the Atmospheric Environmental Service Britt Meteorological Station located approximately 200 km north of Killbear Provincial Park. The Britt Station was chosen because it was the closest coastal meteorological site. A meteorological station is located at Parry Sound however, this site is several kilometres inland and it was felt the data would not be representative of wind conditions

Figure 3.3: Islands of the Parry Sound Area



Source: Georgian Bay Small Craft Route Chart (1988)

along the shoreline. Data used consisted of hourly measurements of wind speed and direction for each day over the study period. The wind data was categorized into 16 sections based on compass direction. Calculations were then conducted to compile values of mean wind speed and percentage frequency direction at both daily and monthly intervals. Values for mean wind speed and direction frequency were plotted on radial graphs to provide visual representation of results (Appendix A). Graphs were also plotted for each individual month. Detailed analysis of monthly wind data can be found in Table 3.2.

In general during the late spring and summer, winds tended to occur more frequently from the westerly directions while winds from the northerly directions occurred more frequently during fall, winter and early spring. Wind speeds also exhibited seasonal trends, with winds occurring from the northerly directions sustaining higher mean wind speeds during spring and summer while during the fall and winter higher mean wind speeds occur from the southwesterly direction. In addition there is noticeable decrease in overall wind speeds during the late spring and summer. More specifically winds occurring between May 1996 and August 1996 exhibited higher frequency from the south to west with strongest mean wind speed occurring from north to east. Between September 1996 and October 1996 winds also show significant frequency from southwesterly directions however, winds from northeasterly directions also became more prevalent. Mean wind speeds for the periods also show similar trends with strongest winds occurring from southwesterly and northeasterly direction. November 1996 to April 1997 exhibit winds with highest frequencies occurring from westerly to easterly directions while mean wind speeds are more variable, occurring from all directions except the southeasterly direction. The frequency and mean wind speed for May 1997 returns to trends for May 1996 with southwesterly winds have the highest frequency and northerly winds being strongest.

3.5 Longshore Current Data

Again, respecting the request of park officials to avoid interfering with the recreation opportunities of the users, permanent surveying techniques were not used. Personal observation and the identification of

Table 3.2: Wind Results

a) Percentage Frequency

Month	Quadrant 1 (North to East)	Quadrant 2 (East to South)	Quadrant 3 (South to West)	Quadrant 4 (West to North)
May 1996	29%	12%	49%	8%
June 1996	10%	16%	46%	26%
July 1996	16%	4%	40%	40%
August 1996	13%	3%	56%	26%
September 1996	35%	28%	23%	16%
October 1996	25%	12%	44%	15%
November 1996	29%	26%	9%	34%
December 1996	33%	25%	24%	15%
January 1997	21%	26%	15%	35%
February 1997	32%	15%	29%	25%
March 1997	29%	16%	13%	42%
April 1997	24%	9%	23%	43%
May 1997	19%	9%	42%	28%
Average	23%	15%	32%	27%

Table 3.2: Wind Results (cont.)

b) Average Wind Speed (km/h)

Month	Quadrant 1 (North to East)	Quadrant 2 (East to South)	Quadrant 3 (South to West)	Quadrant 4 (West to North)
May 1996	9.17	4.67	6.09	5.50
June 1996	6.00	4.40	4.50	5.50
July 1996	9.25	2.50	4.10	5.60
August 1996	5.25	4.00	3.76	4.25
September 1996	5.67	4.00	4.33	3.75
October 1996	8.38	5.00	7.57	12.20
November 1996	4.89	4.13	7.67	6.40
December 1996	6.70	3.50	8.25	5.80
January 1997	8.14	5.88	10.60	6.64
February 1997	8.22	4.00	8.13	6.00
March 1997	4.67	3.60	3.75	5.54
April 1997	4.43	3.33	3.29	3.46
May 1997	6.17	5.00	3.15	5.11
Average	6.69	4.15	5.78	5.83

geomorphic features along the shore were used to determine direction of longshore current. Tracer techniques, based on the Littoral Environment Observation Scheme of the U.S. Army Corps of Engineers (Gardiner et al. 1983), were used to determine current direction and speed over the short term. This technique involved the use of driftwood or another floating object placed within the surf zone and the time required for the object to travel 1 m along the shore measured. This provided information on direction and speed of longshore currents. The results of these longshore current observations are recorded in Table 3.3. Over the field season the direction of current varied therefore geomorphic features along the shore were used as indicators of net current direction over the long term. Such a technique was described by Bird (1996) and Jacobaea and Schwartz (1981).

Based on observations and measurements throughout the study period, it appears that Kilcoursie Bay acts as a single circulation cell. Due to the shallow depth of the Bay, local wind conditions appear to significantly influence the development of longshore currents. As a result currents within the Bay are relatively variable however seasonal trends can be interpreted from the data. During the late spring and summer, wind conditions tend to set up longshore currents which primarily circulate in a counterclockwise direction while during the fall and early spring clockwise current directions are more typical (Figure 3.4). Ice cover from approximately December to April prevents the measurement of currents, but it is assumed that wind induced currents are negligible.

Although the measurements during the study period indicate no predominant direction of longshore current, geomorphic features within Kilcoursie Bay suggests that clockwise current directions exert more influence over the long term. Figure 3.5 illustrates several of these geomorphic features.

3.6 Sediment Transport Analysis

Over the course of the study period sediment transport was measured using two techniques. The first method involved observation and documentation of transport or of features indicative of recent transport, while the second method utilized sand traps. Unfortunately to avoid the possibility of interfering

Table 3.3: Observations of Longshore Current

Date	Clockwise	Counter Clockwise	Approx. Speed (m/s)	Wind Direction
May 5, 1996	/			ENE
May 18, 1996		/		SSW
June 2, 1996		/		S
June 23, 1996	/		0.1	NW
June 25, 1996	/		0.2	WNW
June 26, 1996		/	0.06	SSW
July 20, 1996	/			N
July 21, 1996	/		0.24	WNW
August 17, 1996	/		0.22	W
August 18, 1996	/		0.26	W
August 30, 1996	/		0.34	WSW
September 1, 1996	/		0.22	WSW
September 3, 1996		/	0.14	WSW
September 15, 1996		/	0.15	N/A
October 5, 1996		/	0.17	S
April 22, 1997		/		NE
May 8, 1997		/		SSE
May 15, 1997		/		NE

Figure 3.4: Longshore Current Measurements

a) Observations Recorded for July 31, 1996

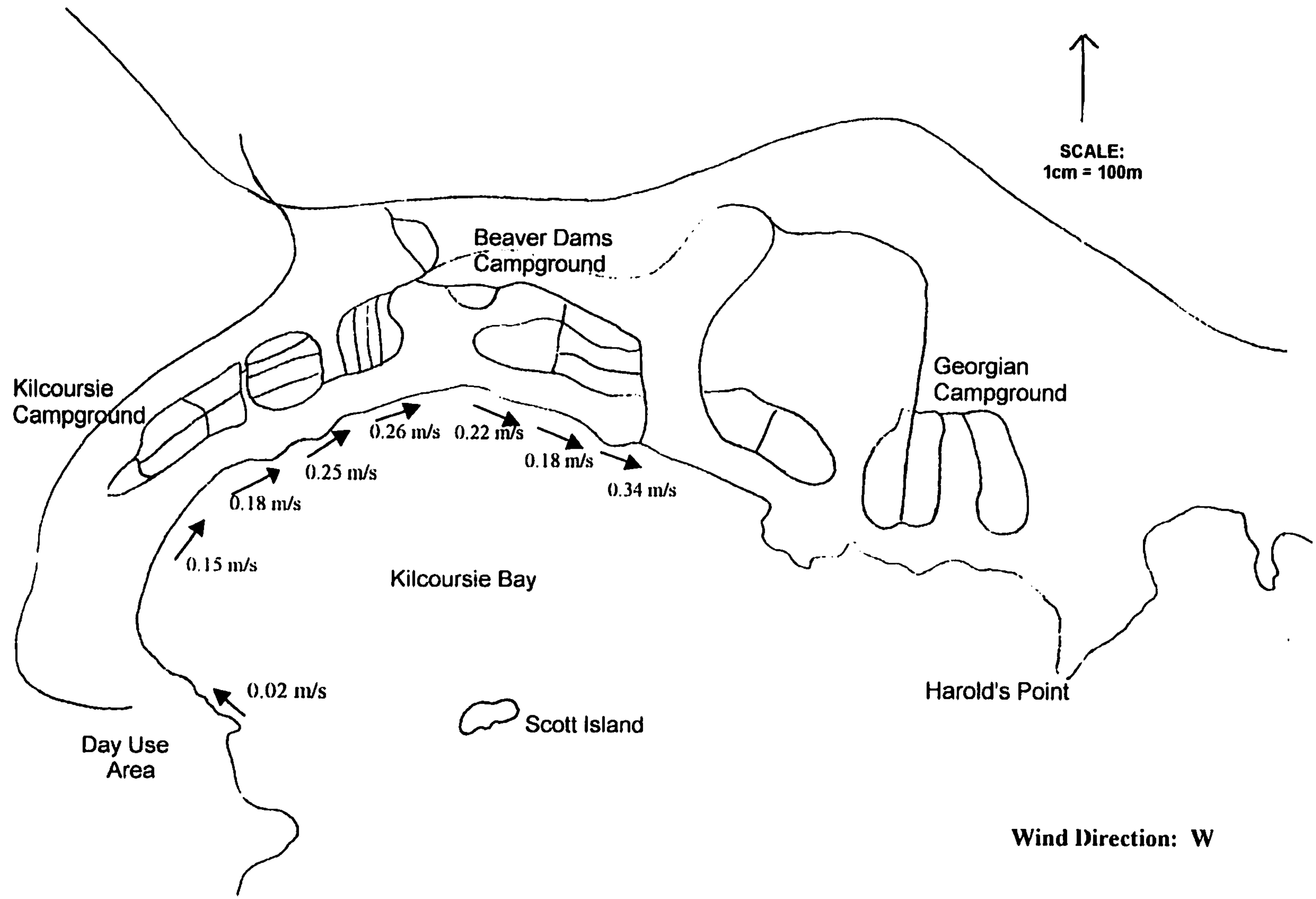


Figure 3.4: Longshore Current Measurements

b) Observations Recorded for August 31, 1996

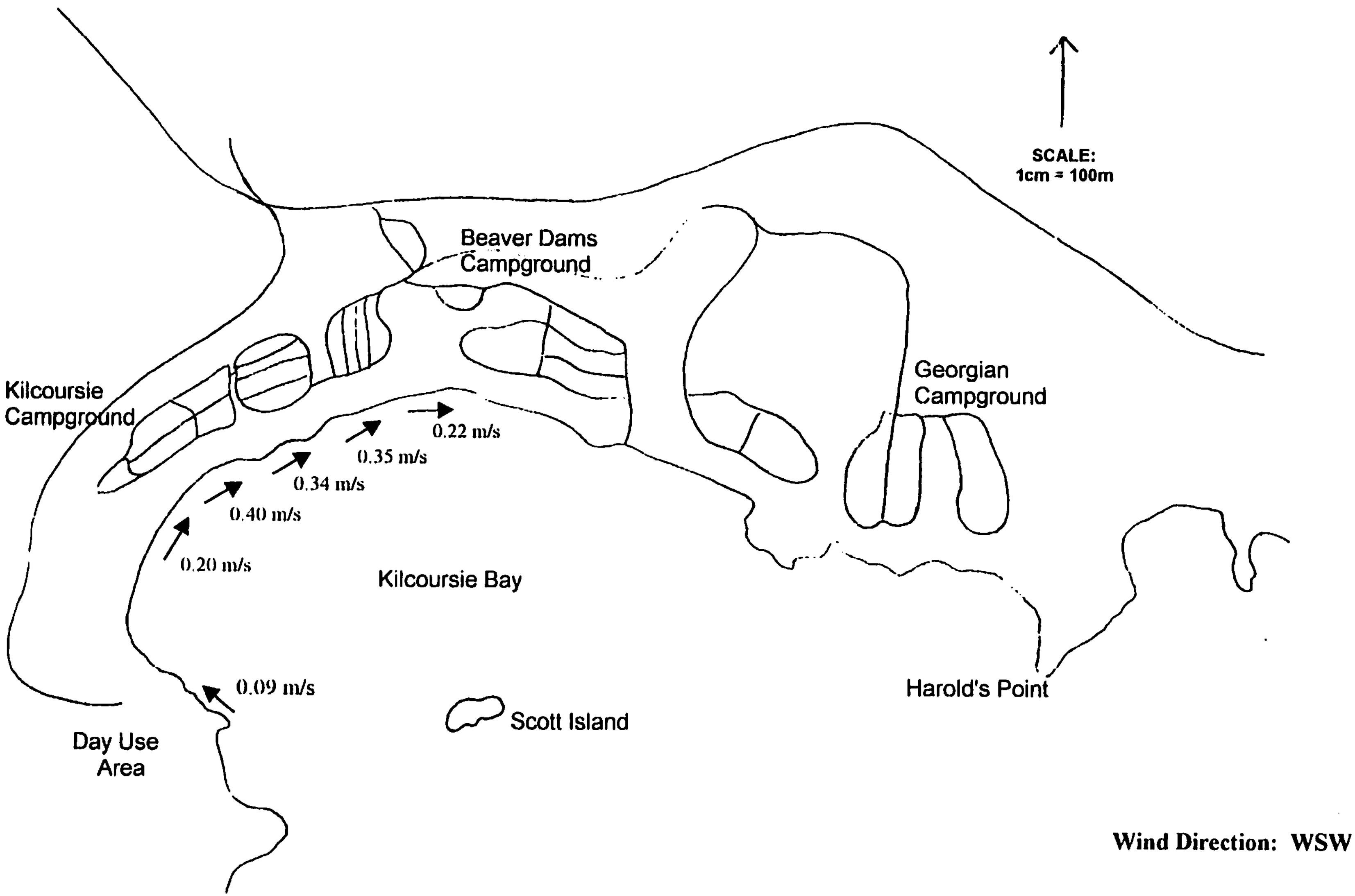


Figure 3.4: Longshore Current Measurements

c) Observations Recorded for September 15, 1996

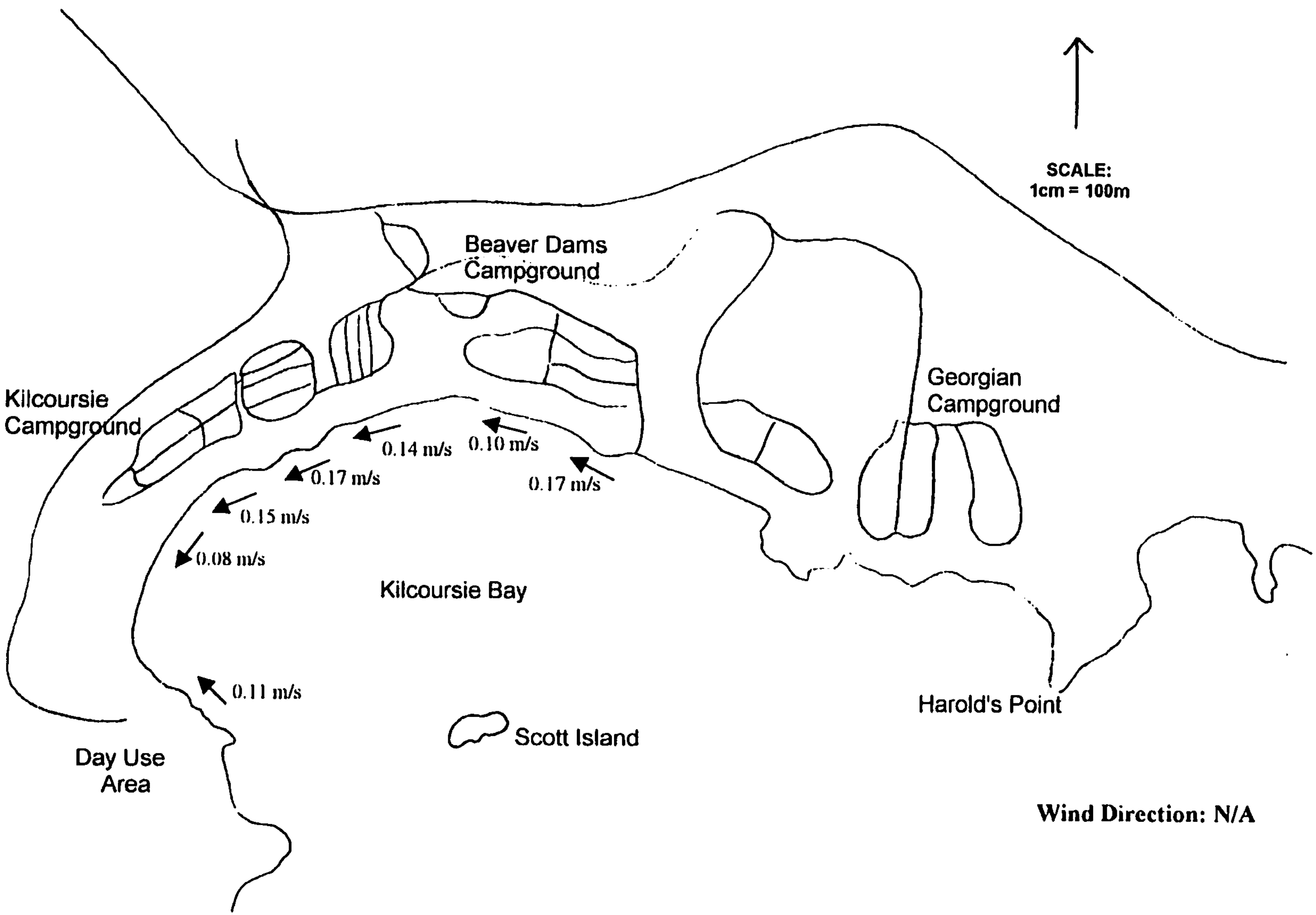


Figure 3.4: Longshore Current Measurements

d) Observations Recorded for October 5, 1995

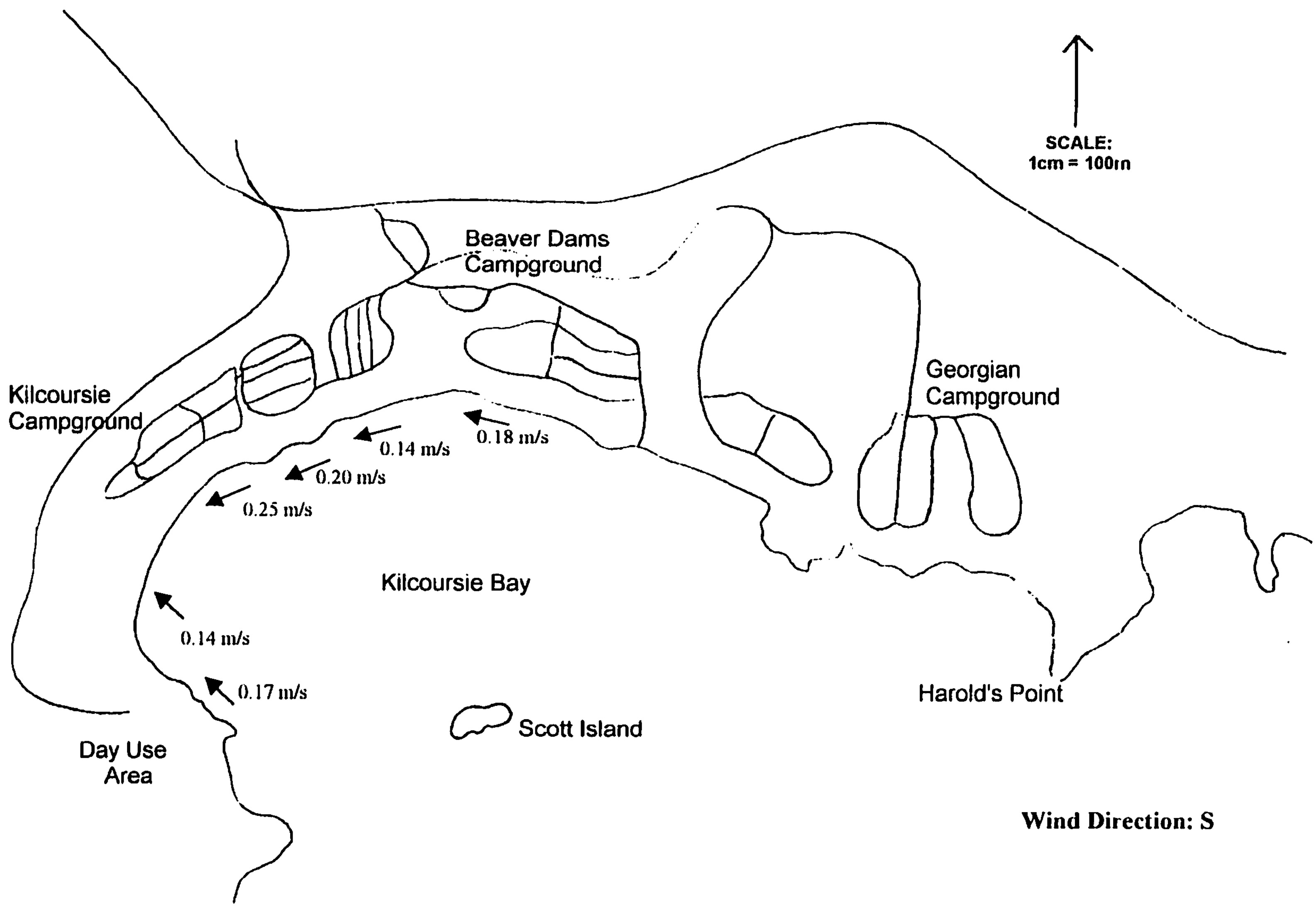


Figure 3.5: Geomorphic Indicators of Longshore Current Direction

a) Spit Formation at Beaver Dams Boat Launch Indicates Counterclockwise Current Direction

Looking Out of Bay

Source: Photo taken May 1996

b) Spit Formation at Kilcoursie Beach Line 3 Indicates Clockwise Current Direction

Looking Out of Bay

Source: Photo taken June 1996

) Spit Formation at Day-Use Beach Indicates Clockwise Current Direction

Looking Into the Bay

Source: Photo taken October 1996

with the visitor's beach activities the sand traps were only established after the park had closed for the season. The data on sediment transport between May 1996 and November 1996 therefore relied on observation and documentation, while quantitative measurements from sand traps were available from November 1996 to May 1997.

Actual sediment transport was rarely observed. Even during relatively strong wind conditions, sediment movement was negligible. However, the presence of aeolian features and structures such as ripples, adhesion structures and the development of pebble lags indicate sediment transport was in fact occurring. In addition, depositional and scouring patterns around several beach obstacles also provided evidence of sediment transport. For example, Beaver Dams parking lot, which was constructed with a gravel surface, has developed a thin blanket of sand along its shoreward margin. Also, the large boulders at the Kilcoursie parking lot developed significant accumulations of sediment on their landward edge and sediment was observed accumulating within the trees opposite these boulders. Photographic evidence of such aeolian transport features are presented Figure 3.6.

Sand traps were established at the research site in late October. Sand traps used were based on those described by Leatherman (1978) and Rosen (1979) and consisted of a 1 m long, 10 cm diameter PVC pipe buried vertically in the sand to a depth of 50 cm (Figure 3.7). The exposed half of the trap had tow 46 cm high slits on opposite sides, with the front slit being approximately 6.5 cm wide, while the back slit was 10 cm wide and covered by a fine mesh. This design allowed wind to blow through the trap but collected any sediment being transported by the wind. A removable inner liner, made of a smaller diameter PVC pipe, was placed inside the buried portion of the trap and collected the sand. The inside liner could therefore be removed and the accumulated sediment bagged and taken to lab analysis and the liner replaced.

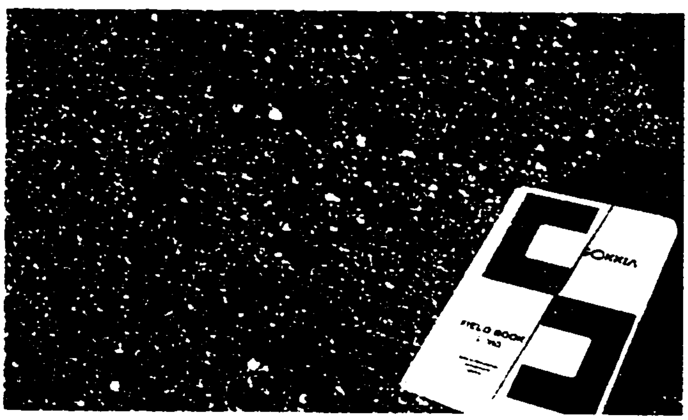
Three groups of traps were established on Kilcoursie Beach and one group on Beaver Dams beach. The traps were installed along previously established profile lines namely Kilcoursie lines 1, 4 and 7 and Beaver Dams line 4 (Figure 3.8a,b). Four sand traps were included in each group, one with each slit facing

Figure 3.6: Evidence of Aeolian Sediment Transport

a) Accumulation of New Sediment in Fresh Footprint

Source: Photo taken October 1996

b) Pebble Lag Deposit at Kilcoursie Line 4



Source: Photo taken October 1996

c) Ripple Formation on Beaver Dams Beach

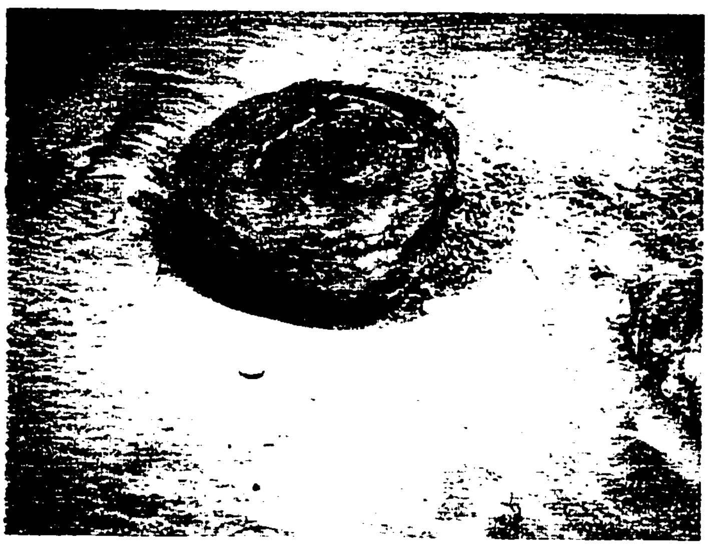
Source: Photo taken October 1996

Figure 3.6 cont...

d) Sediment Shadows Around Beaver Dams Parking Lot Posts

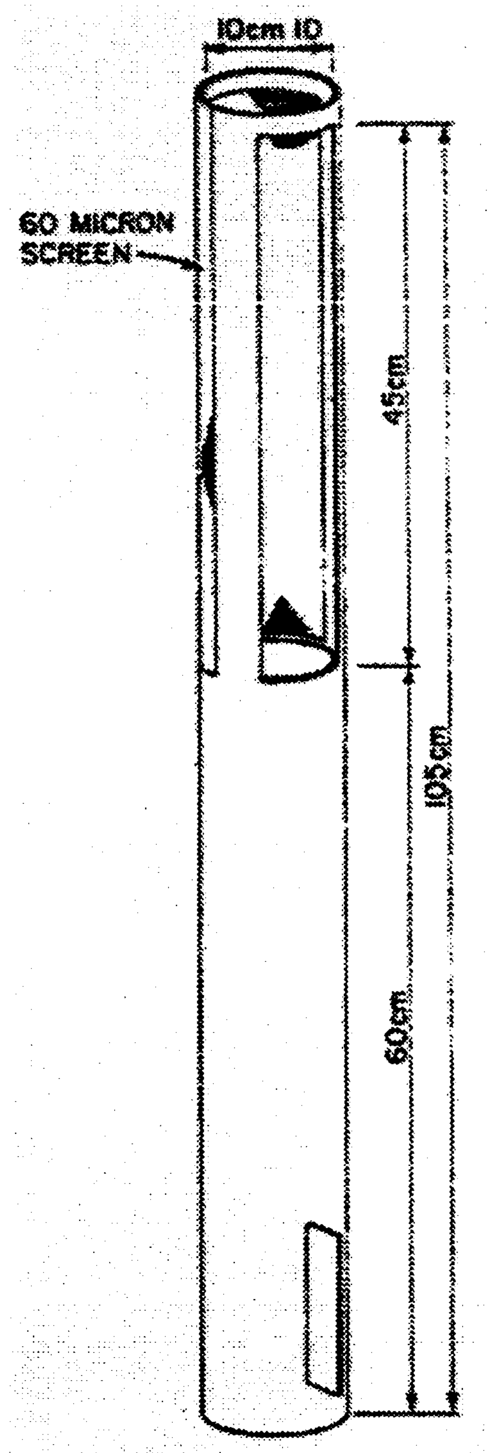
Source: Photo taken June 1996

e) Ripple Formations and Scouring Patterns Around Boulder Near Kilcoursie Line 1



Source: Photo taken October 1996

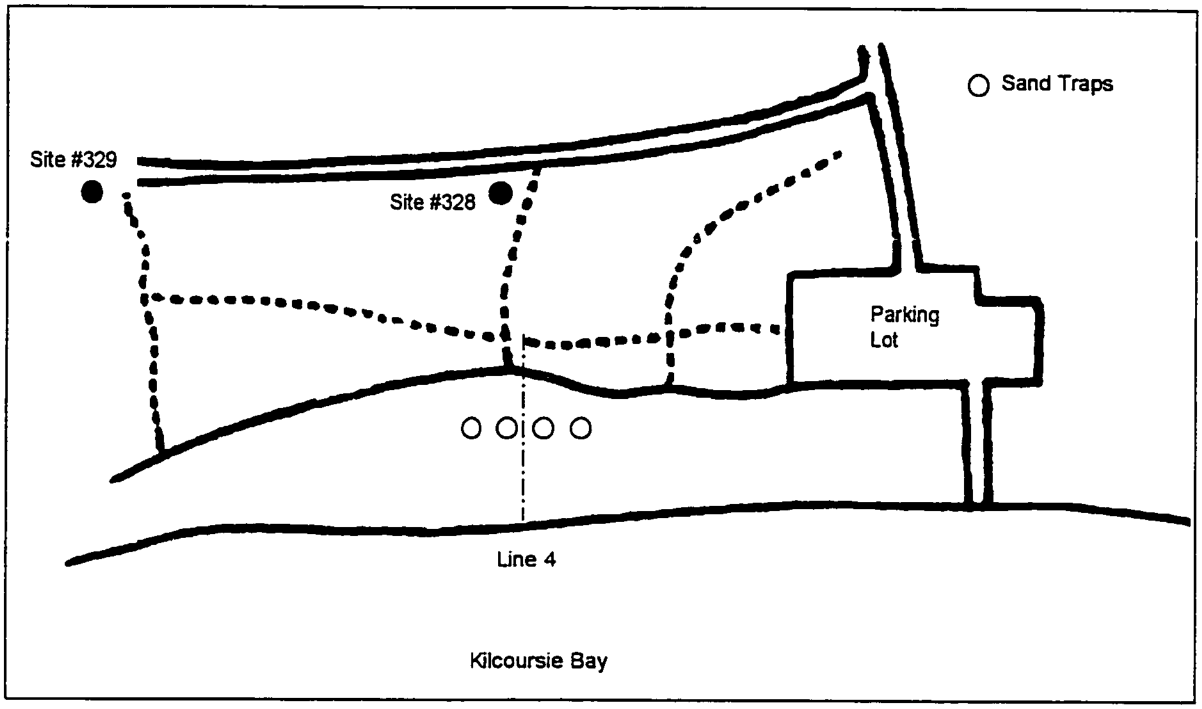
Figure 3.7: Sand Trap Used for Aeolian Sediment Studies



Source: Rosen (1978)

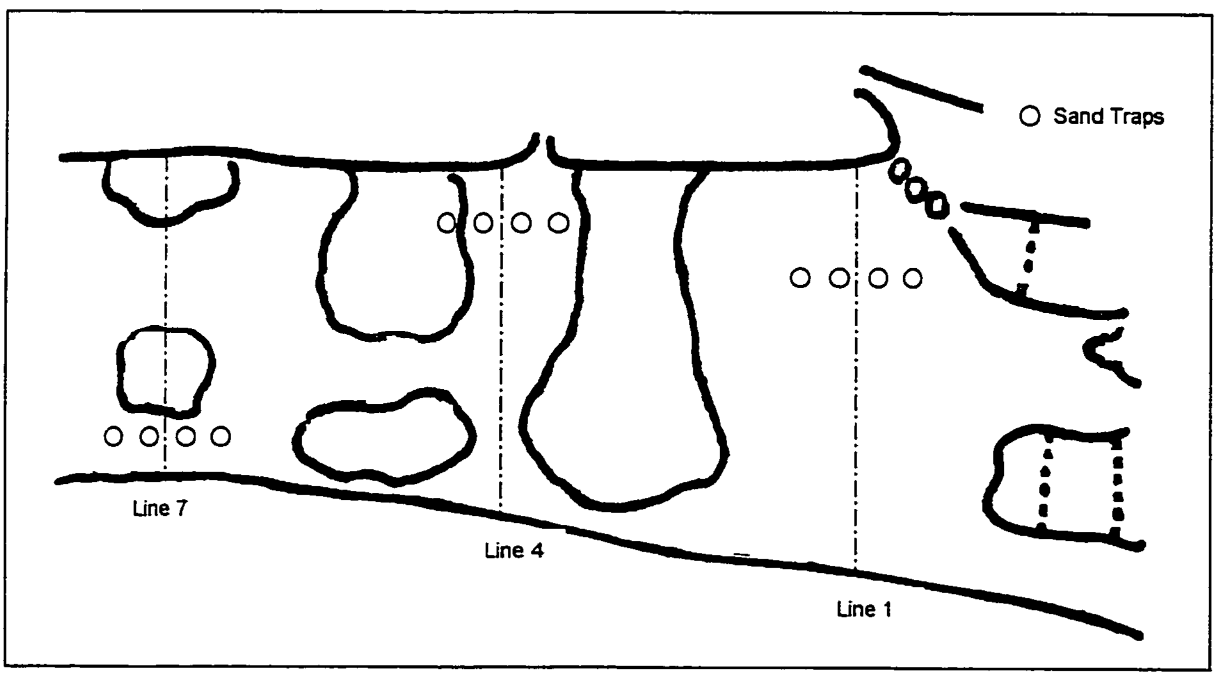
Figure 3.8: Sample Collection and Sand Trap Locations

a) Beaver Dams Campground



Source: Killbear Provincial Park Master Plan (1978)

b) Kilcoursie Campground



Source: Killbear Provincial Park Master Plan (1978)

each cardinal compass direction. The sand traps provided strong evidence on quantity and extent of transport and showed that sand transport was more significant in the northerly to easterly direction.

It should be noted that although sediment transport appears to occur throughout the study period, the most significant evidence was observed and recorded in the fall and early spring. Evidence also suggests a predominantly oblique onshore movement of sand with the most effective transport occurring primarily in an easterly to northeasterly direction.

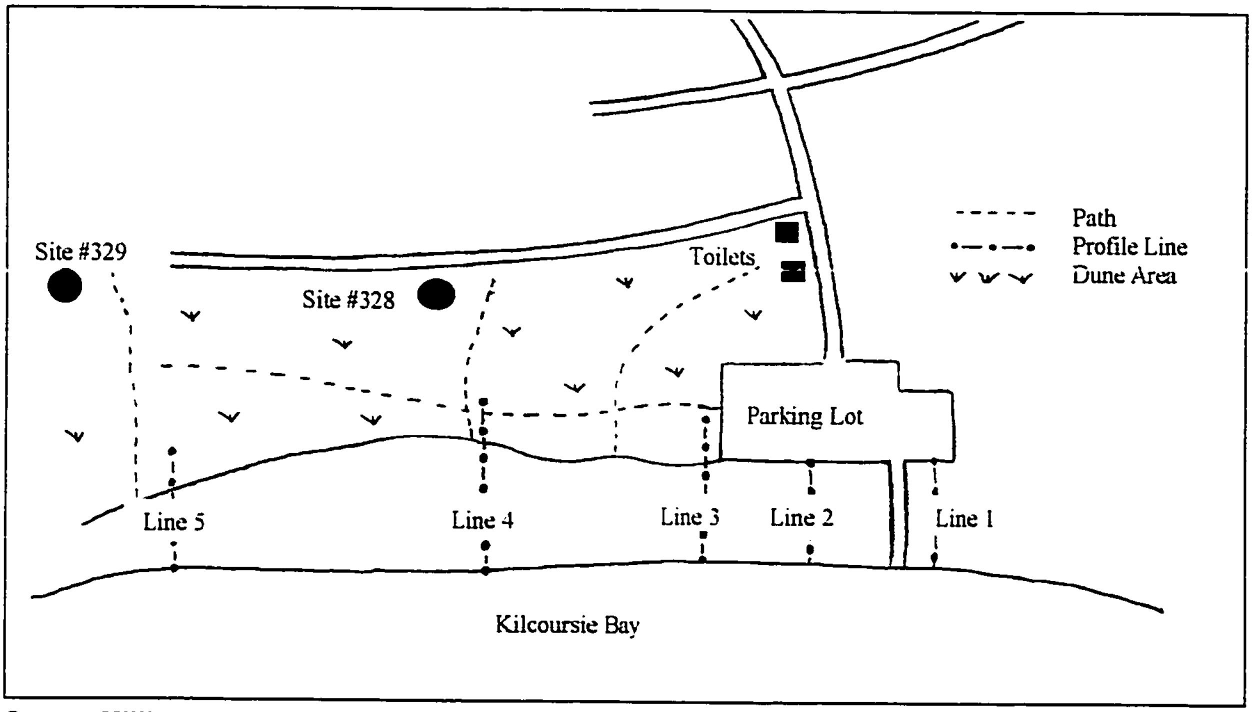
3.6 Profile Lines

Profile lines were established along both the Kilcoursie and Beaver Dams research sites to determine beach profiles, monitor changes in profile and provide information on sediment transport. Five profile lines were established at Beaver Dams beach, while seven line were established at the Kilcoursie beach site (Figure 3.9a,b). Profile lines were at right angles to the beach and typically extended from the forest/beach boundary lakeward to the waterline. Semi permanent 2X2 wooden stakes were established as benchmarks.

Surveys were conducted on a monthly basis, except over the winter, using a level and stadia rod to measure changes in beach slope and elevation. The process of surveying the profile lines was completed with the voluntary assistance of park employees or friends. Due to the significant number of profile lines established along the two survey sites and the time required to train volunteers in the necessary surveying techniques it was often difficult to survey all of the profile lines in a single day. Typically the surveying started with the Beaver Dams site and therefore lines along the Kilcoursie site were not consistently surveyed. In order to ensure survey data gathered from the Kilcoursie beach was suitable for analysis it was decided to focus on profiles 1, 4, and 7 and to conduct surveys of the other profile lines if and when time permitted. As a result only the analysis of lines 1, 4 and 7 are presented here. Survey data are available for the other profiles, and although not enough data was collected to accurately portray or predict morphological changes over the length of the study period, this data could prove useful as a base line or to

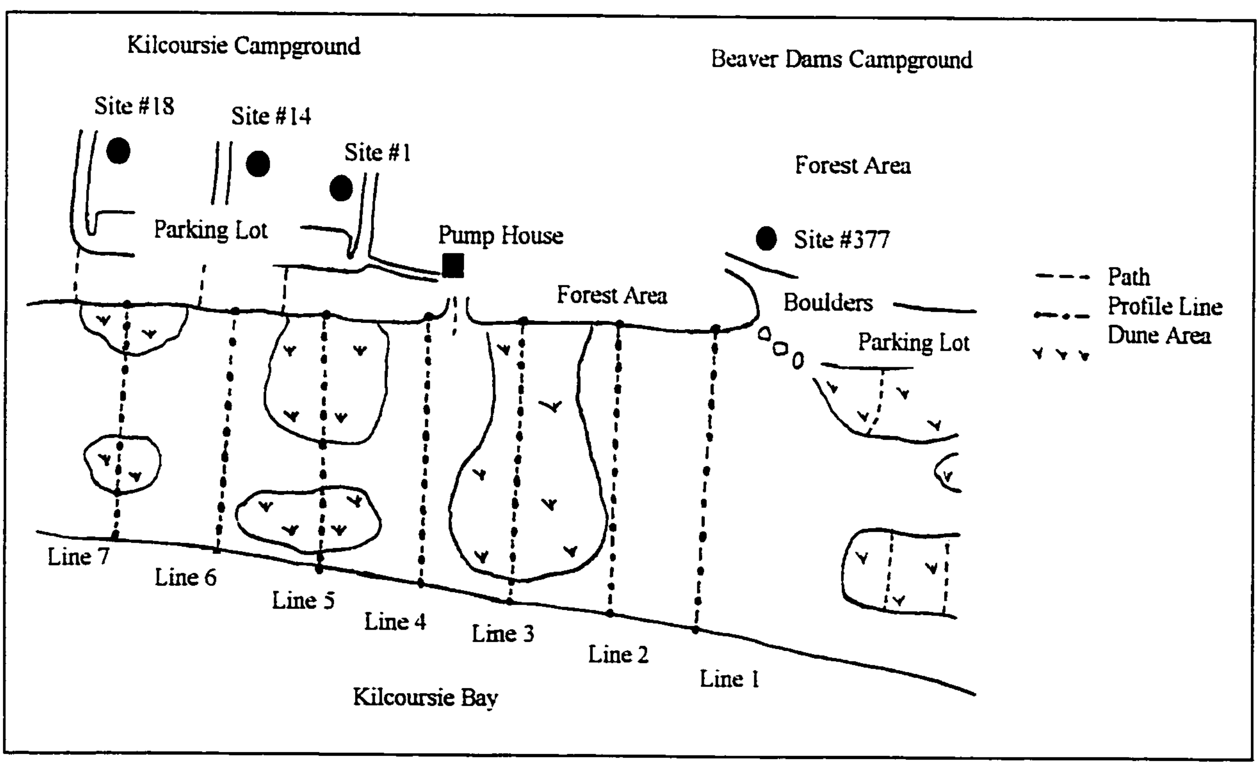
Figure 3.9: Sketch of Profile Lines Locations

a) Beaver Dams Campground



Source: Killbear Provincial Park Master Plan, 1978

b) Kilcoursie Beach Campground



Source: Killbear Provincial Park Master Plan, 1978

discern morphological changes for future surveys.

3.6.1 Beaver Dams

Five profiles were located at the Beaver Dams beach in the vicinity of the parking lot and boat launch (Figure 3.9a). Line 1 is the southernmost line located at the southeast end of the parking lot just past the boat launch. The fifth guard rail post from the southeast corner of the parking lot and the "No Dogs" sign served as benchmarks and the profile line followed a 214 degree bearing. Line 2 is located at the southern portion of the survey site on the southwestern side of the boat launch. The eighth guard rail post to the northwest of the boat launch and the recycle bin metal T-bar serve as benchmarks and the profile line follows a 222 degree bearing. Line 3 is located at the eastern edge of the parking lot just to the southwest of the large eroding pine tree located on the upper beach. A pine tree located in the established dune area served as a benchmark and the line followed a 220 degree bearing. Line 4 is located at the northwestern end of the survey site just southwest of a prominent path leading from the campground through the dunes to the beach. Two wooden stakes were established as benchmarks along a bearing of 203 degrees. Line 5 is the northwestern most profile line at the Beaver Dams site. The line is located at the western end of the beach just southeast of the path from campsite #329 to the beach. The tree near the dune/beach boundary and a wooden stake serve as benchmarks and the profile line follows a 221 degree bearing. A summary of the morphological data collected for the Beaver Dams research site from the field surveys is presented in Table 3.4.

Line 1 has a beach width of approximately 34 m with an average gradient of approximately 0.11, however a significant scarp face was located between 14 m and 18 m with a gradient of approximately 0.24. After analyzing the survey data and plotting profile lines (Figure 3.10a), line 1 shows an accumulation of sand near the water line in the form of a berm or ice push ridge during the spring months which gradually dissipates over the summer to fall. The line also shows an overall accumulation of sediment at the base of the scarp. In addition, there is a slight erosion of sediment on the upper portion of

Table 3.4: Beach Morphology Summary

a) Beaver Dams Survey Site

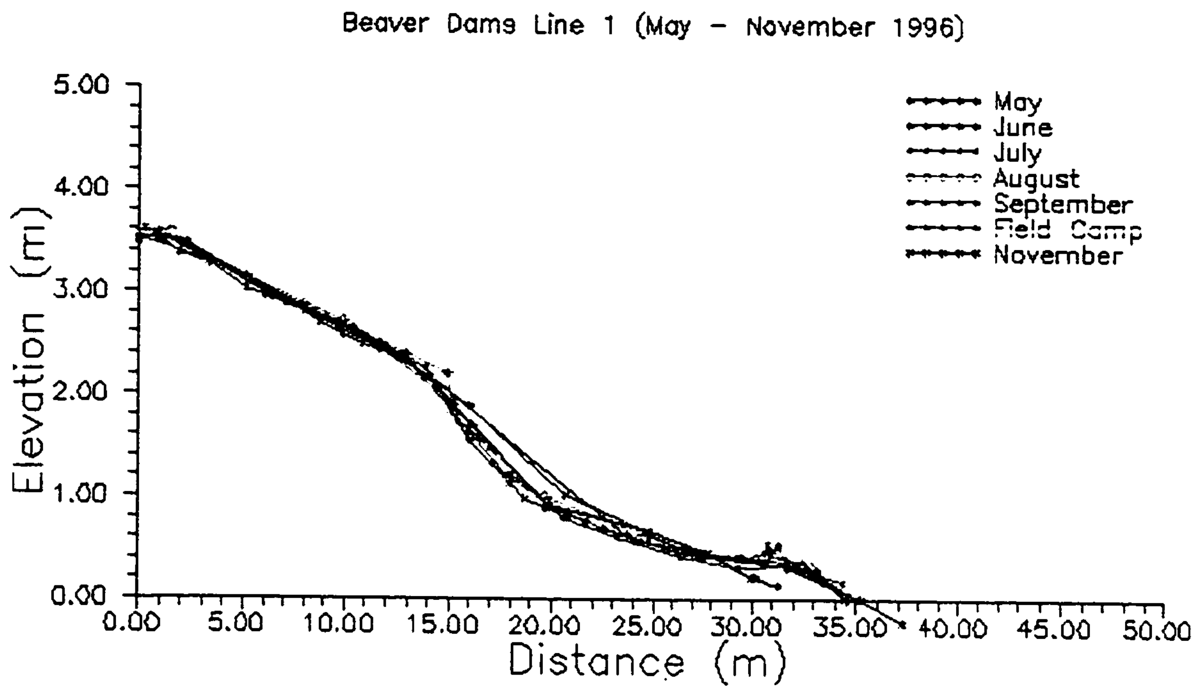
Profile No.	Orientation (degrees)	Orientation (cardinal)	Beach Width (metres)	Average Slope
1	214	SW	34	0.11
2	222	SW	31	0.11
3	220	SW	32	0.11
4	203	SSW	34	0.11
5	221	SW	21	0.10

b) Kilcoursie Beach Survey Site

Profile No.	Orientation (degrees)	Orientation (cardinal)	Beach Width (metres)	Average Slope
1	210	SSW	48	0.08
2	204	SSW	48	N/A
3	208	SSW	42	N/A
4	203	SSW	32	0.14
5	191	SSW	35	N/A
6	190	SSW	39	N/A
7	189	S	38	0.12

Figure 3.10: Profile Line Plots

a) Beaver Dams Survey Area



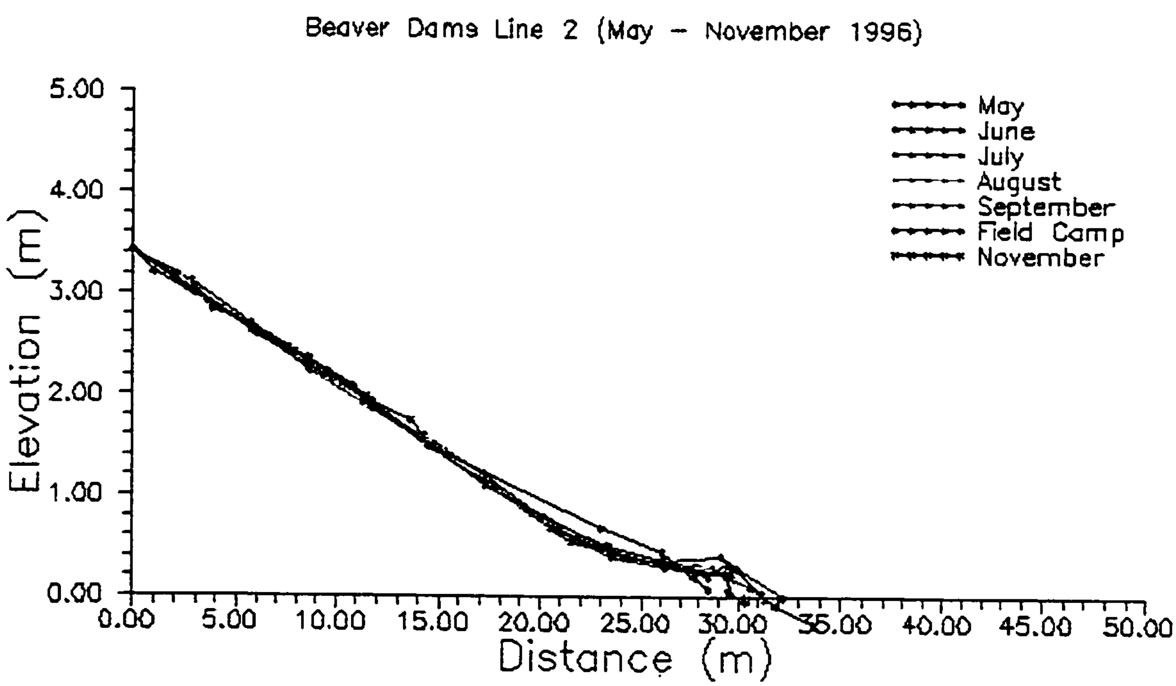
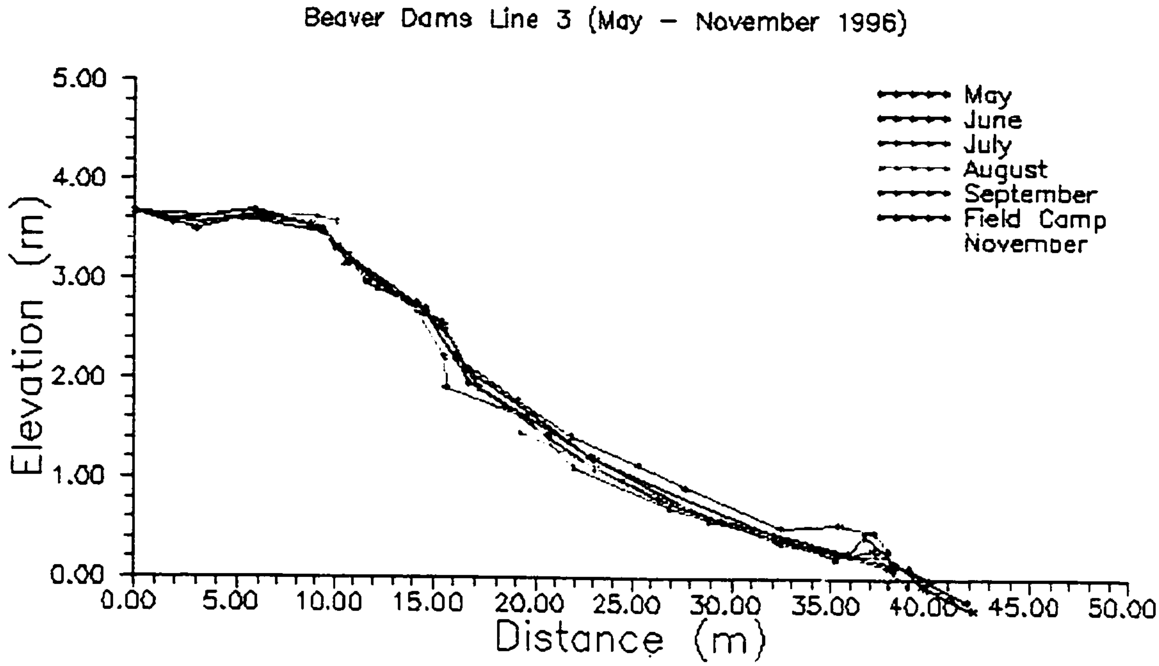


Figure 3.10a cont...



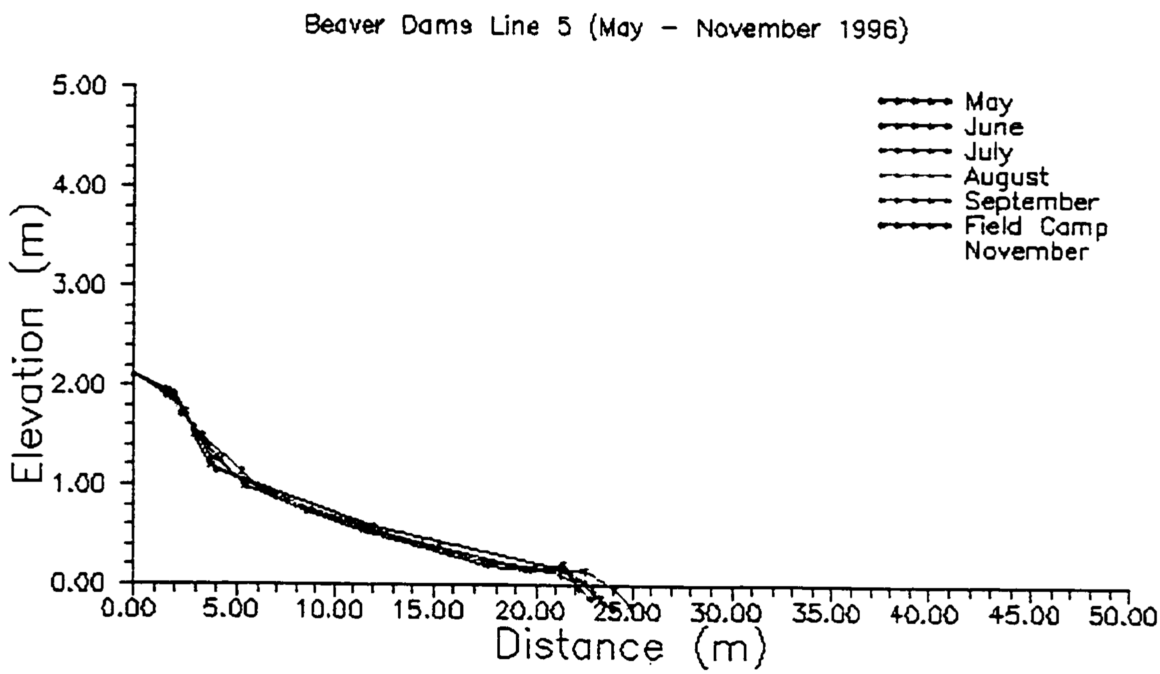
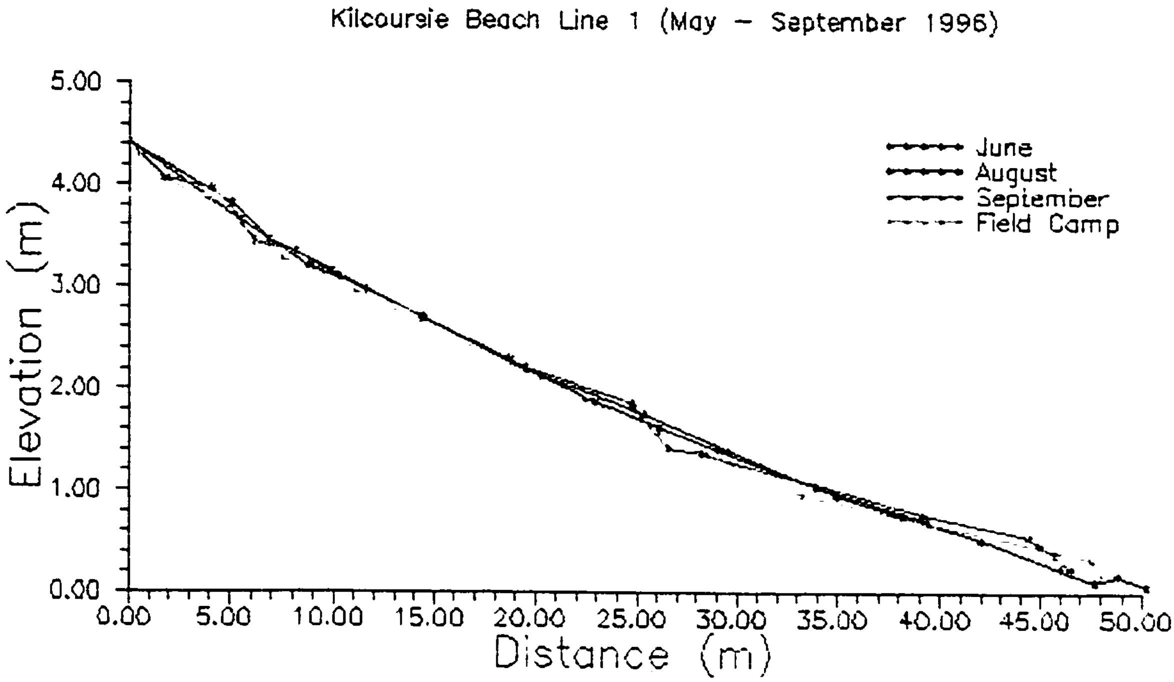


Figure 3.10: Survey Profile Plots

b) Kilcoursie Beach Survey Area



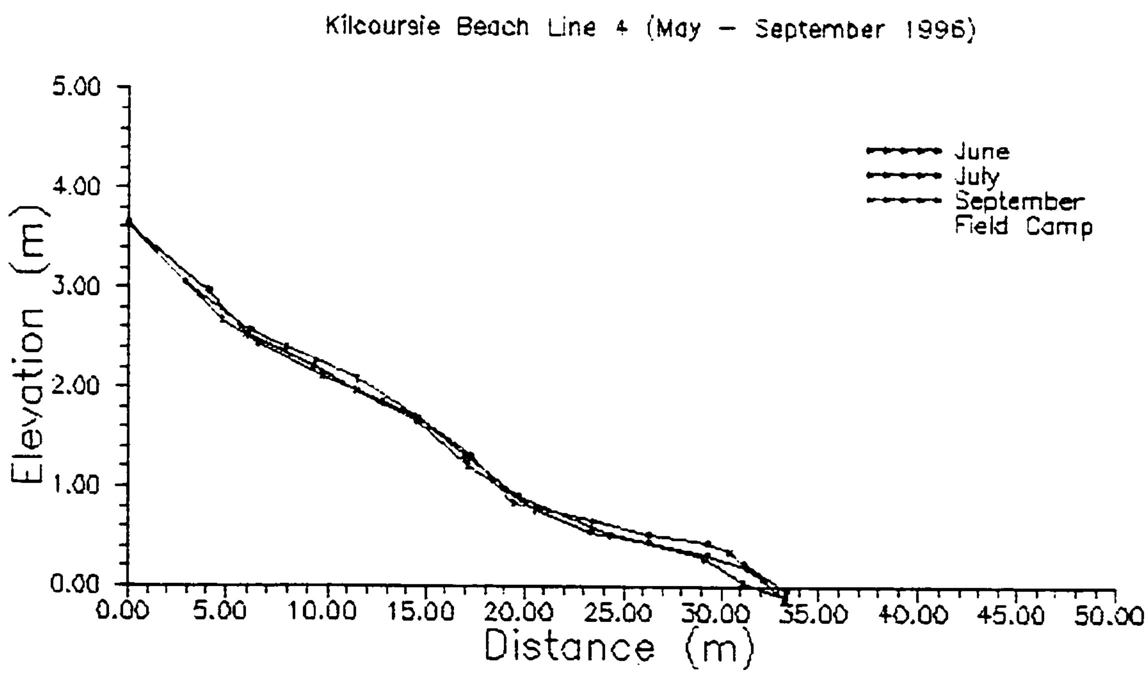
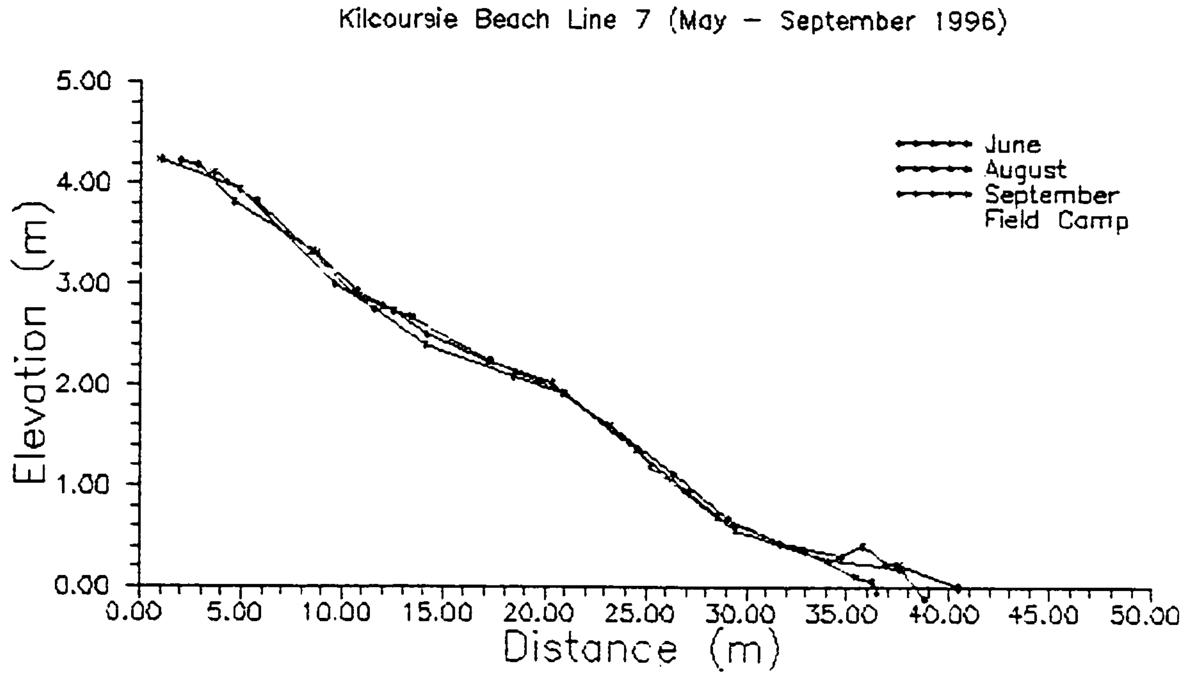


Figure 3.10b cont…



the beach between the parking lot and the top of the scarp.

Line 2 has a beach with of approximately 31 m with an average gradient of approximately 0.11. Figure 3.10a illustrates an accumulation of sediment just above the water line which gradually dissipates over the summer and fall. In addition, the profile suggests a slight accumulation of sediment on the lower portion of the beach and a slight erosion on the upper portion of the beach.

The beach width for line 3 is approximately 32 m with an average gradient of 0.11, however line 3 has a slight scarp located adjacent to the large eroding pine tree on the upper beach between 14 and 17 m. This scarp has an average gradient of approximately 0.25. Analysis of survey data (Figure 3.10a) again shows accumulation of sediment just above the water line in the spring in the form of a berm or ice push ridge which decreases gradually over the summer. The profile also illustrates an accumulation of sediment at both the base and just above the upper portion of the scarp in spring and early summer, however there is an overall erosional trend for these portions of the profile line. In addition, the upper portion of the beach, just lakeward of the dune edge, also shows an overall decrease in sediment levels.

Line 4 has an approximate beach width of 34 m with an average gradient of 0.11. No significant change in slope in present along the beach for this profile line, however a dune scarp at the beach/dune margin has an average gradient of 0.50. The line also has the most significant dune development of the lines surveyed, however for the most part, the profile focused on the beach and the dune region was not included in the study. Unfortunately one of the 2X2 wooden stakes used as a benchmark along line 4 was lost early in the survey season. Surveys of the profile continued, however the exact line orientation could not be replicated and analysis of the data showed severe discrepancies. As a result, the profile analysis for this line was not included here.

The beach width at line 5 is approximately 21 m with an average beach slope of 0.10. Line 5 also has significant dune development but as mentioned above the dune region was not included in the profile surveys. The gradient of line 5 remains relatively constant with no significant changes in slope, however a dune scarp at the beach/dune margin has a gradient of 0.13. Survey data (Figure 3.10a) suggest once again the accumulation of sediment just above the water line in early spring which gradually erodes over the summer. Profile analysis also shows a slight accumulation of sediment on the lower portion of the beach while the base of the scarp shows erosion over the summer but subsequent sediment accumulation over the remainder of the study.

After considering the general morphological changes at each profile line within the Beaver Dams survey site, general trends for the entire site can be estimated. The development of a push ridge or berm just above water level is consistent for all lines. Although the rate of erosion for the ridge varies, the ridge gradually appears to dissipate landward over the summer. In general, the lower portion of the beach shows an overall trend of sediment accumulation. This accumulation is likely to be attributed to the sediment from the push ridge. The upper beach shows an overall erosional pattern. This is possibly due to the presence of a scarp feature on the mid beach at several of the lines. This scarp would likely prevent sediment movement from moving landward from the lower beach. In addition, little vegetation is present on the upper portion of these profiles and therefore this sediment is much more vulnerable to entrainment by the wind.

3.6.2 Kilcoursie Beach

Seven profile lines were established along Kilcoursie Beach starting at the small parking lot near Beaver Dams campsite 336 and extending northwesterly (Figure 3.9b). However, as previously mentioned, only the information and results from Line 1, 4 and 7 are presented here. Line 1 is the southeastern most profile line located just west of the small parking lot near Beaver Dams campsite 336. A large tree at the back of the beach beside a small path was used as a benchmark and the proline line followed a bearing of 210 degrees. Line 4 is located in the central portion of the survey site just to the west of the dune cut which leads through the forest to a pump house. A single wooden stake was used as a benchmark and the line was surveyed along a 203 degree bearing. Line 7 is the northwestern most profile line in the survey site. It is locate just east of the 'staff beach' and posts for a volleyball net. A trail to the parking lot is located just east of the profile line. Two wooden stakes were established as benchmarks along a 189 degree bearing. A summary of the morphological data collected for the Kilcoursie Beach research site from the field surveys is presented in Table 3.4.

Line 1 has a beach width of approximately 48 m with an average gradient of 0.08. The gradient along the profile line is relatively consistent with no significant changes in slope. Analysis of the survey data for line 1 (Figure 3.10b) indicate an accumulation of sand as a berm or ice push ridge just above the water line in the spring which dissipates over the summer. The profile also indicates erosion of sediment on the mid to upper portion of the beach and an increase or accumulation of sediment on the upper portion of the beach.

Line 4 has a beach width of approximately 32 m with a slope averaging 0.11. A significant increase in the slope is present between 14 m and 20 m along the profile with an average of 0.14. The profile of line 4 (Figure 3.10b) indicates an overall increase in sediment levels just above the water line and an accumulation of sediment along the mid to lower portion of the beach over the summer, with a decrease in sediment levels for the remainder of the survey. In addition, the analysis indicates an overall accumulation of sediment on the mid to upper portion of the beach although this section also appears to have suffered erosion in the late spring to early summer while the upper portion of the beach has had an overall erosional trend.

The beach at line 7 is approximately 38 m in width with an average slope of 0.12. The gradient remains relatively constant with no significant changes in slope, however the profiles line does run through two separate and distinct dune ridges, which are observed on the profile at 0 m to 8 m and 18 m to 24 m. Profile 7 (Figure 3.10b) again indicates the presence of a sediment accumulation in the spring which slowly dissipates over the summer. Analysis also indicates an overall increase in the sediment levels on the lower beach. There also appears to be an erosional trend on the lakeward side of the lower dune (24 m) and an overall decrease in sediment levels along the mid section of beach, however profiling suggests little change in either dune ridge or on the upper portion of the beach.

After considering the general morphological change at each profile line within the Kilcoursie survey site, it appears that the development of a push ridge or berm just above water level is consistent for all lines. Although the rate of erosion for the ridge varies, the ridge also appears to gradually dissipate landward over the summer. In general, the lower portion of the beach shows an overall trend of sediment accumulation. This accumulation is likely to be attributed to the sediment from the push ridge. In general, the upper portion of the beach shows a slight increase in sediment levels early in the survey period however overall erosional pattern is predominant.

3.7 Sand Analysis

3.7.1 General Analysis

Sand samples were collected monthly at 5 m intervals along Beaver Dams profile line 4 and profile lines 1, 4 and 7 on Kilcoursie Beach (Figure 3.8a,b). Initially it had been intended to process and analyze each sample, however due to the shear volume of samples, it was decided that only select sample groups would be analyzed. Samples from June 1996, August 1996, October 1996 and May 1997 were chosen for analysis as it was felt they would provide representation of spring, summer and fall sediment conditions.

Analysis of these sediment samples was conducted at Wilfrid Laurier Geomorphology Laboratory and at the Geological Survey of Canada (Atlantic) Sediment Lab. Samples were analyzed to determine grain size distribution and composition. The standard dry sieving techniques, as outlined by Folk (1968), were used as a guideline when conducting sediment analysis. A 500 g sample was sieved through a series of seventeen progressively fining sieves. Mesh sized were between +2.0 phi and -4.0 phi at 0.5 phi intervals. Samples were sieved for approximately 20 minutes and the weight of each separate grain size was measured. This information was then plotted on a cumulative curve to give visual representation of grain size distribution.

The percentage frequency for each phi interval was plotted on a cumulative curve (Appendix B) to give a visual representation of grain size distribution. Statistical analysis was then conducted using numbers read directly from the distribution curve and values for mean, standard deviation, skewness and kurtosis were calculated (Table 3.5). The mean shows the average grain size of the sample (Table 3.6a). Large phi values represent finer sediment sizes, while smaller phi values represent coarser sediment sizes. Mean values also indicate the magnitude of force needed to move the sediment. Standard deviation represents sorting of the sample (Table 3.6b). Values of standard deviation range from very well sorted to extremely poorly sorted. These values represent the range of forces responsible for producing the sediment. In addition, these values also provide evidence on the length of time the material has been within the system. For example, more well sorted material indicates transport within the system for longer durations. Skewness indicates the symmetry of the cumulative curve, and is used in the interpretation of the sample history (Table 3.6c). Higher skewness values signify a more asymmetrical sample curve and indicate extremes of the samples sediment sizes. For example a positive skewness, represented by the curve skewed to the right, consists of a larger concentration of fine material within the sample which indicates that either fine sediment was added by aeolian processes or coarser material was selectively removed by aqueous processes. Beach material typically displays a curve skewed to the left, or negative skewness, because fine particles are often removed, or winnowed by waves. Dune material, on the other hand, tends to have a positive skewness because typically wind is only capable of transporting finer material onshore. However in areas where finer material has been picked up and transported by the wind a negatively skewed coarse sediment lag often remains. Kurtosis indicates the peakedness of the cumulative curve with values signifying platykurtic or flat-peaked curves, mesokurtic and leptokurtic, or sharp-peaked curves (Table 3.6d).

The individual grain size samples were also analyzed for percent mineralogical composition. This analysis was conducted in an attempt to determine the source rock for the sediment. Mineralogical

Table 3.5: Statistical Results of Sand Analysis

a) Beaver Dams Line 4

Profile Distance	Date	Graphic Mean	Grain Size Classification	Inclusive Graphic Standard Deviation	Sorting Classification	Graphic Skewness	Skewness Classification	Kurtosis	Kurtosis Classification
10.00	June 26, 1996	1.26	Medium sand	0.56	Moderately well sorted	0.03	Near-symmetrical	0.85	Platykurtic
	August 3, 1996	1.02	Medium coarse sand	0.56	Moderately well sorted	1.33		1.15	Mesokurtic
	October 6, 1996	1.19	Medium coarse sand	0.58	Moderately well sorted	0.01	Near-symmetrical	1.24	Leptokurtic
	May 15, 1997	1.14	Medium coarse sand	0.58	Moderately well sorted	-0.07	Near-symmetrical	1.12	Leptokurtic
15.00	June 26, 1996	1.01	Medium coarse sand	0.55	Moderately well sorted	-0.02	Near-symmetrical	1.02	Mesokurtic
	August 3, 1996	1.15	Medium coarse sand	0.60	Moderately well sorted	-0.03	Near-symmetrical	1.09	Mesokurtic
	October 6, 1996	1.09	Medium coarse sand	0.60	Moderately well sorted	0.03	Near-symmetrical	1.03	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20.00	June 26, 1996	0.90	Medium coarse sand	0.60	Moderately well sorted	0.09	Near-symmetrical	1.02	Mesokurtic
	August 3, 1996	1.02	Medium coarse sand	0.59	Moderately well sorted	-0.13	Fine-skewed	1.04	Mesokurtic
	October 6, 1996	0.98	Medium coarse sand	0.60	Moderately well sorted	-0.03	Near-symmetrical	1.05	Mesokurtic
	May 15, 1997	1.03	Medium coarse sand	0.61	Moderately well sorted	-0.08	Near-symmetrical	1.11	Leptokurtic
25.00	June 26, 1996	1.08	Medium coarse sand	0.67	Moderately well sorted	-0.04	Near-symmetrical	1.20	Leptokurtic
	August 3, 1996	1.12	Medium coarse sand	0.70	Moderately well sorted	-0.01	Near-symmetrical	1.22	Leptokurtic
	October 6, 1996	1.12	Medium coarse sand	0.67	Moderately well sorted	0.14	Fine-skewed	1.09	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30.00	June 26, 1996	0.96	Medium coarse sand	0.70	Moderately well sorted	0.04	Near-symmetrical	1.19	Leptokurtic
	August 3, 1996	1.03	Medium coarse sand	0.66	Moderately well sorted	-0.15	Fine-skewed	1.16	Leptokurtic
	October 6, 1996	1.00	Medium coarse sand	0.67	Moderately well sorted	-0.05	Near-symmetrical	1.17	Leptokurtic
	May 15, 1997	1.01	Medium coarse sand	0.82	Moderately sorted	0.54	Strongly fine-skewed	1.81	Leptokurtic
35.00	June 26, 1996	0.96	Medium coarse sand	0.51	Moderately well sorted	-0.06	Near-symmetrical	0.97	Mesokurtic
	August 3, 1996	0.86	Medium coarse sand	0.62	Moderately well sorted	-0.19	Coarse-skewed	1.20	Leptokurtic
	October 6, 1996	0.72	Coarse sand	0.53	Moderately well sorted	0.00	Near-symmetrical	0.87	Platykurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40.00	June 26, 1996	0.76	Medium coarse sand	0.34	Very well sorted	0.03	Near-symmetrical	1.15	Leptokurtic
	August 3, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	October 6, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
45.00	June 26, 1996	0.93	Medium coarse sand	0.54	Moderately well sorted	0.20	Fine-skewed	1.06	Mesokurtic
	August 3, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	October 6, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3.5: Statistical Results of Sand Analysis

b) Kilcoursie Beach Line 1

Profile Distance	Date	Graphic Mean	Grain Size Classification	Inclusive Graphic Standard Deviation	Sorting Classification	Graphic Skewness	Skewness Classification	Kurtosis	Kurtosis Classification
5.00	June 26, 1996	1.28	Medium sand	0.71	Moderately well sorted	0.14	Fine-skewed	1.02	Mesokurtic
	August 3, 1996	1.55	Medium sand	0.68	Moderately well sorted	0.14	Fine-skewed	1.13	Leptokurtic
	October 6, 1996	1.49	Medium sand	0.67	Moderately well sorted	0.06	Near-symmetrical	1.07	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10.00	June 26, 1996	1.49	Medium sand	0.66	Moderately well sorted	0.09	Near-symmetrical	0.96	Mesokurtic
	August 3, 1996	1.53	Medium sand	0.57	Moderately well sorted	0.30	Fine-skewed	1.07	Mesokurtic
	October 6, 1996	1.51	Medium sand	0.60	Moderately well sorted	0.16	Fine-skewed	1.13	Leptokurtic
	May 15, 1997	1.54	Medium sand	0.60	Moderately well sorted	0.18	Fine-skewed	1.06	Mesokurtic
15.00	June 26, 1996	1.43	Medium sand	0.67	Moderately well sorted	0.06	Near-symmetrical	0.97	Mesokurtic
	August 3, 1996	1.44	Medium sand	0.58	Moderately well sorted	0.12	Fine-skewed	1.06	Mesokurtic
	October 6, 1996	1.46	Medium sand	0.65	Moderately well sorted	0.06	Near-symmetrical	0.96	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20.00	June 26, 1996	1.37	Medium sand	0.65	Moderately well sorted	0.11	Fine-skewed	0.88	Platykurtic
	August 3, 1996	1.43	Medium sand	0.52	Moderately well sorted	0.18	Fine-skewed	1.01	Mesokurtic
	October 6, 1996	1.36	Medium sand	0.60	Moderately well sorted	0.11	Fine-skewed	1.03	Mesokurtic
	May 15, 1997	1.39	Medium sand	0.60	Moderately well sorted	0.05	Near-symmetrical	1.06	Mesokurtic
25.00	June 26, 1996	1.28	Medium sand	0.71	Moderately well sorted	0.14	Fine-skewed	1.02	Mesokurtic
	August 3, 1996	1.34	Medium sand	0.63	Moderately well sorted	0.03	Near-symmetrical	1.12	Leptokurtic
	October 6, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30.00	June 26, 1996	1.25	Medium sand	0.72	Moderately sorted	0.17	Fine-skewed	1.04	Mesokurtic
	August 3, 1996	1.33	Medium sand	0.69	Moderately well sorted	-0.03	Near-symmetrical	-6.72	
	October 6, 1996	1.24	Medium coarse sand	0.68	Moderately well sorted	0.12	Fine-skewed	1.05	Mesokurtic
	May 15, 1997	1.30	Medium sand	0.71	Moderately well sorted	0.00	Near-symmetrical	1.21	Leptokurtic
35.00	June 26, 1996	1.21	Medium coarse sand	0.66	Moderately well sorted	0.13	Fine-skewed	0.99	Mesokurtic
	August 3, 1996	1.23	Medium coarse sand	0.62	Moderately well sorted	-0.04	Near-symmetrical	1.16	Leptokurtic
	October 6, 1996	1.20	Medium coarse sand	0.64	Moderately well sorted	0.11	Fine-skewed	1.15	Leptokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40.00	June 26, 1996	1.18	Medium coarse sand	0.63	Moderately well sorted	0.07	Near-symmetrical	1.10	Mesokurtic
	August 3, 1996	1.20	Medium coarse sand	0.62	Moderately well sorted	0.02	Near-symmetrical	1.13	Leptokurtic
	October 6, 1996	1.14	Medium coarse sand	0.63	Moderately well sorted	0.17	Fine-skewed	1.00	Mesokurtic
	May 15, 1997	1.18	Medium coarse sand	0.36	Well sorted	-0.15	Coarse-skewed	1.29	Leptokurtic
45.00	June 26, 1996	1.27	Medium sand	0.64	Moderately well sorted	0.01	Near-symmetrical	1.05	Mesokurtic
	August 3, 1996	1.09	Medium coarse sand	0.79	Moderately sorted	-0.04	Near-symmetrical	1.19	Leptokurtic
	October 6, 1996	0.90	Medium coarse sand	0.56	Moderately well sorted	0.13	Fine-skewed	1.09	Mesokurtic
	May 15, 1997	1.03	Medium coarse sand	0.45	Well sorted	-0.14	Coarse-skewed	0.96	Mesokurtic

Table 3.5: Statistical Results of Sand Analysis

c) Kilcoursie Beach Line 4

Profile Distance	Date	Graphic Mean	Grain Size Classification	Inclusive Graphic Standard Deviation	Sorting Classification	Graphic Skewness	Skewness Classification	Kurtosis	Kurtosis Classification
0.00	June 26, 1996	1.45	Medium sand	0.55	Moderately well sorted	0.18	Fine-skewed	1.08	Mesokurtic
	August 3, 1996	1.50	Medium sand	0.54	Moderately well sorted	0.17	Fine-skewed	1.06	Mesokurtic
	October 6, 1996	1.45	Medium sand	0.58	Moderately well sorted	0.12	Fine-skewed	1.01	Mesokurtic
	May 15, 1997	1.48	Medium sand	0.51	Moderately well sorted	0.20	Fine-skewed	1.10	Mesokurtic
5.00	June 26, 1996	1.33	Medium sand	0.67	Moderately well sorted	0.06	Near-symmetrical	1.18	Leptokurtic
	August 3, 1996	1.33	Medium sand	0.62	Moderately well sorted	-0.01	Near-symmetrical	1.11	Mesokurtic
	October 6, 1996	1.27	Medium sand	0.68	Moderately well sorted	0.10	Near-symmetrical	1.09	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10.00	June 26, 1996	1.30	Medium sand	0.77	Moderately sorted	-0.01	Near-symmetrical	1.22	Leptokurtic
	August 3, 1996	1.40	Medium sand	0.80	Moderately sorted	0.04	Near-symmetrical	1.38	Leptokurtic
	October 6, 1996	1.27	Medium sand	0.76	Moderately sorted	0.00	Near-symmetrical	1.24	Leptokurtic
	May 15, 1997	1.28	Medium sand	0.94	Moderately sorted	-0.09	Near-symmetrical	1.41	Leptokurtic
15.00	June 26, 1996	1.29	Medium sand	0.93	Moderately sorted	-0.02	Near-symmetrical	1.58	Extremely leptokurtic
	August 3, 1996	1.40	Medium sand	0.83	Moderately sorted	0.01	Near-symmetrical	1.47	Leptokurtic
	October 6, 1996	1.34	Medium sand	0.87	Moderately sorted	-0.03	Near-symmetrical	1.24	Leptokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20.00	June 26, 1996	1.29	Medium sand	0.83	Moderately sorted	-0.01	Near-symmetrical	1.36	Leptokurtic
	August 3, 1996	1.26	Medium sand	0.83	Moderately sorted	-0.09	Near-symmetrical	1.43	Leptokurtic
	October 6, 1996	1.26	Medium sand	0.84	Moderately sorted	-0.02	Near-symmetrical	1.24	Leptokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
25.00	June 26, 1996	1.14	Medium coarse sand	0.57	Moderately well sorted	-0.04	Near-symmetrical	0.98	Mesokurtic
	August 3, 1996	1.26	Medium sand	0.59	Moderately well sorted	-0.15	Fine-skewed	1.06	Mesokurtic
	October 6, 1996	1.24	Medium coarse sand	0.61	Moderately well sorted	0.02	Near-symmetrical	1.09	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30.00	June 26, 1996	1.07	Medium coarse sand	0.54	Moderately well sorted	-0.10	Fine-skewed	1.05	Mesokurtic
	August 3, 1996	1.11	Medium coarse sand	0.55	Moderately well sorted	-0.05	Near-symmetrical	1.10	Mesokurtic
	October 6, 1996	1.26	Medium sand	0.50	Moderately well sorted	0.09	Near-symmetrical	1.04	Mesokurtic
	May 15, 1997	1.00	Medium coarse sand	0.32	Very well sorted	-0.01	Near-symmetrical	0.67	Very platykurtic

Table 3.5: Statistical Results of Sand Analysis

d) Kilcoursie Beach Line 7

Profile Distance	Date	Graphic Mean	Grain Size Classification	Inclusive Graphic Standard Deviation	Sorting Classification	Graphic Skewness	Skewness Classification	Kurtosis	Kurtosis Classification
0.00	June 26, 1996	1.55	Medium sand	0.51	Moderately well sorted	0.01	Near-symmetrical	0.99	Mesokurtic
	August 3, 1996	1.55	Medium sand	0.52	Moderately well sorted	0.07	Near-symmetrical	1.09	Mesokurtic
	October 6, 1996	1.41	Medium sand	0.51	Moderately well sorted	0.17	Fine-skewed	1.07	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10.00	June 26, 1996	1.44	Medium sand	0.52	Moderately well sorted	0.06	Near-symmetrical	1.05	Mesokurtic
	August 3, 1996	1.52	Medium sand	0.53	Moderately well sorted	0.17	Fine-skewed	1.14	Leptokurtic
	October 6, 1996	1.40	Medium sand	0.56	Moderately well sorted	-0.03	Near-symmetrical	0.95	Mesokurtic
	May 15, 1997	1.42	Medium sand	0.51	Moderately well sorted	0.30	Strongly fine-skewed	1.11	Leptokurtic
15.00	June 26, 1996	1.37	Medium sand	0.57	Moderately well sorted	0.05	Near-symmetrical	0.96	Mesokurtic
	August 3, 1996	1.41	Medium sand	0.50	Moderately well sorted	0.10	Fine-skewed	0.92	Mesokurtic
	October 6, 1996	1.36	Medium sand	0.55	Moderately well sorted	0.20	Fine-skewed	1.15	Leptokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20.00	June 26, 1996	1.38	Medium sand	0.58	Moderately well sorted	0.04	Near-symmetrical	1.03	Mesokurtic
	August 3, 1996	1.35	Medium sand	0.42	Well sorted	0.04	Near-symmetrical	0.58	Very Platykurtic
	October 6, 1996	1.34	Medium sand	0.60	Moderately well sorted	0.06	Near-symmetrical	0.95	Mesokurtic
	May 15, 1997	1.48	Medium sand	0.50	Moderately well sorted	0.21	Fine-skewed	1.08	Mesokurtic
25.00	June 26, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	August 3, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	October 6, 1996	1.30	Medium sand	0.64	Moderately well sorted	0.02	Near-symmetrical	1.08	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30.00	June 26, 1996	1.29	Medium sand	0.55	Moderately well sorted	0.00	Near-symmetrical	1.14	Leptokurtic
	August 3, 1996	1.36	Medium sand	0.47	Well sorted	0.05	Near-symmetrical	1.04	Mesokurtic
	October 6, 1996	1.31	Medium sand	0.56	Moderately well sorted	-0.04	Near-symmetrical	0.94	Mesokurtic
	May 15, 1997	1.35	Medium sand	0.53	Moderately well sorted	0.08	Near-symmetrical	1.10	Mesokurtic
35.00	June 26, 1996	1.12	Medium coarse sand	0.51	Moderately well sorted	0.07	Near-symmetrical	0.99	Mesokurtic
	August 3, 1996	1.16	Medium coarse sand	0.50	Moderately well sorted	-0.09	Near-symmetrical	1.09	Mesokurtic
	October 6, 1996	1.13	Medium coarse sand	0.50	Moderately well sorted	-0.09	Near-symmetrical	1.10	Mesokurtic
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40.00	June 26, 1996	1.36	Medium sand	0.49	Well sorted	0.12	Fine-skewed	1.17	Leptokurtic
	August 3, 1996	1.33	Medium sand	0.33	Very well sorted	0.09	Near-symmetrical	0.52	Very Platykurtic
	October 6, 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	May 15, 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3.6: Statistical Values for Sediment Analysis

a) Grain Size Distribution

U.S. Standard Sieve Mesh #	Millimeters		Microns	Phi	Wentworth Size Class
		4096		-12	
		1024		-10	Boulder (-8 to -12)
Use		256		-8	
wire		64		-6	Cobble (-6 to -8)
squares		16		-4	Pebble (-2 to -6)
5		4		-2	
6		3.36		-1.75	
7		2.83		-1.5	Granule
8		2.38		-1.25	
10		2.00		-1	
12		1.68		-0.75	
14		1.41		-0.5	Very coarse sand
16		1.19		-0.25	
18		1.00		0	
20		0.84		0.25	
25		0.71		0.50	Coarse sand
30		0.59		0.75	
35	1/2	0.50	500	1.00	Medium coarse sand
40		0.42	420	1.25	
45		0.35	350	1.50	Medium sand
50		0.30	300	1.75	
60	1/4	0.25	250	2.00	Medium fine sand
70		0.210	210	2.25	
80		0.177	177	2.50	Fine sand
100		0.149	149	2.75	
120	1/8	0.125	125	3.00	
140		0.105	105	3.25	
170		0.088	88	3.50	Very fine sand
200		0.074	74	3.75	
230	1/16	0.0625	62.50	4.00	
270		0.053	53	4.25	
325		0.044	44	4.50	Coarse silt
		0.037	37	4.75	
	1/32	0.031	31.00	5.00	
	1/64	0.0156	15.60	6.00	
Analyzed	1/128	0.0078	7.80	7.00	Medium silt
by	1/256	0.0039	3.90	8.00	Fine silt
		0.0020	2.00	9.00	Very fine silt
Pipette		0.00098	0.98	10.00	
		0.00049	0.49	11.00	Clay
or		0.00024	0.24	12.00	
		0.00012	0.12	13.00	
Hydrometer		0.00006	0.06	14.00	

Table 3.6: Statistical Values for Sediment Analysis

b) Verbal Classification Scale for Sorting

Phi Size (ƒ) Range	Sorting Classification
Under 0.36	Very well sorted
0.35 - 0.50	Well sorted
0.50 - 0.71	Moderately well sorted
0.71 - 1.0	Moderately sorted
1.0 - 2.0	Poorly sorted
2.0 - 4.0	Very poorly sorted
Over 4.0	Extremely poorly sorted

c) Verbal Classification Scale for Skewness

Phi Size (ƒ) Range	Skewness Classification
+1.00 to +0.30	Strongly fine-skewed
+0.30 to +0.10	Fine-skewed
+0.10 to -0.10	Near-symmetrical
-0.10 to -0.30	Coarse-skewed
-0.30 to -1.00	Strongly coarse-skewed

d) Verbal Classification Scale for Kurtosis

Phi Size (ƒ) Range	Kurtosis Classification
Under 0.67	Very platykurtic
0.67 - 0.90	Platykurtic
0.90 - 1.11	Mesokurtic
1.11 - 1.50	Leptokurtic
Over 3.00	Extremely leptokurtic

Source: Folk (1968)

identification was simplified to three basic categories: granitic material, dark material and red material. Granitic material included sediment grains composed of fragments of granite or individual grains of minerals such as quartz, feldspars and muscovite. Dark material consisted of fragments of mafic rocks or individual grains of such minerals as hornblende, biotite and magnetite. Finally, the category for red material consisted of grains of red garnets. The results for this analysis are presented in Appendix C

Sand size analysis indicates that Killbear's beaches are composed primarily of medium grained, moderately to moderately well sorted sand. The sand is generally near symmetrical to finely skewed and displays a mesokurtic to leptokurtic cumulative curve. Sand composition was primarily quartz and feldspars with constituent material typical of a light to medium granite as well as varying concentrations of dark and/or heavy minerals (ie: magnetite, red garnet). The most significant concentrations of dark minerals typically occurred in the finer portions of the sediment and also were more common is samples collected near the water line.

Sand samples from Beaver Dams line 4 indicate that this portion of the beach is composed of predominantly medium coarse sand with an average grain size of 1.03 phi. However sediment size becomes slightly more coarse near the water line. The sand is moderately well sorted with a near symmetrical skewness and a mesokurtic to leptokurtic curve. It is also interesting to note that the sediment is typically less well sorted on the upper portion of the beach and more well sorted on the lower portion. In addition, particularly coarse skewed samples were collected from the mid portion of the beach along the profile. The concentration of dark minerals was relatively low for this profile resulting in the sand having a light colouration. The sand was composed primarily of quartz and feldspar with constituent material from light to medium granites.

Samples from Kilcoursie Beach line 1 indicate medium sized sand with an average grain size of 1.31 phi. Grain size again becomes coarser toward the water line. The sand is moderately to moderately well sorted and is typically near symmetrical to finely skewed. The sediment also appears to become less finely skewed toward the water line. Cumulative curves produced for the samples primarily display a mesokurtic to leptokurtic peakedness. Sand composition is again quartz and feldspars with additional minerals derived from light to medium granites, however concentrations of dark minerals were greater here than for the previous sample group.

Kilcoursie Beach line 4 is composed predominantly of medium sand with an average grain size of 1.29 phi. As with the previous sample sites the sediment size becomes slightly more coarse toward the water line. The sand is moderately to moderately well sorted becoming slightly more well sorted toward the water line. Sediment from this profile line displays a near symmetrical skewness, as well as a mesokurtic to leptokurtic peakedness on its cumulative curve. Sand composition is similar to that of line 1, however the sand appears to be slightly lighter in colour suggesting a lower concentration of dark minerals.

Samples from Kilcoursie Beach line 7 indicate sediment is composed of medium grained sand with an average grain size of 1.35 phi. Again the grain size shows a slight coarsening trend toward the water line but the change in grain size is not as significant as other sample groups. Sand is moderately well to well sorted, which again becomes more well sorted toward the water line. Sand composition is similar to that of the other two Kilcoursie Beach sample groups with no significant change in the concentration of dark and heavy minerals.

3.7.2 Temporal Analysis

Analysis of samples from Beaver Dams line 4 collected over the duration of the study period indicate a fining in sediment size on the upper portion of the beach and a coarsening in sediment size on the lower portion of the beach over the summer. In addition, over the same period of time the sediment generally becomes less well sorted and more coarsely skewed. For the remainder of the study period however, the sediment along line 4 generally becomes more coarse grained. Skewness is a little less regular, varying from coarsely skewed to more finely skewed. This variation in skewness suggests some form of sediment transport however, precise interpretation was not possible.

It is interesting to not that on Kilcoursie Beach line 1, the sediment becomes less finely skewed and more coarsely skewed toward the water line. Over the course of the study period the sediment along the profile line becomes finer grained on the upper portion of the beach and coarser grained on the lower portion. As well, the upper beach becomes more finely skewed while the lower beach becomes more coarsely skewed. It is also interesting to note that the sediment becomes progressively more well sorted over the study period.

On Kilcoursie Beach line 4 statistical analysis of sediment shows a consistent increase in standard deviation on the middle portion of the beach. Analysis of group samples collected over the study period indicated an overall fining of the grain size on the upper portion of the beach and a coarsening of sediment on the remainder of the beach. Sediment shows a more fine skew on the top portion of the beach, more coarse skewness on the middle portion and more fine skewness on the lower portion.

On Kilcoursie Beach line 7 analysis of samples shows a coarsening of the sediment between May and October, but a fining of the sediment for the remainder of the season. The October samples are generally less well sorted while the remainder of the samples become more well sorted. The sediment becomes more finely skewed between May and October except near the 10 m sample point where the sediment is more coarse. However for the remainder of the study period the sediment on the sample line becomes more finely skewed.

3.8 Human Use

Human use of the Killbear beach site was studied primarily from analysis of photographs compiled over the study period and from historical photographs obtained from the Ontario Provincial Archives. Personal communication with long term park staff and visitors was also used to assist in the interpretation of long term human use patterns. The information collected was used to determine patterns and distribution of use along the beach and to determine the effect of such activity on the beach/dune environment. This process was also used to identify areas particularly vulnerable to use and high impact activities.

Killbear Point peninsula was developed into a provincial park in the early 1960s, however prior to this time the area was used extensively for forestry and also provided some agricultural and recreational opportunities (MNR 1978). According to the Killbear Master Plan (1978), the most significant impact on the original landscape was caused by logging. Logging within the area began sometime around 1898 and ceased in 1945, and resulted in the alteration of much of the original vegetation cover. The area also appears to historically have been a significant recreational resource because, in the early 1900s, plans were made to develop a large park and hotel resort. The Georgian Bay Park and Hotel Company Ltd. was to contain a large hotel with tennis courts, bowling lawns and 800 cottages, however due to lack of funds, the project never materialized.

Killbear Provincial Park is officially open for camping between mid May and mid October, however peak visitor use occurs only between the end of June and the end of August. During the peak season all of Killbear's six campgrounds are opened and vacancy rates are often very low. Outside the peak season visitor volume is drastically reduced and only one of two selected campgrounds is utilized. For example during the 1996-97 research period the Kilcoursie Beach campground was the only site available for camping until June and after September 1st the only campground remaining opened was Harold Point. It should also be noted that during the period when the park is closed, day-use activity is still permitted but access is limited.

Kilcoursie Beach and Beaver Dams campgrounds are the most popular campgrounds within Killbear. Many of the sites within these areas are situated along the back of the beach and provide easy access to the shore. Beaches at both campgrounds also provide boat launch facilities and in 1995 a parking lot was constructed at Beaver Dams for the convenience of boaters using the launch. In addition, park managers developed a new marketing scheme based on the popularity of Kilcoursie and Beaver Dams in an attempt to increase revenue for the park. The highest camping fees would be charged for the most popular shore front sites.

The design of both the Kilcoursie and Beaver Dams campgrounds has access roads to campsites oriented parallel to the shoreline. Basic coastal management strategies, as outlined in Carter (1988) and Trider (1988), suggest designing beach facilities that limit beach access and funnel visitors to specifically designed access routes located through more tolerant dune areas (Figure 2.7a). Unfortunately the design of campgrounds within the park do not funnel visitor traffic to the beach but allow for an infinite number of access routes (Figure 2.7b). The numerous network of paths from the campsites to the beach provide evidence of the uncontrolled beach access.

Killbear officials appear concerned with the cleanliness of the beach and quality of recreational experience for park users. Dogs are prohibited on beaches and garbage receptacles are typically located away from the beach near washroom facilities in order to prevent accumulation of litter and the presence of scavengers (ie: seagulls) on the beach. Recycling bins are located on the beach but they are intended only for collecting drink bottles and cans. Unfortunately to prevent the interfering with visitor use of the beach the recycling bins are generally situated within the dunes or along the edge of dune hummocks. Although no longer a practice within the park, in the past park staff frequently raked the beaches to maintain a pristine image for users (personal communication, park staff). In addition vegetation was removed from along a large portion of the Kilcoursie Beach particularly along the section adjacent to the former day-use area (now current staff beach). The majority of the vegetation was removed during the construction of the pump house and water intake pipe near Kilcoursie Beach profile line 4 (personal communication, park staff). Some vegetation however was removed to create a wider and more open beach for park users. Vegetation that presented potential safety risk, such are dying or unstable trees, were also removed (personal communication, park staff and park visitors).

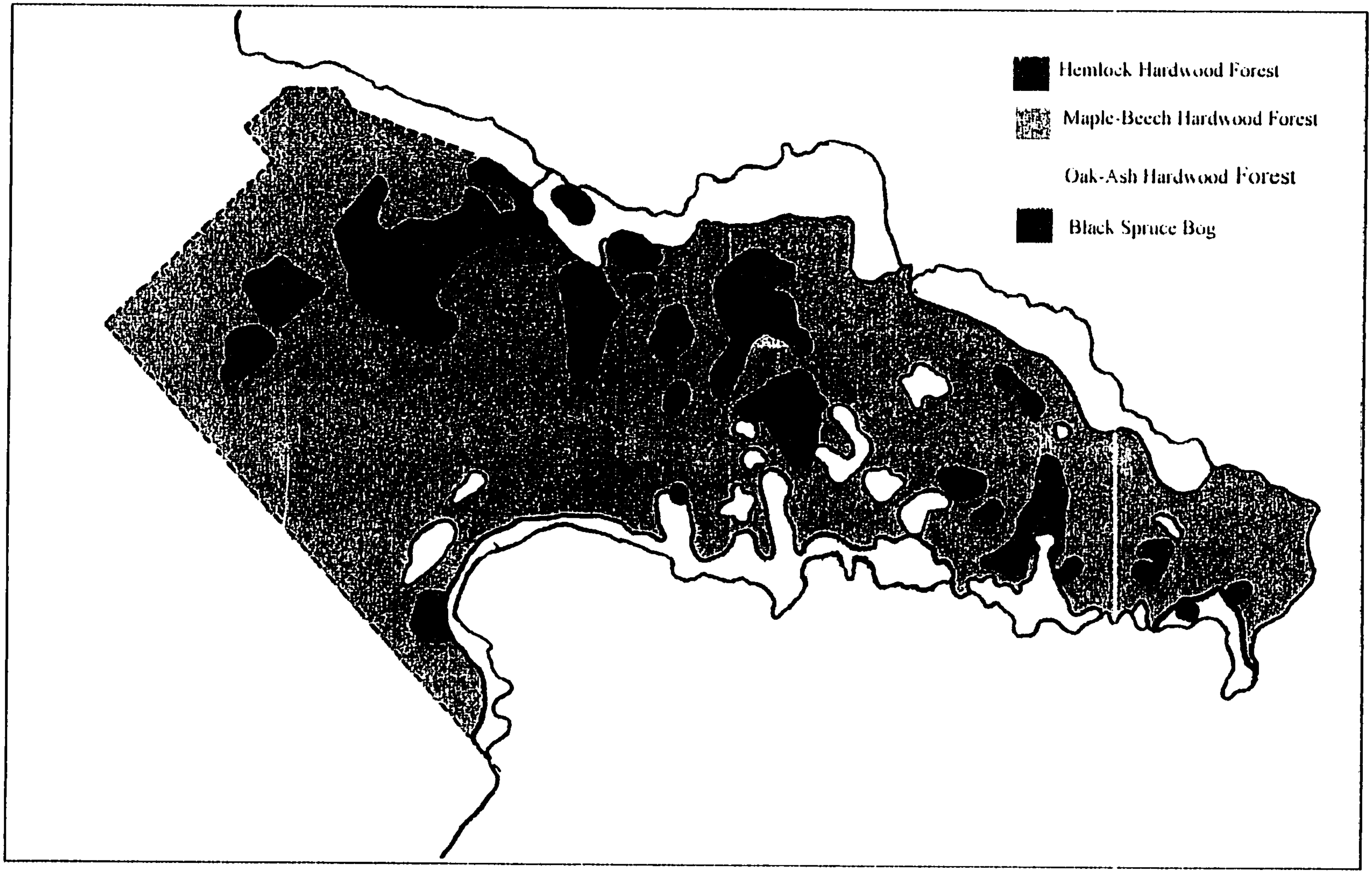
On the beach itself users tend to congregate in the open unvegetated sections. Areas located near dune hummocks and trees were also popular as they provide shade for those concerned about excessive sun exposure. Beach use was typically the heaviest between the months of July and August, and between the hours of 10 am and 4 pm. Beach activity during these time periods was primarily sunbathing and swimming. Sports such as beach volleyball, touch football and frisbee were also commonly observed activities. In fact park officials provide a volleyball net to users which is located on the 'staff beach' near Kilcoursie Beach profile line 7. Children were also observed digging and building in the sand as well as exploring the dunes and jumping off the dune scarps. Water craft owners also frequently utilized the beach for access to the water and owners of smaller boats and sailboards often landed their equipment on the beach and in the dunes when they were not being used. Walking the beach was also extremely popular.

3.9 Vegetation

According to the Killbear Master Plan (1975), the forest cover within the park consists primarily of northern hardwoods such as maple, beech, birch and poplar. however distribution of these species varies significantly ranging from pure to mixed stands. As a result, park officials have divided Killbear's forest into four vegetation communities which include maple-beech forest. oak-ash forest, black spruce bog and hemlock forest (Figure 3.11). The beach and shoreline regions of the park are typically restricted to the oak-ash community although there often is slight overlap with the maple-beech forest. The oak-ash forest can be further divided into two sub-communities, rock outcrop communities and the beach community, depending as the names suggest on the topography and habitat of the shore area. The beach sub-community has suffered severe degradation due to constant trampling and picking by park users as well as construction of roads, parking lots, campsites and user facilities. As a result, the vegetation within this sub-community has been reduced to hardy tree and shrub species such as white ash, red oak, aspen, poplar, sweet gale and meadowsweet (Haffner et al. 1971).

Identification and classification of beach vegetation was conducted with the assistance a Park Naturalist. A list of the species inventoried is included in Table 3.7. Based on the species identified, it appears the study site consists of a mixed beach-forest vegetation cover. The oak-ash forest beach sub-community constitutes the majority of vegetation species, however several species indicative of the maple-

Figure 3.11: Vegetation Classification of Killbear Provincial Park



Source: Killbear Provincial Park Master Plan (1978)

Table 3.7: Vegetation Index

Scientific Name	Common Name
Trees	Trees
Pinus strobus	White Pine
Quercus borealis Michx	Red Oak
Betula papyrifera Marsh	White Birch
Populus grandidentata Michx	Big Tooth Aspen
Populus tremuloides Michx	Trembling Aspen
Acer saccharum Marsh	Sugar Maple
Fraxinus americana L.	White Ash
Shrubs	Shrubs
Ribes hirtellum Michx	Gooseberry
Spiraea alba du roi	Narrow Leaf Meadow Sweet
Aralia nudicaulis	Wild Sasparilla
Apocynum androsaernifolium	Spreading Dogbane
Diervilla lonicera P. Mill	Bush Honeysuckle
Herbaceous	Herbaceous
Pteridium aquilinum L. Kuhn	Braken Fern
Cakile edentula	Sea Rocket
Vaccinium angustifolium	Blueberry
Lathyrus maritimus Bigel	Beach Pea
Oenothera biennis	Evening Primrose
Vitis raparia Var. Syrticola	Dune Grape
Linaria vulgaris	Butter and Eggs
Solidago puberula Nutt	Rough Goldenrod
Hieracium scabrum	Rough Hawkweed
Crepis capillaris	Smooth Hawksbeard
Ammophila brevuligulata	Marram
Epipactis helleborine (L.) Crantz	Helleborine

beech community are also present. In addition, several vegetation species not identified in the Killbear Master Plan (1978) or Heffner et al. (1970) were also present. These species consist primarily of vegetation characteristic of a sandy beach environment such as marram and sea rocket.

Vegetation along Kilcoursie Bay shoreline is under stress and in many cases has suffered severe degradation. Evidence of trampling by park users can be seen from the number of paths that cut through the forest and dune systems. Construction of roads and parking lots along the shoreline have also impacted the vegetation cover. In some areas damage is significant enough that only isolated patches of vegetation or individual species remain.

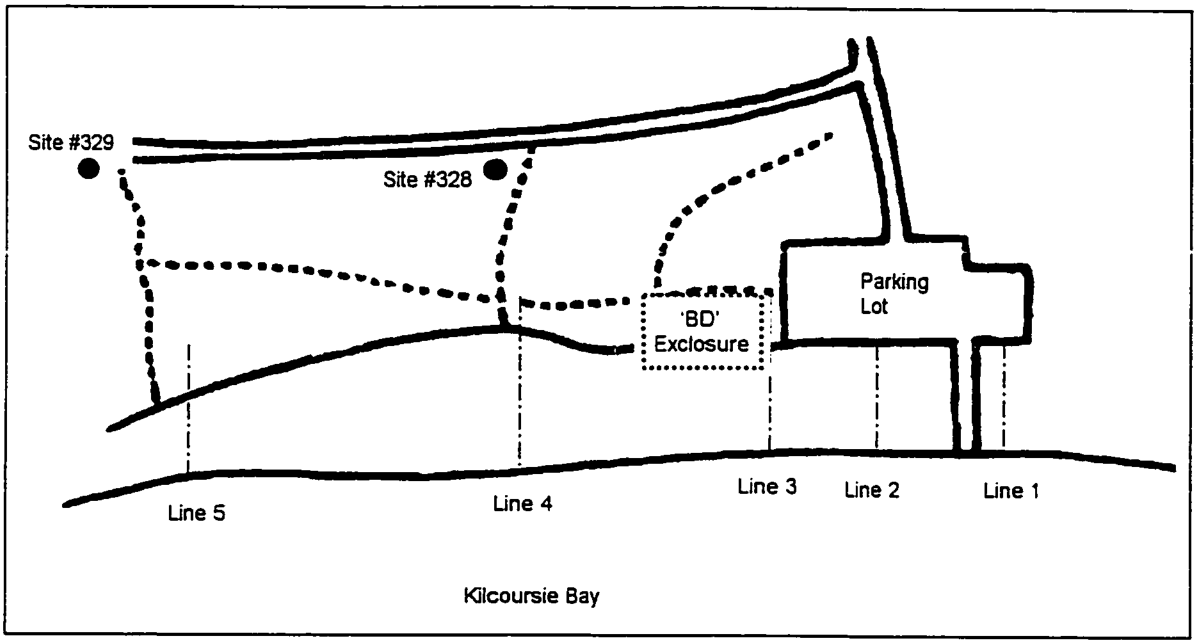
3.9.1 Vegetation Impacts

Studying the impacts of human use on the vegetation of Kilcoursie and Beaver Dams beaches was conducted primarily from visual documentation of changes, analysis of photos compiled over the study period and the establishment of fenced exclosures within the study area. These exclosures were based on a concept used for horses on Sable Island (Taylor et al. 1990) and deer at Pinery Provincial Park, Ontario (Crabe et al. 1988). The exclosures were constructed to prevent human access and therefore allow the natural undisturbed vegetation growth to be observed. The exclosures consisted of fences constructed from 2X2 wooden stakes and orange plastic snow fencing. The fences were established so they were approximately 1 m above the ground surface to avoid interference in the natural aeolian processes.

Three exclosures were installed in early May 1996 and remained in place until the following May (Figure 3.12). The exclosure sites were carefully selected to include pathways created by beach users in previous years so regeneration potential of damaged areas could be observed. Two areas were chosen along the Kilcoursie Beach site and one at the Beaver Dams site. The largest exclosure on the Kilcoursie beach was located between profile lines 5 and 6. The site encompassed the foredune and primary dune, and included a path which cut parallel between the two dune ridges. The second exclosure was located near profile 1 in a small dune patch on the lower portion of the beach. Two small paths oriented perpendicular

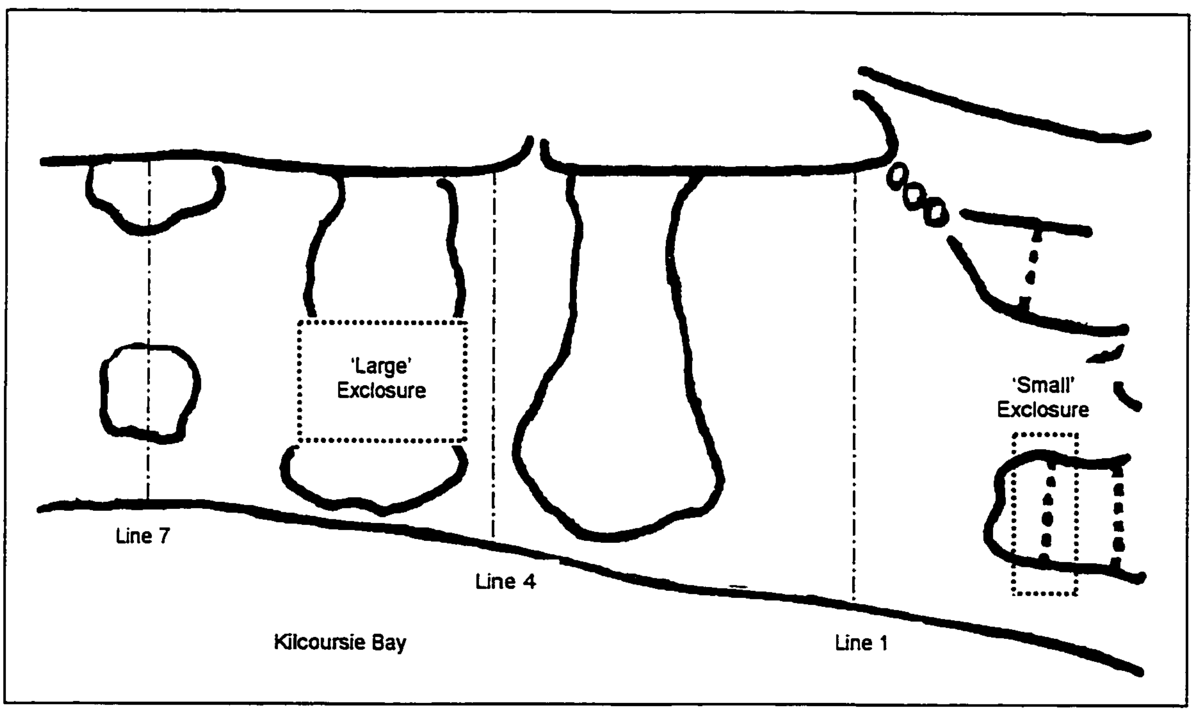
Figure 3.12: Sketch of Exclosure Locations

a) Beaver Dams Campground



Source: Killbear Provincial Park Master Plan (1978)

b) Kilcoursie Beach Campground



Source: Killbear Provincial Park Master Plan (1978)

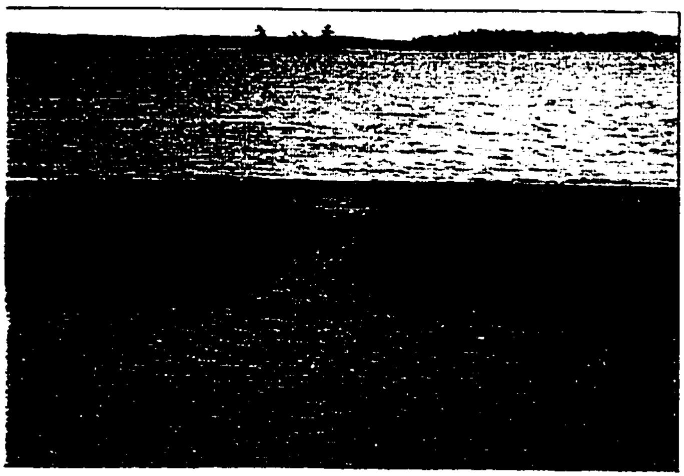
to the shoreline cut through this dune. The western path within this dune was included in the exclosure while the eastern path remained opened to users. The exclosure on the Beaver Dams beach was located near profile line 3, at the western end of the Beaver Dams parking lot. This exclosure encompassed a path cutting through the dune, as well as the dune scarp. All of this information was used to determine the sustainability of current levels of human use on the beach/dune systems and to provide insight on management and/or conservation strategies.

Recorded observations and photographs from early within the study period show significant initial vegetation growth during the spring season both inside and outside of the exclosure sites. Vegetation growth occurred laterally from the edges of dune hummocks as well as extending into previously trampled pathways (Figure 3.13). The percent coverage of new vegetation is relatively sparse. After the end of June, when visitor use began to increase, much of the new vegetation growth outside of the fenced exclosure, particularly along pathways, was subjected to trampling. As a result subsequent vegetation growth in these area declined and vegetation growth from earlier in the season was destroyed (Figure 3.13). Exclosures showed continual vegetation growth, however rates of new plant growth appear the have slowed. Throughout the peak visitor season the paths along the beach as well as the edges of dune hummocks showed signs of suffering damage from trampling. New vegetation growth in that area has basically ceased and any vegetation from the current growth season has been destroyed. In addition, established vegetation cover in many area is also damaged or destroyed. As a result, paths along the beach have become well defined and scarping along the edges of dune hummocks begins to appear. Inside the fenced exclosures new vegetation growth continues although growth rate are slower and vegetation from the current growing season is becoming established. The rate of vegetation regeneration within the study site is relatively slow. Unfortunately many beach users disregarded the exclosures and simply climbed over or under the fences and walked through the study area. Also several incidents of vandalism occurred and exclosures were damaged, during one particular incident the fenced exclosure was completely destroyed

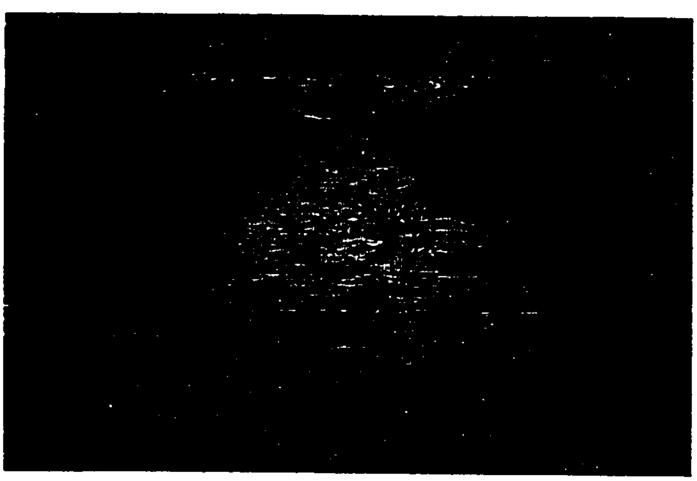
Figure 3.13: Impact of Human Use on Dune Vegetation

a) Small Exclosure (Closed Path) on Kilcoursie Beach

Source: Photo taken early June 1996



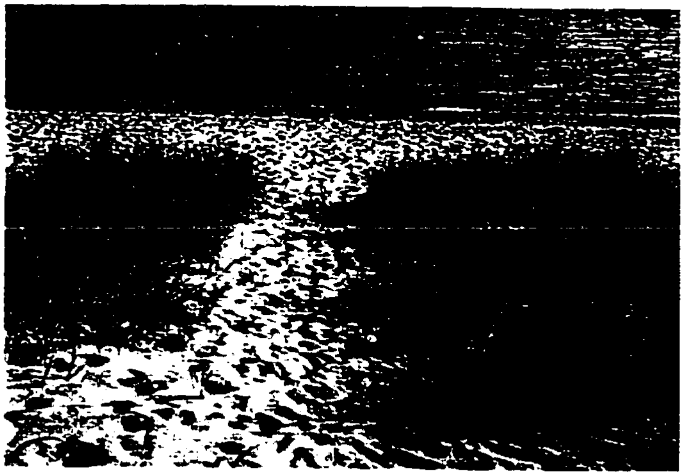
Source: Photo taken late June 1996



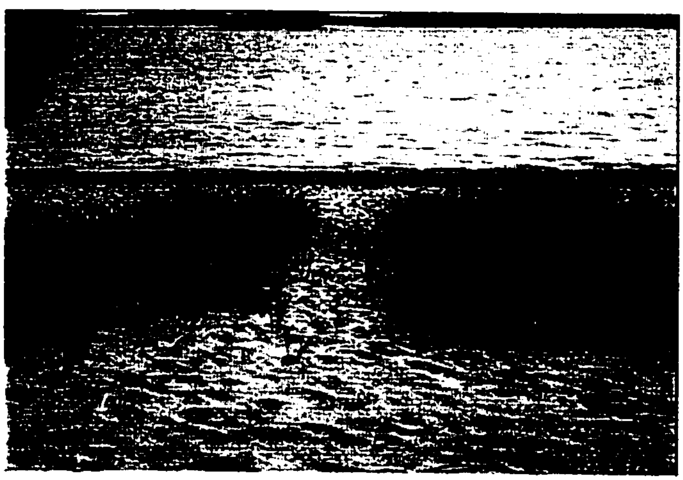
Source: Photo taken July 1996

Figure 3.13 cont..

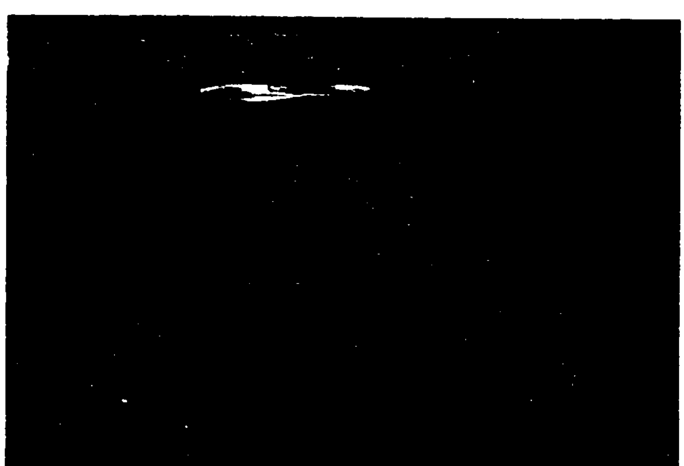
b) Small Exclosure (Open Path) on Kilcoursie Beach



Source: Photo taken early June 1996



Source: Photo taken late June 1996



Source: Photo taken July 1996

and the majority of the vegetation within the area was ripped up. As a result the study on vegetation regeneration rates produced only generalized results.

Chapter 4: Discussion

Killbear Provincial Park is located in the District of Parry Sound. It lies along the eastern shore of Georgian Bay on a peninsula which forms the northwestern boundary of Parry Sound (Figure 1.1). The park occupies approximately 1456-hectares, which is made up of 1123-hectares land area and 623-hectares of water. The land is typically flat with a few rolling hills and large areas of exposed bedrock. The shoreline varies from gently sloping rock to steep, jagged cliffs or sandy beaches.

The majority of the sandy beaches within Killbear are located along Kilcoursie Bay. The bay is a small sheltered bay which contains one small island, Scott Island, with two small islands, Cousin Island and Davy Island, located just outside the extent of the bay. Several small islands, and the larger Rose and Parry Islands are located adjacent to the mouth of the bay (Figure 3.3). These islands appear to shelter the bay from the open waters of Georgian Bay. Kilcoursie Bay is generally oriented in a north-south (head to mouth) direction, with a length of just over 1 km and a width of less that 2 km. The bay is relatively shallow with a maximum depth ranging from 32 m to 33.9 m, however off the research site the depth only ranges to a maximum of 22.6 m (Figure 3.1).

Sediment supply is important in determining the development potential of beaches and dunes. In addition, the sediment supply determines the amount of material available along a shoreline for deposition and accumulation, and therefore influences the extent and level of beach development. According to the Small Craft Route Charts examined for this study, the bathymetry of Kilcoursie Bay has had no change in over 20 years (Figure 3.2). The lack of change in the depth contours suggests sediment levels in the bay have not undergone any significant changes. This suggests that there has been no net loss or gain in sediment within the bay. It also suggests however, that the amount of sediment available for beach and dune development is limited to the original amount of sediment deposited within the bay. Since the beach receives no fresh, new sediment, Bird (1996) would suggest that the beaches within Kilcoursie Bay are relict beaches and depend on the continual reworking of *in situ* material for their maintenance.

Unfortunately, some concern arises as to the accuracy of these bathymetric charts because of the indication by park staff that significant quantities of sediment were dredged from the bay. This poses the question as to whether the quantity of sediment removed from the bay was significant enough to cause a change in depth contours or if the bathymetric charts are simply re-published every few years without actual re-surveying of the area. Kilcoursie Bay is located along a major shipping route to Parry Sound but the bay itself is used only by small motor craft and sail boats and therefore may not warrant re-survey on a continual basis. In addition, the limited number of depth measurements actually recorded for Kilcoursie Bay, also raises concern about the accuracy of these charts for determining the bathymetry of the bay. These problems suggest that the Georgian Bay Small Craft Route Charts may not have been a valid source for determining sediment availability, although the determination of an *in situ* sediment source still appears to be accurate.

The largest aerial extent of beach, and the only substantial present day dune development, occur within Kilcoursie Bay adjacent to Kilcoursie and Beaver Dams campgrounds. These campgrounds, which are the most popular among park users, provide users with approximately 300 campsites, many with direct access to the beach. The intensive use of these campgrounds provides the most significant potential for degradation to the beach/dune system. As a result the research site was established along the northeastern edge of Kilcoursie Bay adjacent to Kilcoursie and Beaver Dams campgrounds (Figure 1.3).

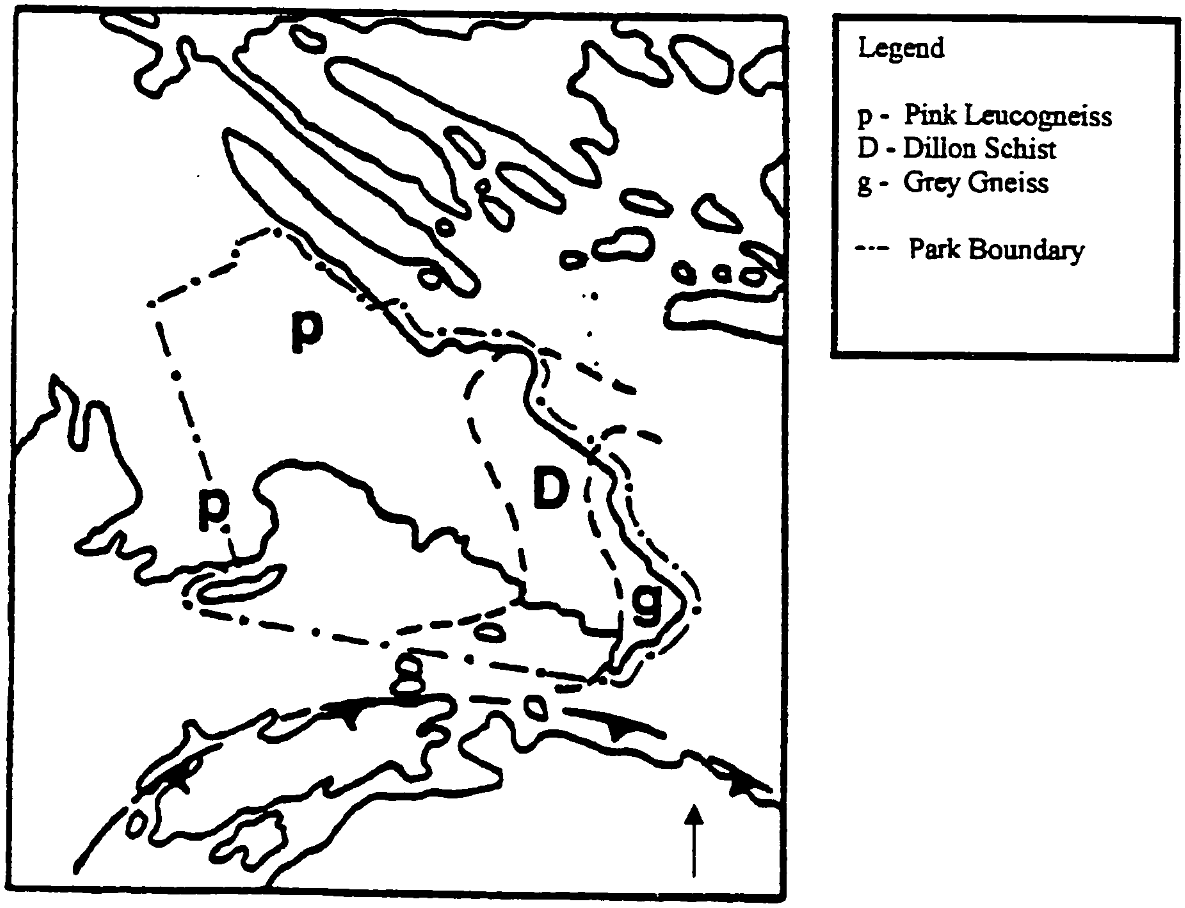
The beach within this research site has a width ranging from approximately 20 m to 40 m extending from the waterline to the dune or forest margin (Table 3.4). The portion of the research site fronting the Kilcoursie campground has a wider expanse of beach than that at the Beaver Dams site. However the width of the actual beach at the Beaver Dams site is probably reduced due to the more substantial dune development between the back of the beach and the forest margin. This dune, which has not been included in the calculation of beach extent is approximately 10 m is width. The average slope of the beach within the research sites ranges from approximately 0.08 to 0.12. Again the Kilcoursie site has a steeper average gradient than the beach at the Beaver Dams site, however the Beaver Dams beach displays much more significant changes in slope. For example, Beaver Dams Line 1 and 2 exhibit a steep scarp along the middle portion of the beach while line 3, 4 and 5 have significant scarp developments at the beach and dune boundary. In general the Kilcoursie beach site exhibits a more continuous sloping surface, which is probably due to underlying morphology as opposed to beach sediment accumulation.

Sediment along the research site is generally a medium sized sand (Table 3.5). This sand is typically moderately to moderately well sorted and exhibits a near symmetrical to finely skewed standard deviation. The cumulative phi curve produced for the samples also suggests a mainly mesokurtic to leptokurtic curve. Sand composition is primarily quartz and feldspar with varying concentrations of dark and/or heavy minerals (Figure 3.7). Most noticeable among the darker minerals are biotite, magnetite and garnet. According the Master Plan(1978) and Haffner et al. (1971), the sediment on Killbear's beaches originates from glacial or fluvio-glacial deposits that were reworked by waves and wind. More specifically, the Haffner et al. (1991) suggests that fluvial action which drained Parry Sound at the end of the last glacial periods transported sediment into Kilcoursie Bay providing the sediment for the present day beaches.

The Parry Sound area has undergone several glaciations in the last 2 million years, the last of which occurred approximately 12000 years ago during the Wisconsin Age. The retreat of this last glacial advance resulted in the highest water levels ever experienced in the area. Lake Algonquin, formed by these extreme water levels covered Killbear to a depth of approximately 160 metres. As sediment laden glacial streams flowed into the lake, small deltas were deposited beneath the ice. It is these deltas, called subaqueous fans, that are believed to have filled depressions in the bedrock and provided the sediment supply for the present day beaches (MNR 1994, MNR 1978).

The beach sediment at Killbear suggests an origin in a light coloured granite, which is deficient in dark material, or a pegmatite. Its composition is typical of the local geology (Figure 4.1), therefore

Figure 4.1: Geology of Killbear Provincial Park



Source: Kor (1994)

suggesting that locally derived glacial or fluvial-glacial material was deposited within the above mentioned subaqueous fans. The northwestern portion of the Park is composed of a pink leucogneiss. This rock unit is generally considered to be massive with little evidence of structure, and only a few small veins of pegmatite. The rocks are generally a pale pink and noticeably deficient in dark minerals. These rocks extend along Kilcoursie Bay to Harold Point where they contact with a paragneiss or metasedimentary rock unit know as the Dillon schist. This rock unit is composed primarily of quart, plagioclase, biotite and muscovite. The rock unit is also associated with alternating layers of a calc-silicate material made up of epidote, hornblende, plagioclase, quartz, calcite and scapolite. The eastern part of Killbear consists of a grey gneiss. These rocks are primarily fine grained rocks composed of bands of biotite and granite. Layers of amphibolite and hornblende are also present at several locations. Granite pegmatites, made up of coarse quartz and feldspars, are also commonly found within the park (MNR 1994, MNR 1978). In addition, the presence of significant concentrations of red garnet suggests a host rock composed of hornblende gneiss and mica schist. An example of such host rocks can be observed on the north side of Parry Island near Depot Harbour (MNR 1978).

The sorting of the sand suggests that material that has been transported in the system for significant duration of time. This conclusion would be indicative of continually reworked glacial material. In addition, the skewness of the sediment suggests both aeolian and subaqueous processes play a role in sediment transport. The statistical analysis of the sediment samples collected at the study site will be discussed in more detail later in this section.

The sand available to the beach and dune system appears to be supplied primarily from sediment deposited in the bay by glacial and/or fluvio-glacial processes. This sediment is moved onshore by wave and ice action. During storm events, or periods of larger waves, sediment is transported onshore and deposited on the beach just above the water level. In addition, during the winter as the bay freezes over sediment is scoured from the nearshore and pushed shoreward in a ridge of sediment just above the landward extent of ice. Such phenomena are documented for other coastal areas where tidal action is negligible or not present in subaqueous processes..

The wind regime is the primary force behind the generation of waves and currents. The amount of energy within a wave depends primarily on the wind speed over the water surface, the length of time the surface is exposed to the wind and the fetch. Unfortunately Kilcoursie Bay is a relatively sheltered body of water with several islands located between the mouth of the bay and the open waters of Georgian Bay. As a result the duration of exposure and the fetch are limited which results in limited wave development within the bay. Although extreme storm events may influence the wave and current activity within Kilcoursie Bay, these phenomena occur periodically and generally have a very short term duration. Local winds are therefore more significant in wave development within Kilcoursie Bay. The energy of these waves therefore depends on the strength and direction of local winds. The wave orientation and nearshore currents within the bay also reflect local wind conditions.

Generally the development of nearshore currents depends on the amount of wave energy reaching the shore, as well as the angle of wave approach. Waves breaking parallel to the shore tend to generate shore normal currents. It is these currents that are responsible for moving sediment onshore and offshore. Waves breaking at oblique angles to the shoreline generate alongshore currents. These currents move along the shore away from the direction of wave approach. However, as previously mentioned, Kilcoursie Bay is a relatively shallow and sheltered bay, meaning that local winds play a more significant role in current generation. The local winds create surface waves oriented perpendicular to the wind direction and move the surface waters of the bay in the direction of the prevailing wind. However, depending on their direction these local winds are still capable of setting up both onshore and alongshore currents.

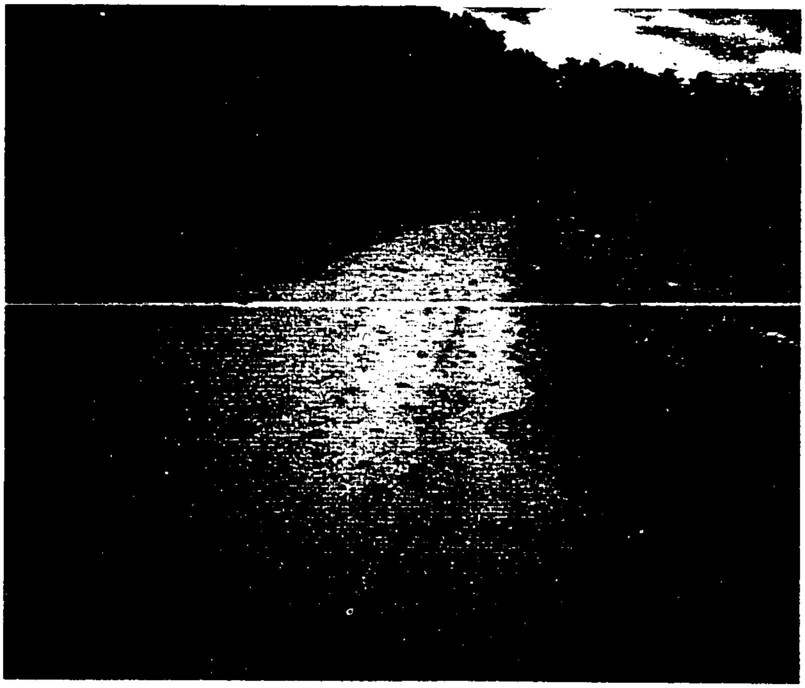
Within such a lake environment the wind regime is responsible for variations in water level. According to The Great Lakes Water Levels Newsletter (Environment Canada 1991) daily changes in water levels on the Great Lakes can be caused by local winds that push water on shore, however larger regional storm winds produce more wide spread water level changes known as seiche. Although the changes in water level associated with seiche were not directly observed, a litter line observed approximately 10 metres (October 1996) above the normal lake water level suggests that seiche is a process effecting water level in Kilcoursie Bay (Figure 4.2). The significant increase in water level indicated by this litter line is likely the result of strong westerly wind blowing across Georgian Bay. The likelihood of this increase in water level being generated solely by large storm waves is small and more likely to be a combination of both seiche and increased wave heights.

Lake levels can also be altered by variations in the annual precipitation and evaporation rates or by long term climate change (Cain 1988, Carter 1988, Changnon 1997). Typically, higher water levels correspond with periods of more abundant levels of precipitation and lower temperatures which reduce the rate of evaporation (Fuller et al 1995). According to a water level data presented in Fuller et al (1995), periods of particularly low lake levels were recorded for the Great Lakes during the mid 1920s, mid 1930s, late 1940s, mid 1960s and late 1980s, while higher lake levels were shown for the late 1920s, early 1940s, early 1950s, mid 1970s, mid 1980s and early 1990s. The Great Lakes Water Levels Newsletter (1991), suggests that water levels within the Great Lakes were increasing in the early 1990s. In addition, profile surveys at the Killbear research site also indicated an overall increase in local water levels between 1996 and 1997. Water levels within the Great Lakes during 1999 however, were significantly lower.

The fluctuations in water level generally serve to alter the shoreline morphology, by shifting the position of the zone where wave activity and subaqueous sediment transport occurs. In other words, the water level determines the shoreward extent of wave activity on the beach and the depth to which waves can affect the lake bottom. During periods of higher water levels this zone is moved shoreward resulting in increased erosion, while during lower water levels the zone is moved lakeward and promotes beach and dune growth.

Within the Great Lakes region the wind regime is closely associated with climate and

Figure 4.2: Evidence of Higher Lake Level



Note litter line several metres above the current water level

Source: Photo take October 1996

meteorological trends. According to The Great Lakes Environmental Atlas: An Environmental Atlas and Resource Book (1995) the prevailing movement of air is from the west and the highly variable weather is the result of interaction of alternating flows of warm humid air masses which originate from the Gulf of Mexico and cold dry Arctic air masses. The Atlas also suggests that in the summer, the Arctic air masses are more influential in the northern regions of the Great Lakes, while the southern regions are influenced by the air masses from the Gulf of Mexico. Arctic air masses from the northwest are more significant in influencing winter weather conditions for the Great Lakes. These air masses are particularly cold and dry systems, however as they travel southeasterly over the lakes they are warmed and accumulate moisture. As a result, when these systems reach land the moisture which was picked up condenses to produce snow. Therefore the lee, or eastern shores, of the lakes tend to receive significant amounts of snowfall and are commonly referred to as a snowbelt. Killbear is located on the eastern shore of Georgian Bay and therefore falls into the snowbelt region. Pacific air masses from the west also influence winter climate conditions within the Great Lakes basin. These air masses are typically dry as they have lost most of their moisture content as they traveled over the western mountains. Air masses originating from the Gulf of Mexico are typically less important in influencing winter weather conditions within the Great Lakes. During the spring and fall months weather condition are quite variable. This is due to the interaction of warm and cold air masses which move rapidly through the region during these months. The interaction of these air masses commonly results in increased cloud cover over the area in addition to the generation of strong winds and severe storm events (Environment Canada et al. 1995)

In the Parry Sound area, the wind regime appears to be influenced by such climatic conditions. In general, the wind appears to exhibit a seasonal trend, however the strongest winds do not necessarily occur in conjunction with the most frequently occurring wind directions (Table 3.2). Typically the more frequently occurring winds are associated with moderate wind speeds while the strongest winds are associated with wind from a less frequently occurring direction. This suggests that these stronger winds are probably associated with storm events occurring in the region. During the spring and summer, winds at Killbear tend to occur most frequently from the southwesterly directions suggesting air masses moving northward through the United States have the greatest influence on the weather for the area. However, the strongest winds occur from the northeasterly directions suggesting polar air masses move through the region producing strong winds and storm events. During the fall, northeasterly and southwesterly winds occur most frequently suggesting both Arctic and air masses moving north from the United states influence the local weather conditions. Wind speeds in this season are stronger than those experienced during the spring and summer months and the direction of these winds is significantly more variable. However the strongest winds tend to occur from westerly directions. The alternating wind direction and direction of strongest wind speeds suggest frequent interactions between air masses of different origin and therefore less settled and more variable weather conditions including stronger winds and more frequent storm events. During the winter the frequent occurrence of northwesterly and northeasterly winds suggests that Arctic air masses have the greatest influence on weather conditions at Killbear. The fact that Killbear also lies within the snowbelt region also suggests the importance of northwesterly winds. The strongest wind speeds during this season occur from the southwest and northeast. This suggests that air masses moving northward through the United States contribute to the development of storm events, however the fact that the strong northeasterly winds are also among the most frequently occurring winds suggests that the Arctic air flows contain strong sustainable winds and are most significant climatic control during the winter.

Wave refraction must also be considered as a process affecting waves within Kilcoursie Bay when dealing with local wind generated waves. Due to the sheltered nature of the bay and the irregular shape of the coastline, local waves may undergo considerable refraction before actually reaching the shoreline. In many cases, despite the actual wind direction, the waves entering Kilcoursie Bay have been refracted in such a manner as to approach the shoreline in a northerly (ie: northwest to northeast) direction. However, typically waves formed originally from westerly winds even after undergoing refraction will approach the shore in a northwesterly to northerly direction while waves formed from easterly wind will strike the shore in a north to northeasterly direction. In cases where wave orientation has been significantly altered from the local wind direction small waves can be observed forming on the water surface moving in a direction corresponding to the direction of wind gusts.

Generally current direction along the shoreline is determined by the orientation of wave approach. However in the case of a sheltered and shallow bay such as Kilcoursie Bay, local wind conditions can also play a significant role in the generation of nearshore currents. Based on a comparison of longshore current measurements and the recorded wind direction for the corresponding day it appears local wind directions significantly influence current development (Table 3.3). In particular it appears that southwest to northeast winds tend to generate currents moving through the bay in a clockwise direction while southwest to northeast winds tend to generate currents which move in a counterclockwise direction. Statistical analysis of the wind data suggests therefore that clockwise nearshore currents should be more frequent within Kilcoursie Bay. Due to the importance of these local winds in generating nearshore currents it should be noted that ice cover within Kilcoursie Bay from late fall to early spring would indicate negligible current development over this period.

Because waves and nearshore currents within Kilcoursie Bay are related to local wind direction, subaqueous sediment transport is also indirectly dependant on the local wind regime. The variability of nearshore currents indicate a variability in subaqueous sediment transport. The indication that over the long term currents are more frequent in the clockwise direction, however suggests that net subaqueous sediment transport also occurs in the clockwise direction. Geomorphic shoreline features also provide evidence in support of a net clockwise movement of sediment. The accumulation of sediment just lakeward of the water line also indicates the importance of storm waves and onshore currents in the process of subaqueous sediment transport.

Evidence of subaerial sediment transport is negligible during the spring and summer. However the dissipation of the sediment ridge located just landward of the water line suggests gradual aeolian transport over this time period. Sand traps established at the research site between October 1996 and May 1997 suggest the majority of aeolian sediment transport occurs in the fall. Little sediment transport occurs during the winter months because the beach and dune surface are covered with snow. Evidence of aeolian features produced on the snow surface suggest that if snow cover were not a limiting factor sediment transport would likely occur. The general landward decrease in sediment size along the sampled profiles suggest aeolian sediment transport in a landward direction (Table 3.5). The development of a coarse pebble lag on the lower portion of the profiles also supports this theory. In addition, the overall trend of sediment becoming more finely skewed landward across the beach also suggests a landward transport of the finer sediment fraction. Aeolian structures, such as adhesion structures, ripples, scour marks and depositional features (Figure 3.6) again support the theory of an overall landward movement of sediment. In particular depositional features located at the small parking lot within the Kilcoursie Campground near profile #1 and within the Beaver Dams parking lot, as well as sediment trap accumulations indicate the most significant aeolian transport occurs in a north to easterly direction. Therefore it should be noted that aeolian sediment transport within the research site does not typically occur perpendicular to the shoreline but on an oblique angle.

Although southwesterly winds occur frequently during the spring and summer, the strength of these winds appears to be insufficient for producing any rapid or substantial sediment movement. Higher water levels and wind speeds associated with storm events are likely responsible for the gradual dissipation of the sediment ridge over this period. During the fall, winds occur most frequently from the northeast and southwest respectively, however winds from out of the southwest are significantly stronger. These winds are also significantly stronger than those experienced in the spring and summer months. The evidence of sediment transport indicated above suggests that these stronger southwesterly winds are capable of moving more significant quantities of sediment than winds from other directions. Northeasterly winds in the fall may have the strength to transport sediment however the forest backing the beach shelters the sediment from potential transport. Evidence of ripple marks oriented perpendicular to the shoreline along both Day Use and Beaver Dams beach also indicate the transport potential of northwesterly winds. Although not the strongest winds that occur, these winds are evidently strong enough to initiate sediment transport but they occur much less frequently than the northeasterly or southwesterly winds.

The profile lines were established at the research site in an attempt to provide information on sediment transport at Killbear. Although morphological change along the profiles was minimal over the research period, and the difference recorded in the profiles within the limit of errors of the surveying technique, general transport patterns could be inferred. In the spring of 1996 when the profile lines were established a small sediment ridge, located just above the water line, was documented along each profile. Subsequent surveys indicate that this ridge slowly dissipates over the course of the summer. The surveys also show that a new sediment ridge had developed by the following spring, however the location of the ridge had shifted landward due to an increase in water levels in the bay also indicated by the surveys. Sediment levels along the lower portion of the beach, particularly just above water level vary significantly over the study period. Typically the late fall and spring show an increase in sediment levels, while sediment levels over the summer and early fall tend to decrease. This would support the idea of a landward dissipation of sediment from the ridge during the spring and summer with continual landward transport throughout the remainder of the year. A landward movement is more likely than the removal of this sediment from the beach by wave action because during this time of year wave development is minimal and therefore one would expect wave action on the shore to be insignificant. The middle portion generally shows an overall increase in sediment levels although between subsequent surveys the profiles showed variable increase and decrease in sediment levels. The upper portion of the beach generally shows a decrease in sediment levels, with the majority of sediment being lost to the forest margin. Beaver Dams lines 1, 2 and 3 lose sediment to the parking lot as evident in the photos. A wide cut through the dune adjacent to Kilcoursie Line 4 probably contributes to the loss of sediment along the upper portion of this profile. As wind blowing across the beach reaches this point it is funneled through the dune cut. Funneling results in a concentration of the wind and increases its sediment transport potential, therefore causing scouring along the upper portion of the beach. However, Kilcoursie Line 1 shows an increase in sediment levels in the fall, this increase in sediment corresponds with the increase in sediment documented at the small parking lot. The location of this profile at the northeastern end of the site suggests sediment being transported across the beach by southwesterly winds was probably accumulated at the upper portion of the profile as the wind encountered the forest and dune margin and was no longer able to maintain sediment entrainment. Unfortunately the location of Kilcoursie Line 7 was not suitable for examining sediment transport along the upper beach as this portion of the profile was situated within an established dune and therefore sheltered from the effects of aeolian sediment transport.

The Killbear Master Plan (1978) identified four different vegetation communities within the park including maple-beech forest, oak-ash forest, black spruce bog and hemlock forest (Figure 3.11). According to this Plan the beach and shoreline regions are typically limited to the oak-ash community although there may be slight overlap with the maple-beech forest. For this study, the identification and classification of the vegetation located within the research site was completed with the assistance of a Park Naturalist (Table 3.8). A total of 24 different species were identified. Of the species identified, 29% were those classified as part of the oak-ash forest, 29% were from the maple-beech forest and 21% of the species were considered to be common among all of the vegetation communities or in disturbed areas. However, 21% of the species identified were not included in the species list of Killbear Provincial Park in Haffner et al. (1971). Several of these plant species, including Ammophila breviligulata and Cakile edentula, are plants specifically associated with coastal environments and in particular beaches and dunes. It should also be noted that Vitis riparia occurred only in a section of the dune near Kilcoursie Line 5. The beach system within the research site is therefore an even mixture of the oak-ash and maple-beech forest communities with several additional species characteristic of a shoreline environment, not predominantly composed of the oak-ash forest as Haffner at el. (1971) suggested.

Within the larger, less disturbed dune sections the vegetation is relatively stable, however along the margins of each dune section, as well as along well used paths, the vegetation has become less stable and has suffered severe degradation due to trampling and other damaging activities. The large dune located at the Beaver Dams site supports the greatest diversity of vegetation species. The smaller dune patches within both the Beaver Dams and Kilcourse sites consist primarily of the characteristic beach vegetation with small populations of herbaceous plant species and isolated individual hardy tree and shrub species.

Photographs taken over the course of the study period provided visual documentation on the health and growth of dune vegetation, as well as on the impacts of human use. Based on photographs taken in the late fall and early spring it appears the majority of the dune vegetation dies back over the winter (however dune stability is still maintained by the dead grass), however vegetation regrowth begins by the late spring. In addition, prior to the high tourist season, vegetation growth occurred laterally from the edges of the dune sections and also expanded into established pathways (Figure 3.13). Vegetation cover within the established dune sections grew relatively quickly and returned to the stage of the previous year by early summer, however the rate of new growth was fairly slow and the resulting vegetation cover quite sparse. Once the number of park visitors increased, the new vegetation began to suffer significant trampling damage and by the end of the summer the majority of this new vegetation had been destroyed (Figure 3.13). For example, the vegetation that had attempted to colonize established pathways was quickly trampled and destroyed leaving the pathways devoid of vegetation. In addition, trampling also resulted in the damage of vegetation along the edges of many established dune sections and several pathways were widened due to the destruction of the vegetation along their margins.

The establishment of human exclosures at the study site indicate that trampling and crushing of vegetation have a significant impact on the beach and dune system at Killbear. Within the established exclosures vegetation growth continued throughout the study period, while outside theses exclosures vegetation growth was quickly trampled and destroyed by park users. Although the rate of vegetation growth within the exclosures slowed significantly by late summer, vegetation did grow and remain. Therefore the exclosures indicate that if human impact is eliminated, or limited, new vegetation growth could successfully establish. However it should be noted that the rate of growth is relatively slow and it would require several years of undisturbed growth for significant vegetation cover to develop.

Chapter 5: Conclusion and Recommendations

Studies suggest a limited sediment supply within Kilcoursie Bay, with the majority of available sediment originating from glacial and/or fluvio-glacial sources deposited over 10,000 years ago. This limited sediment supply to the bay also means a limited sediment supply to the beach and dune system. Therefore beach and dune development is also limited and sediment availability is likely the result of a continual reworking of material within the system. In other words, the sediment cycles from the offshore to the beach and dunes and back to the offshore. However, because the validity of the bathymetric charts used to determine the sediment availability is questionable, it would be advisable for the park to conduct their own in-depth bathymetric studies. Theses studies could provide detailed information on the quantity and type of sediment within Kilcoursie Bay and be used as a baseline for determining future changes in sediment availability.

Kilcoursie Bay is a relatively shallow and sheltered bay, as such local wind and wave conditions have a more significant influence on subaqueous and aeolian processes than larger more regional weather conditions. Because local winds seem to play such a significant role in the development of these processes, it is recommended that a small meteorological station be set up within Killbear to more accurately monitor the winds. Although an Atmospheric Environment Service Meteorological Station is located in nearby Parry Sound, this station is considered to be an inland monitoring site and is not likely to portray accurate wind conditions at the shoreline, and closest shoreline Meteorological Station is located at Britt, some 200 km north of Parry Sound.

Studies suggest slow subaqueous and aeolian transport processes. The primary onshore subaqueous processes occur as a result of large wave and ice action. Due to the fact that these actions are more common in the fall and winter it is likely that the majority of onshore sediment transport occurs at these times.

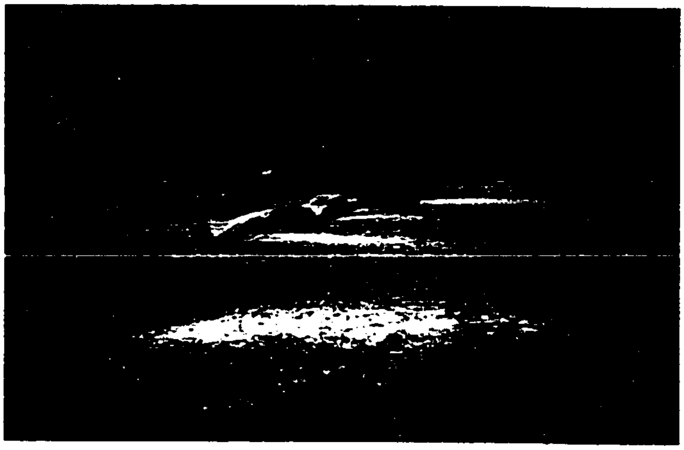
Local wind conditions also have a significant influence on longshore currents. Since the local wind directions vary, longshore current directions also vary. The currents alternate between a clockwise and counterclockwise movement of water. Current directions vary with the wind and therefore alter on different time scales and in many instances can alternate daily or even hourly. This study suggests that the most predominant current direction is in a clockwise direction therefore indicating that the most significant sediment transport is also in a clockwise direction. Southwest to northeast winds are responsible for producing clockwise directions and since these winds occur most frequently during the fall it can be assumed that the majority of longshore sediment transport occurs at these times.

Local winds tend to be light over the spring and summer and therefore produce slow aeolian transport. However in the fall and early spring, wind conditions produce much greater wind speeds which result in more significant sediment transport. During the fall and early spring, southwesterly winds produce the strongest conditions, therefore the majority of sediment transport within Kilcoursie Bay occurs during the fall and early spring in a north to easterly direction. During this time period, sediment moves obliquely across the beach and landward to the dune/forest margin. At several locations along the beach evidence of sediment accumulations landward of this margin can be observed (Figure 5.1). This suggests that sediment is being lost from the beach to the forest and ultimately removed from the sediment cycle.

A major contributing factor to the loss of sediment to the forest is the state of dune vegetation along the beach. Typically beach vegetation acts as a sediment stabilizer and also helps to accumulate new fresh supplies of sediment. The vegetation along Kilcoursie and Beaver Dams beach consists of a mix of characteristic beach vegetation such as marram, beach pea and sea rocket, and the oak-ash and beech-maple forest communities. However, Haffner et al. (1971) classified the beach vegetation as predominantly composed of oak-ash forest community. This difference in interpretation suggests that a new, in depth survey of the shoreline vegetation should be conducted. This study could then be used to determine and document changes in vegetation cover, as well as any change in floral biodiversity and/or loss of vegetation species.

Figure 5.1: Evidence of Landward Sediment Loss

a) Sediment Accumulation at Kilcoursie Parking Lot



Source: Photo taken October 1996

b) Sediment Accumulation in Forest at Kilcousie Parking Lot

Source: Photo taken October 1996

Unfortunately the dune system at Killbear has become patchy with isolated dune sections of various size now scattered along the beaches, however one can visualize that theses dune patches may have at one time formed a relatively continuous ridge. Some of the damage to the dune system has resulted from the construction of roads, parking lots, campsites and user facilities. For example, installation of a water intake pipe on Kilcoursie Beach resulted in the destruction a significant portion of the dune, and a large portion of the dune system at the Beaver Dams research site was recently removed to build a parking lot and boat launch. Within the larger, less disturbed sections of these isolated dunes the vegetation is relatively healthy and stable, however along their margins, as well as along footpaths, the vegetation has become less stable and has suffered severe degradation due to trampling and other damaging activities.

Overall the dunes are in a severe state of degradation and in general have deteriorated back to an embryonic state, with vegetation reduced to small populations of herbaceous plant species and isolated individual hardy tree and shrub species. Evidence obtained from the human exclosures suggests that regeneration of dune vegetation is possible although the process would be quite slow. Within the exclosures vegetation continued to grow throughout the study period, while outside these exclosures new growth was quickly trampled and destroyed. However the rate of vegetation growth within the exclosures was relatively slow and it would require several years of undisturbed growth for significant vegetation cover to develop.

Due to the limited sediment supply available to the beaches the extent of dune development is also limited, meaning dune formation at Killbear occurs on a much smaller scale than places like Pinery. The slow subaqueous and aeolian processes within the bay and the slow rate of vegetation regeneration also suggest that dune formation would occur on a much longer time scale than other dune locations within the Great Lakes. As a result the impacts of human use on the beach should be of more concern to park managers as it would appear that damage to the dune system is occurring at a much faster rate than the system can tolerate. In other words, the degradation of the dune system by park visitors can not be compensated for by the processes that naturally build and regenerate the dunes.

At present, evidence suggests that sediment is being lost to the forest and if dune degradation continues the quantity of sediment lost will increase. With only a limited supply of sediment available to the beaches within Kilcoursie Bay this sediment is permanently lost from the system. An important question not addressed in this research is the actual quantity of sediment available and how long it will be before the loss of sediment from the system will reach a critical stage. Therefore it is important for park managers to consider management of the beach and dune system at Killbear.

Because of the slow processes within the system any attempts at regeneration, either artificial or natural, will require several years. Therefore it is also important to reduce the level of impact park users are having on the system in an attempt to slow any further degradation. Attempts to reduce impacts can be accomplished by several simple techniques. The most significant and easiest technique is education. Education must first begin with the park managers and staff so they recognize the significance of dunes and dune management. Park users can be educated of the importance of dunes, their fragility and the impacts of human use by displays at the interpretative centre, administrative office or articles in the park newspaper. Relocation of recycling bins from within to dunes to more open areas will also help to reduce the impact along dune margins. The use of the dunes for drying sailboards also resulted in significant crushing of the dune vegetation therefore park may also consider the installation of several small racks on the beach for this purpose. Of particular importance is preventing park users from walking through the dunes. Preventing this activity may take a little more effort as the majority roads within the campgrounds parallel the beach any park users simply cut through the dunes to access the beach. Ideally any roads should be developed perpendicular to the shoreline with a single access route to the beach which funnels users through a tolerant portion of the dune system. This option is not available to park managers at Killbear, therefore park managers should select already well developed paths and designate these paths as beach access routes. Smaller, less frequently traveled paths should be abandoned and the vegetation allowed to regenerate. Small, friendly signs should be posted at key areas as a friendly reminder to park users about the importance using designated paths and preventing the damage of dune vegetation.

Park managers may also wish to initiate dune regeneration practices. These practices will require a significant level of commitment as the regeneration process may take several years. Because of the time scale involved for such projects it is recommended that only small areas be designated for regeneration at a time. Key areas to be designated for regeneration should start with pathways and areas identified as points were sediment is being lost to the forest. Regeneration will require that human activities be eliminated therefore the establishment of some form of barrier, such as an exclosure will be required. This barrier must be erected in such a manner as not to prevent natural aeolian sediment transport (1 m above ground). Because the majority of sediment transport occurs within the fall and the majority of new vegetation growth in the early spring it is also recommended that transplants be established in these areas in the early fall. This will allow the plants to become established before the winter sets in and will also help to trap sediment that is being transported in the fall. In addition these transplants will establish new growth shoots in the spring and help to further anchor the sediment accumulated in the fall. Regeneration sites will likely require up to 5 years to establish a solid vegetation cover therefore periodic monitoring of these sites will be required.

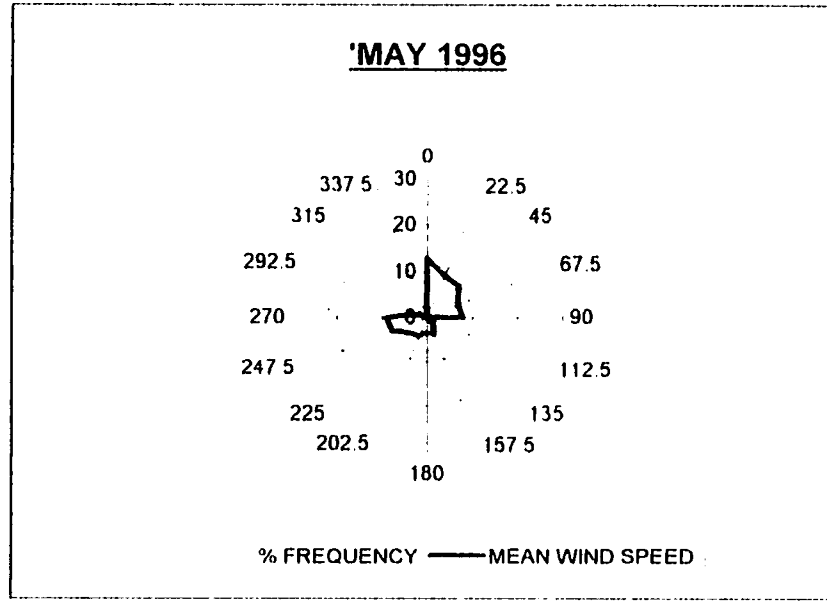
The preparation of the Killbear Master Plan (1978) resulted in the development of several management policies. Specifically, policies were written to ensure user control and minimize vandalism, rowdiness and activities which conflict with the goals for management and to preserve significant land and water area in their natural state. While the Master Plan (1978) recognizes the overall importance of conservation within the park and identifies the importance of Killbear's beaches as a resource, these policies have not been implemented in regard to these systems. This suggests that there is a disparity between the written management plan and the actual management activities implemented within the park.

This project has attempted to determine the natural processes active within the beach and dunes at Killbear Provincial Park, as well as to document the impacts of human activity on this system. It is hope that this information will now provide park managers with a better understanding of this environment and encourage the development of a management program. Several recommendations have also been made as an incentive to the development of such a program. The beaches and dunes at Killbear are a significant feature within the park and a major factor contributing to its popularity with campers, therefore it is imperative that park managers develop some form of management plan to ensure future preservation of this resource.

Appendix A: Wind Data

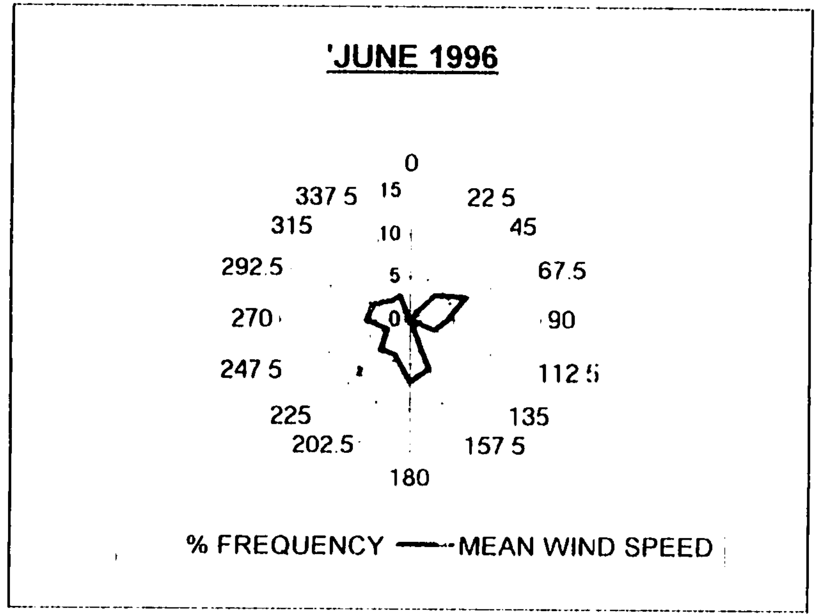
Wind Speed and Direction Analysis
May 1996

COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	4	13
NNE	22.5	13	10
NE	45	4	10
ENE	67.5	8	7.5
E	90	4	8
ESE	112.5	0	0
SE	135	4	2
SSE	157.5	4	4
S	180	8	3.5
SSW	202.5	8	4.5
SW	225	8	5
WSW	247.5	25	8.2
W	270	4	9
WNW	292.5	4	2
NW	315	0	0
NNW	337.5	0	0



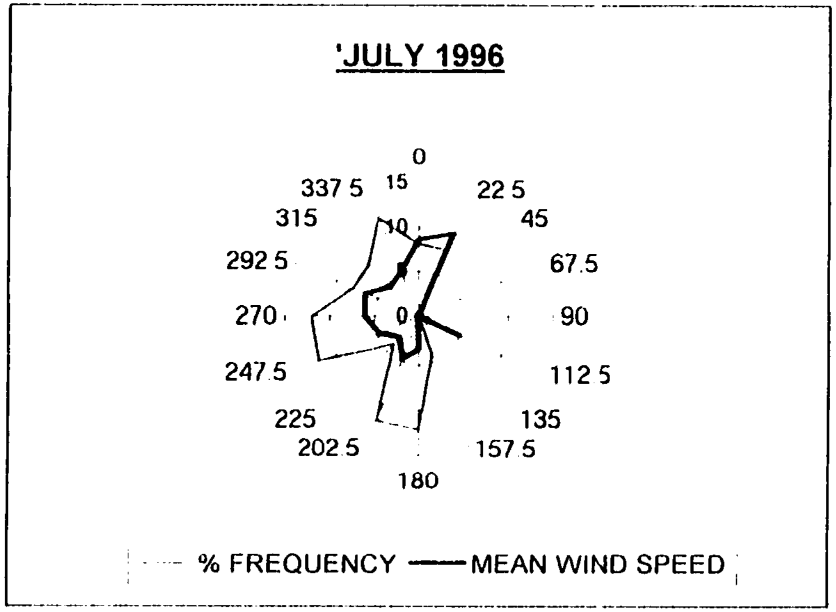
Wind Speed and Direction Analysis
June 1996

COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	0	0
NNE	22.5	0	0
NE	45	3	4
ENE	67.5	7	7
E	90	10	4.3
ESE	112.5	3	3
SE	135	0	0
SSE	157.5	3	6
S	180	10	7
SSW	202.5	13	4.25
SW	225	10	4.7
WSW	247.5	13	2.75
W	270	7	5
WNW	292.5	13	4.5
NW	315	3	3
NNW	337.5	3	3



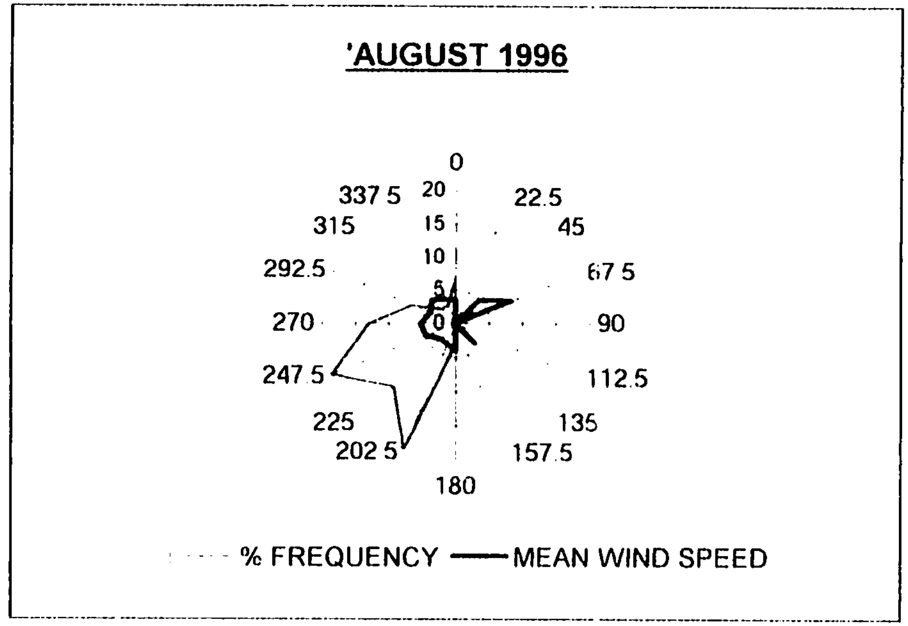
Wind Speed and Direction Analysis
July 1996

COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	8	8 5
NNE	22 5	8	10
NE	45	0	0
ENE	67 5	0	0
E	90	0	0
ESE	112 5	4	5
SE	135	0	0
SSE	157 5	4	0
S	180	12	3 3
SSW	202 5	12	4 7
SW	225	4	3
WSW	247 5	12	4 7
W	270	12	6
WNW	292 5	8	6 5
NW	315	8	4 5
NNW	337 5	12	5 3



Wind Speed and Direction Analysis
August 1996

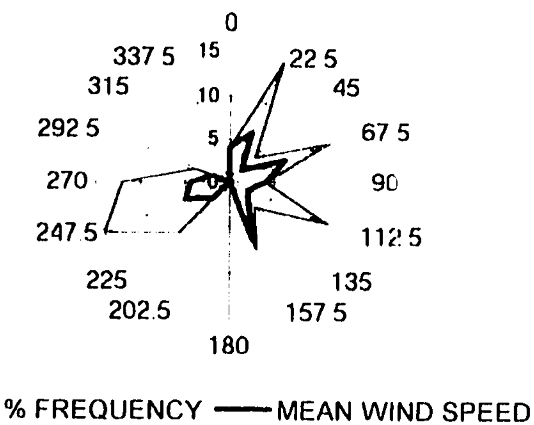
COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	7	3.5
NNE	22.5	0	0
NE	45	3	5
ENE	67.5	3	9
E	90	0	0
ESE	112.5	0	0
SE	135	3	4
SSE	157.5	0	0
S	180	3	4
SSW	202.5	20	3.2
SW	225	13	3.25
WSW	247.5	20	4.7
W	270	13	5.25
WNW	292.5	7	4
NW	315	3	5
NNW	337.5	3	4



Wind Speed and Direction Analysis
September 1996

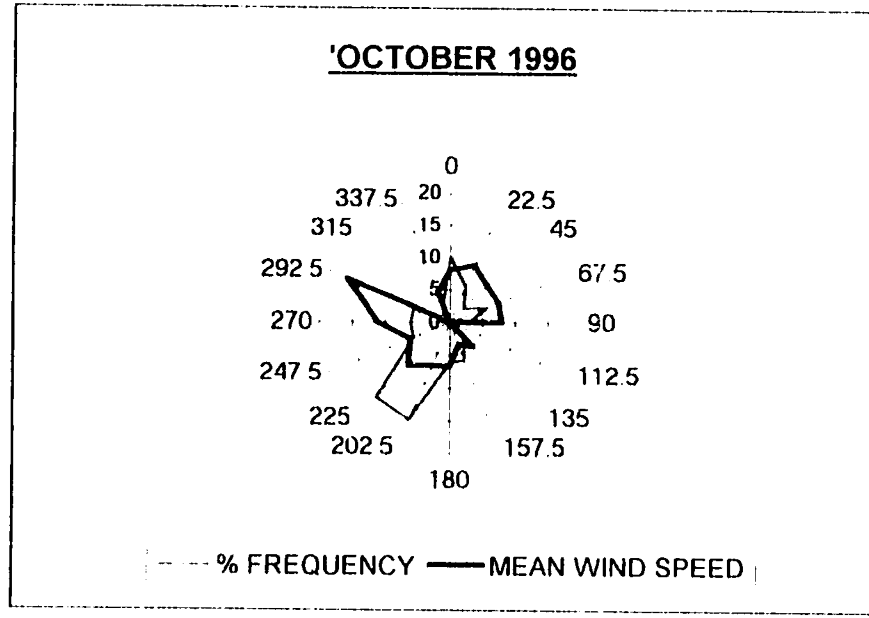
COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	4	4
NNE	22.5	15	6.25
NE	45	4	2
ENE	67.5	12	6.7
E	90	4	4
ESE	112.5	12	2.3
SE	135	4	3
SSE	157.5	8	7
S	180	0	0
SSW	202.5	0	0
SW	225	8	2.5
WSW	247.5	15	5.25
W	270	12	4.3
WNW	292.5	4	2
NW	315	0	0
NNW	337.5	0	0

SEPTEMBER 1996



Wind Speed and Direction Analysis
October 1996

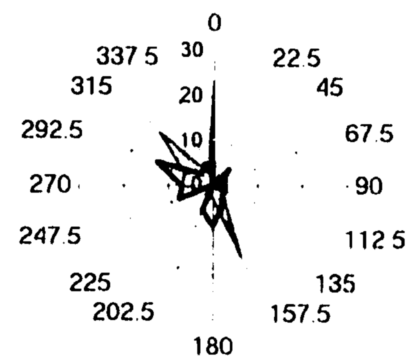
COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	10	8
NNE	22.5	6	9.5
NE	45	3	8
ENE	67.5	6	8
E	90	3	8
ESE	112.5	0	0
SE	135	3	5
SSE	157.5	6	3.5
S	180	6	6.5
SSW	202.5	16	7
SW	225	16	9
WSW	247.5	6	6.5
W	270	6	11
WNW	292.5	6	17
NW	315	0	0
NNW	337.5	3	5



Wind Speed and Direction Analysis
November 1996

COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	23	5.3
NNE	22.5	0	0
NE	45	3	5
ENE	67.5	3	2
E	90	3	0
ESE	112.5	3	3
SE	135	3	3
SSE	157.5	17	5.4
S	180	3	9
SSW	202.5	3	6
SW	225	0	0
WSW	247.5	3	8
W	270	7	7
WNW	292.5	7	13.5
NW	315	17	3.6
NNW	337.5	3	5

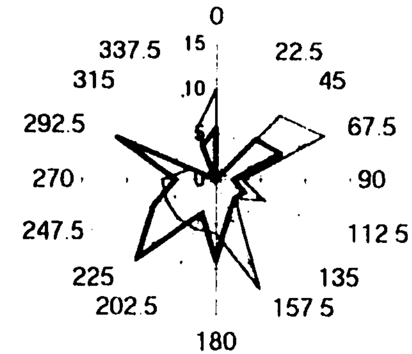
'NOVEMBER 1996



Wind Speed and Direction Analysis
December 1996

COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	10	5 7
NNE	22.5	0	0
NE	45	10	6.3
ENE	67.5	13	7.75
E	90	3	2
ESE	112.5	6	3 5
SE	135	3	3
SSE	157.5	13	4
S	180	6	9
SSW	202.5	6	4
SW	225	6	12 5
WSW	247.5	6	7 5
W	270	6	4.5
WNW	292.5	3	12
NW	315	0	0
NNW	337.5	6	4

'DECEMBER 1996

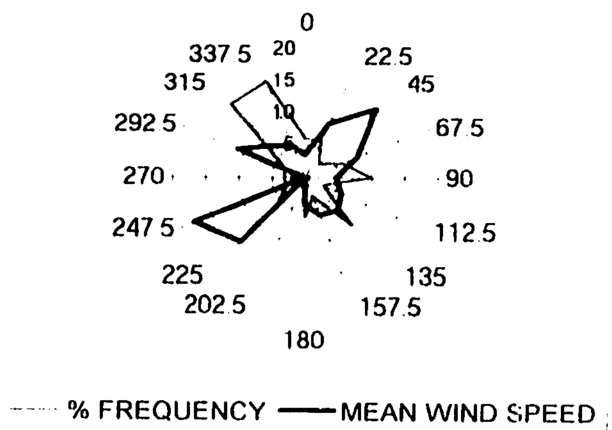


% FREQUENCY —— MEAN WIND SPEED

Wind Speed and Direction Analysis
January 1997

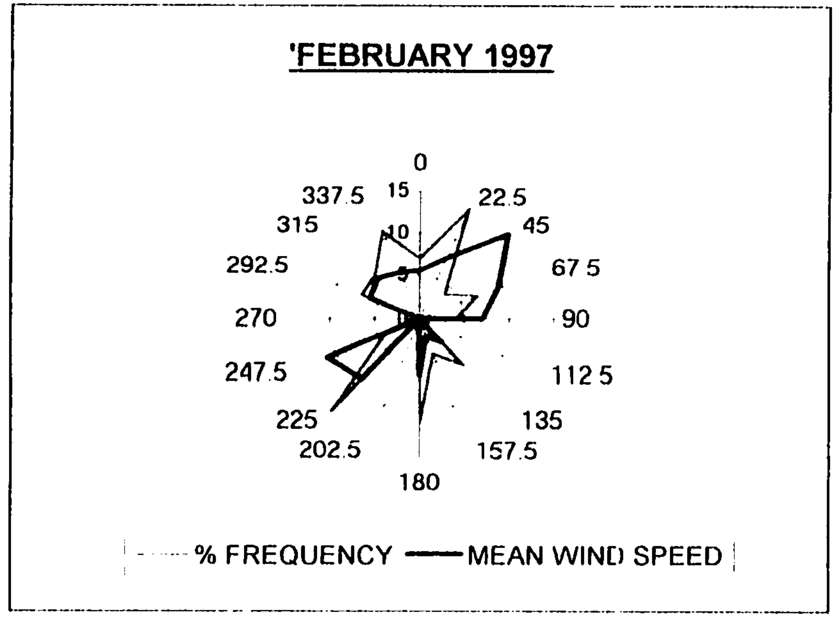
COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	6	3.5
NNE	22.5	6	9
NE	45	3	15
ENE	67.5	6	8.5
E	90	10	4.7
ESE	112.5	3	6
SE	135	10	7
SSE	157.5	3	6
S	180	6	4
SSW	202.5	0	0
SW	225	6	13.5
WSW	247.5	3	18
W	270	0	0
WNW	292.5	3	11
NW	315	16	6.8
NNW	337.5	16	5.25

'JANUARY 1997



Wind Speed and Direction Analysis
February 1997

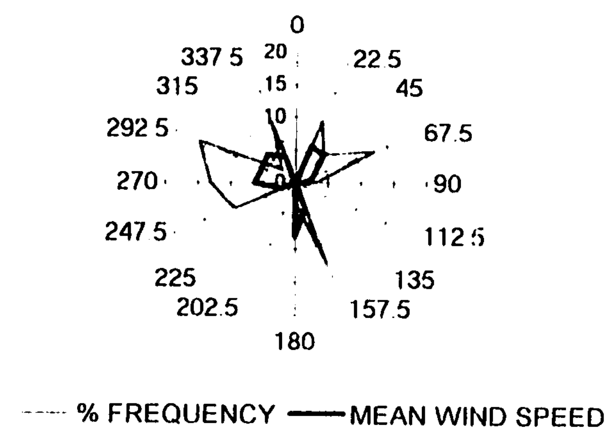
COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	7	5.5
NNE	22.5	14	7 5
NE	45	4	14
ENE	67.5	7	9.5
E	90	4	7
ESE	112.5	0	0
SE	135	7	3.5
SSE	157.5	4	2
S	180	11	6
SSW	202.5	0	0
SW	225	14	9
WSW	247 5	4	11
W	270	0	0
WNW	292.5	7	6
NW	315	7	6 5
NNW	337.5	11	5 7



Wind Speed and Direction Analysis
March 1997

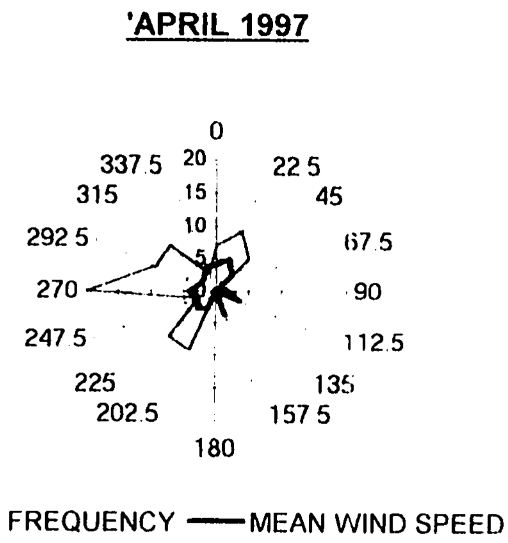
COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	0	0
NNE	22.5	10	6
NE	45	6	6
ENE	67.5	13	3
E	90	3	2
ESE	112.5	0	0
SE	135	0	0
SSE	157.5	13	4
S	180	3	8
SSW	202.5	0	0
SW	225	0	0
WSW	247.5	10	2.3
W	270	13	6.25
WNW	292.5	16	5.6
NW	315	3	6
NNW	337.5	10	4.3

'MARCH 1997



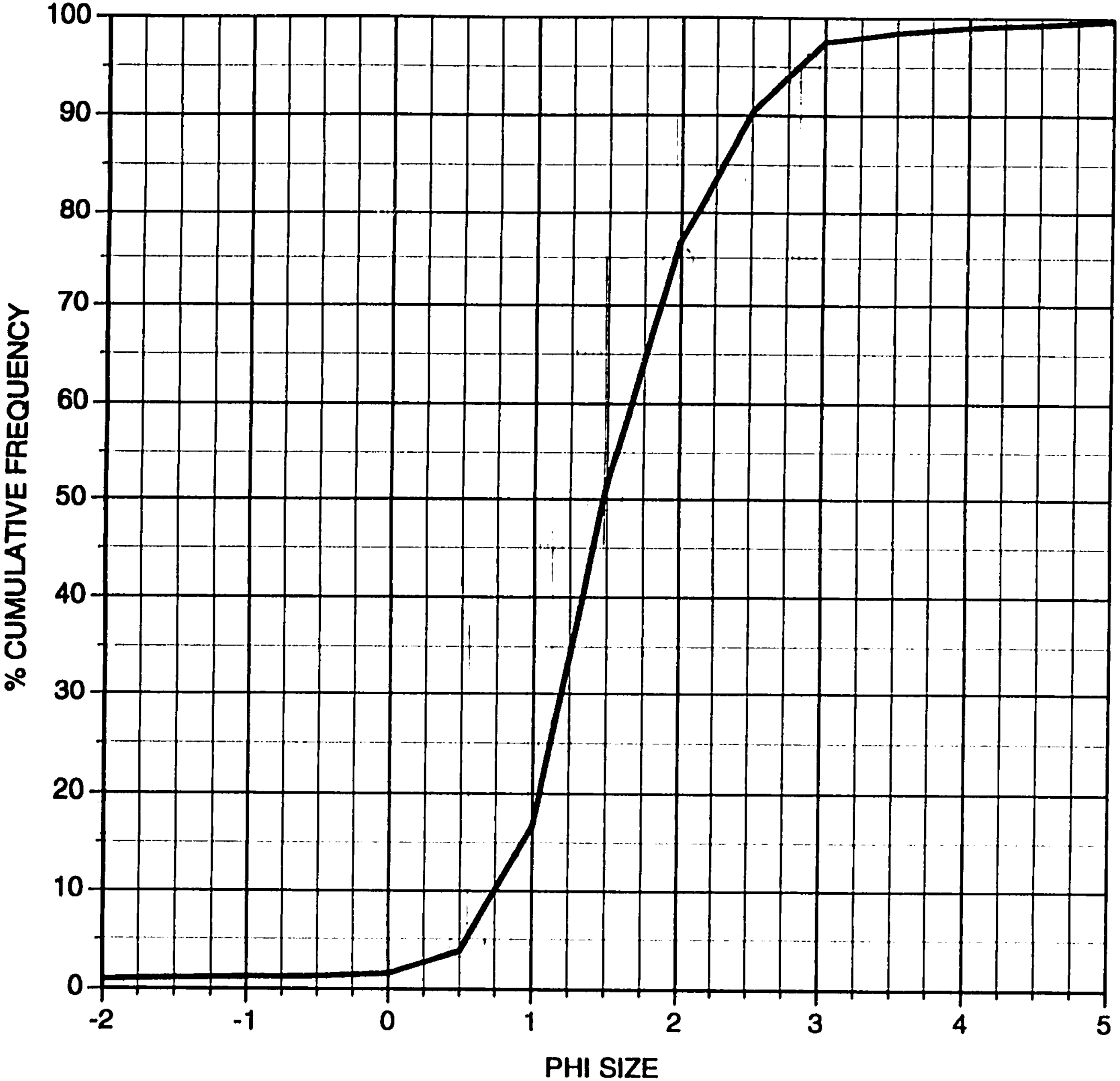
Wind Speed and Direction Analysis
April 1997

COMPASS DIRECTION	DEGREE DIRECTION	% FREQUENCY DIRECTION	MEAN SPEED (KM/H)
N	0	7	4
NNE	22.5	10	5.3
NE	45	7	3.5
ENE	67.5	0	0
E	90	3	2
ESE	112.5	3	4
SE	135	0	0
SSE	157.5	3	4
S	180	0	0
SSW	202.5	10	3
SW	225	10	3.7
WSW	247.5	3	3
W	270	20	4.2
WNW	292.5	10	2.7
NW	315	10	2.7
NNW	337.5	3	4



Appendix B: Sample of Cumulative Phi Curves

KILCOURSIE BEACH
AUGUST 3, 1996.
LINE 1
5.0 METRES



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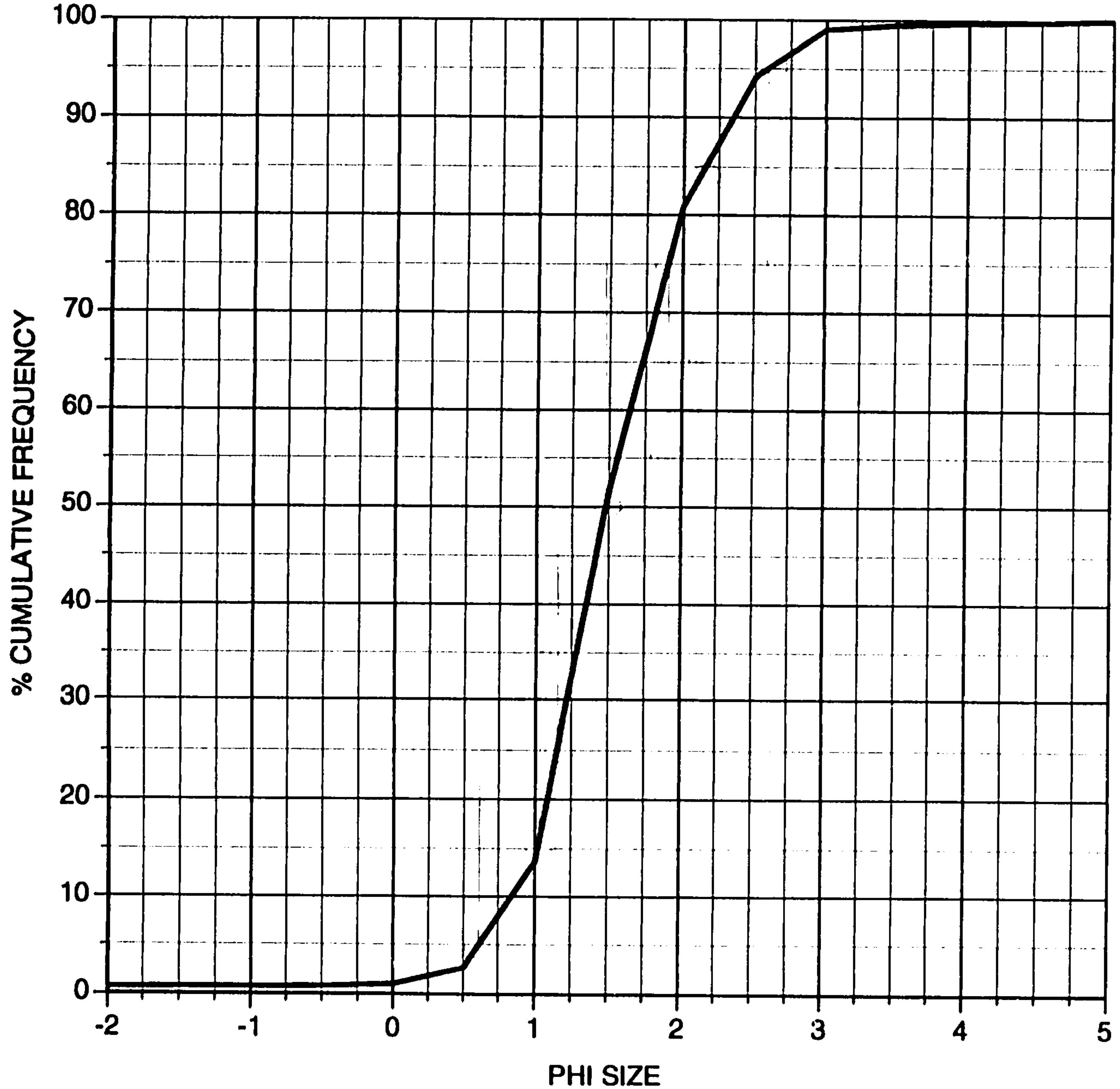
10.0 METRES



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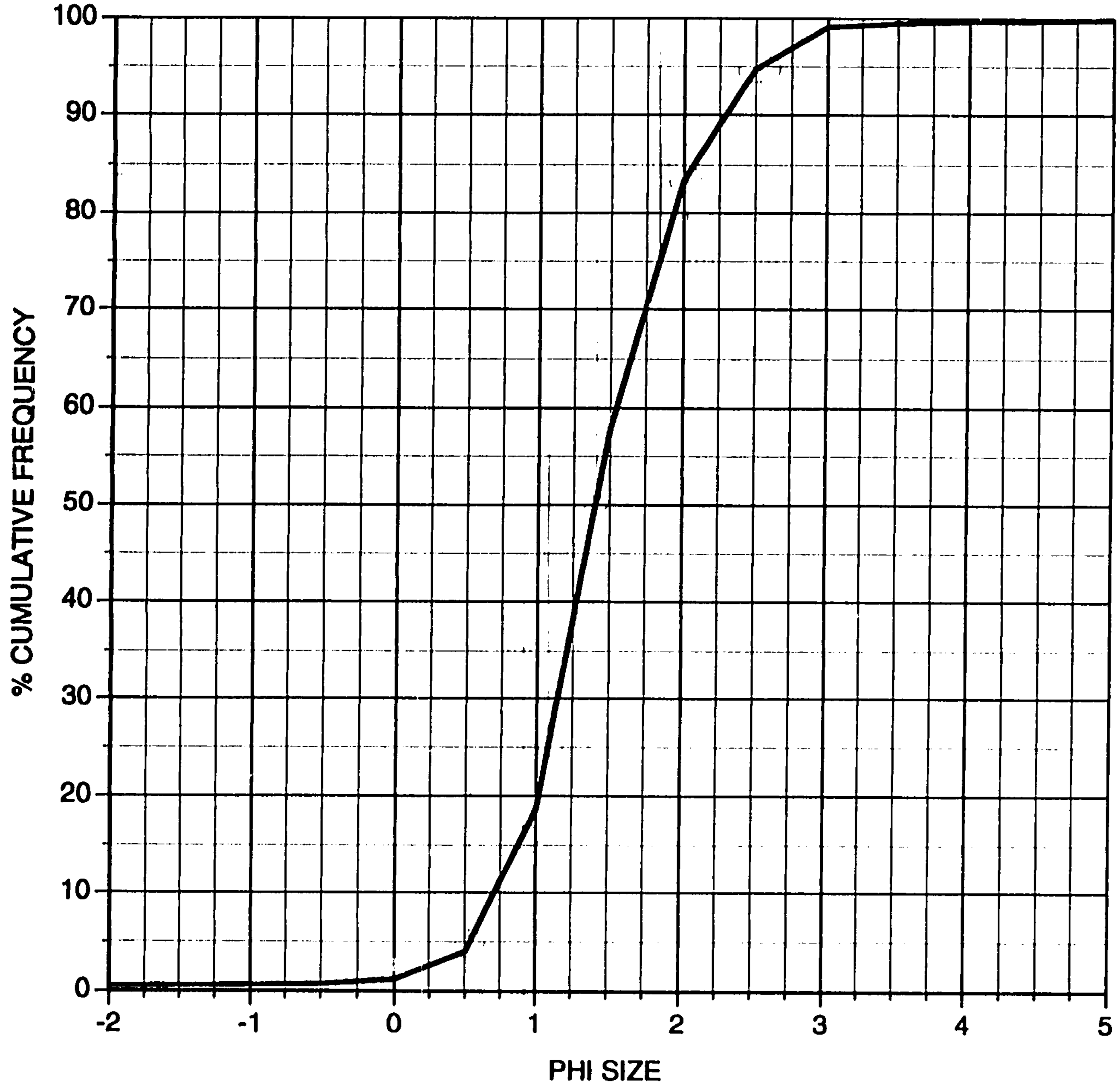
AUGUST 3, 1996.
LINE M1
15.0 METRES



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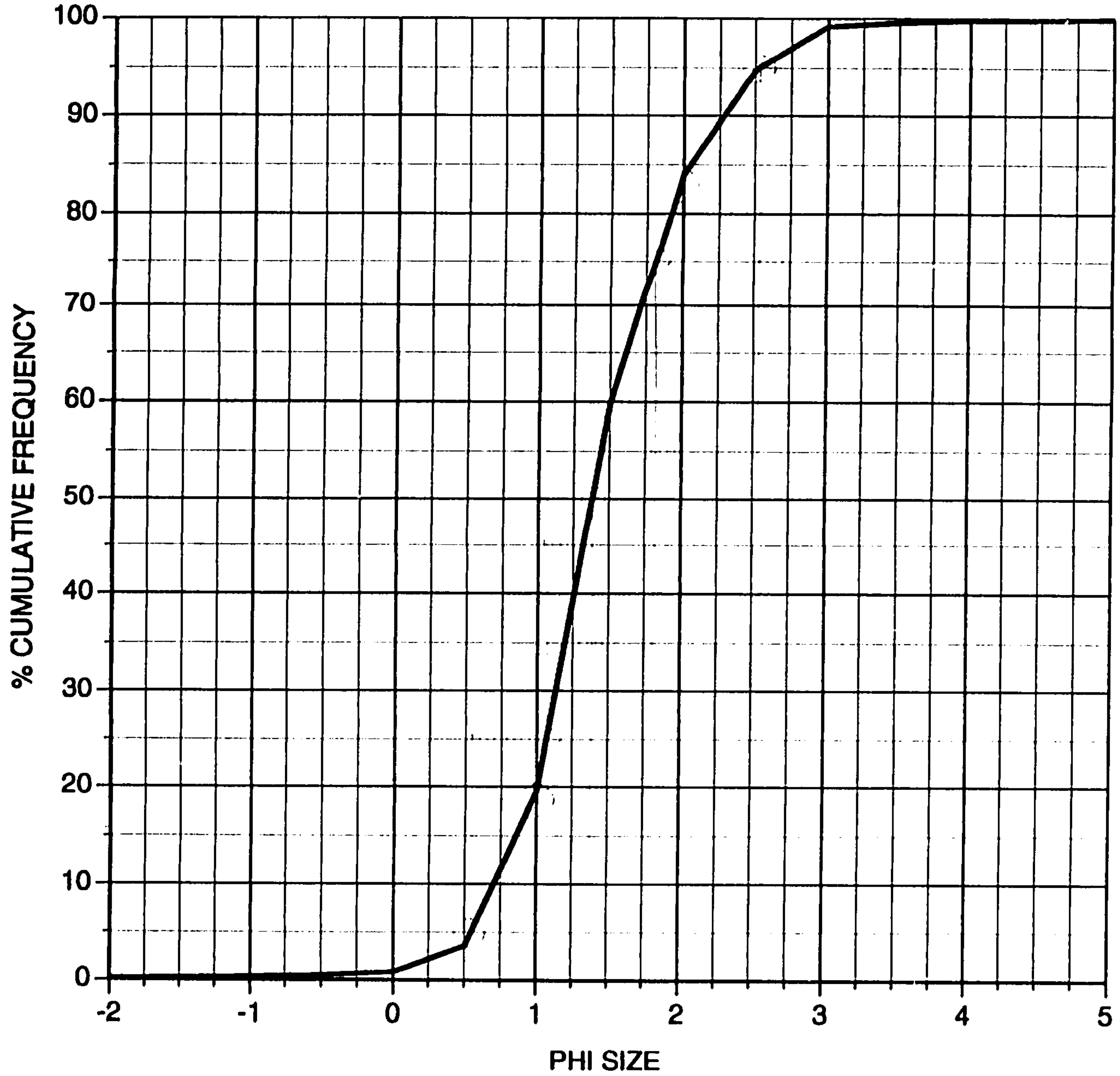
LINE 1
20.0 METRES



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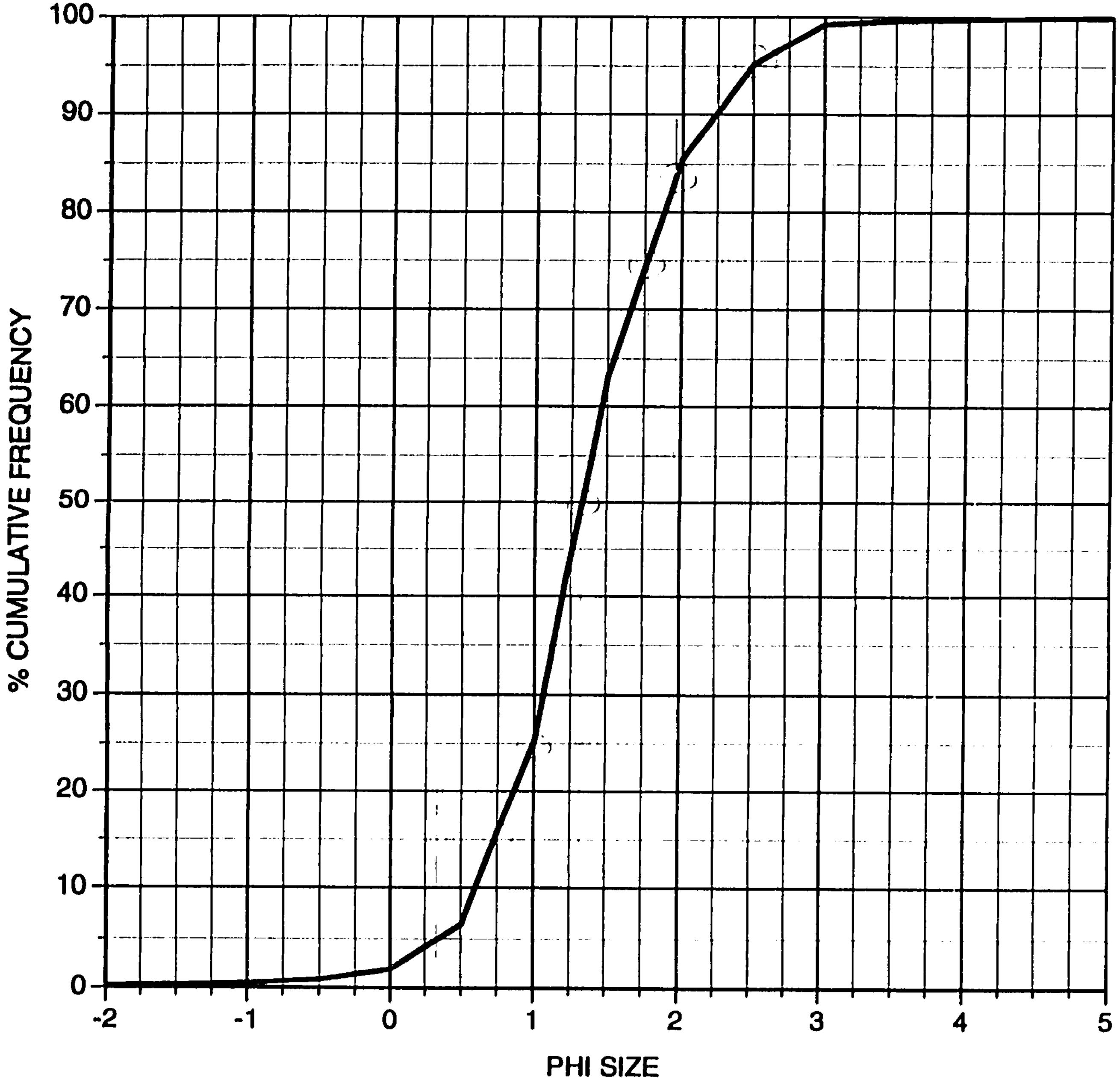
LINE 1
25.0 METRES



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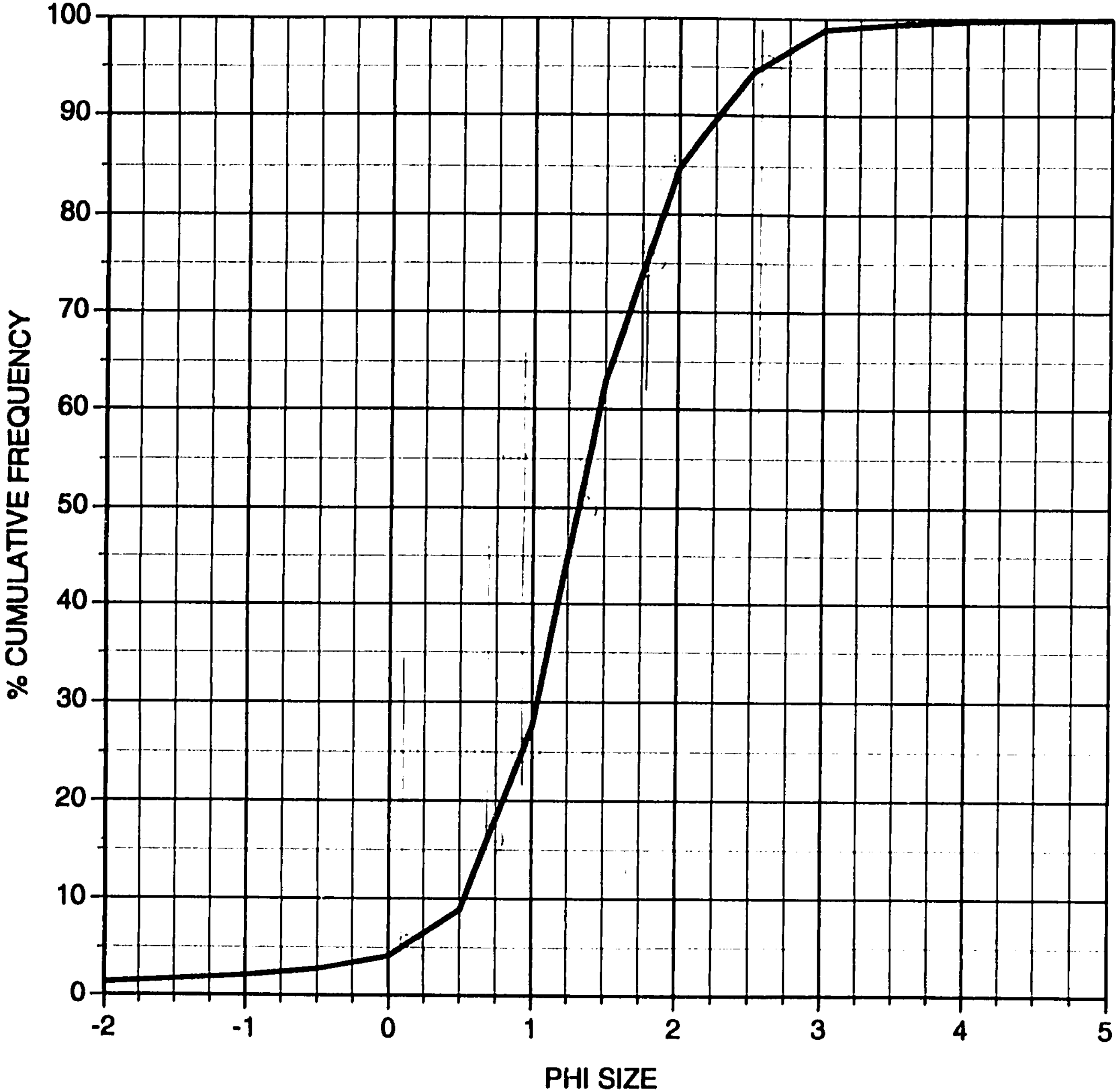
AUGUST 3, 1996.
LINE 1
30.0 METRES



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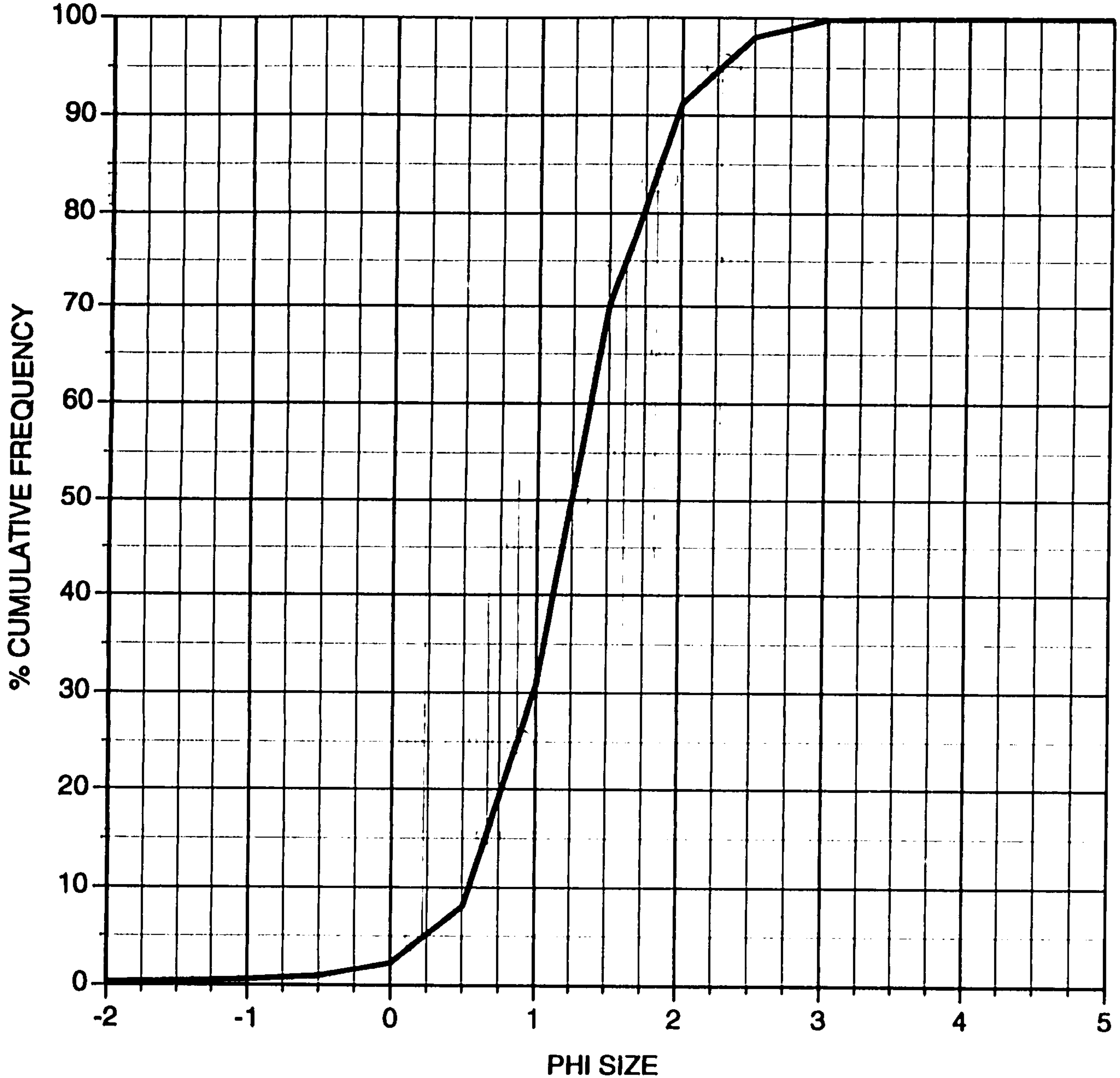
LINE 1
35.0 METRES



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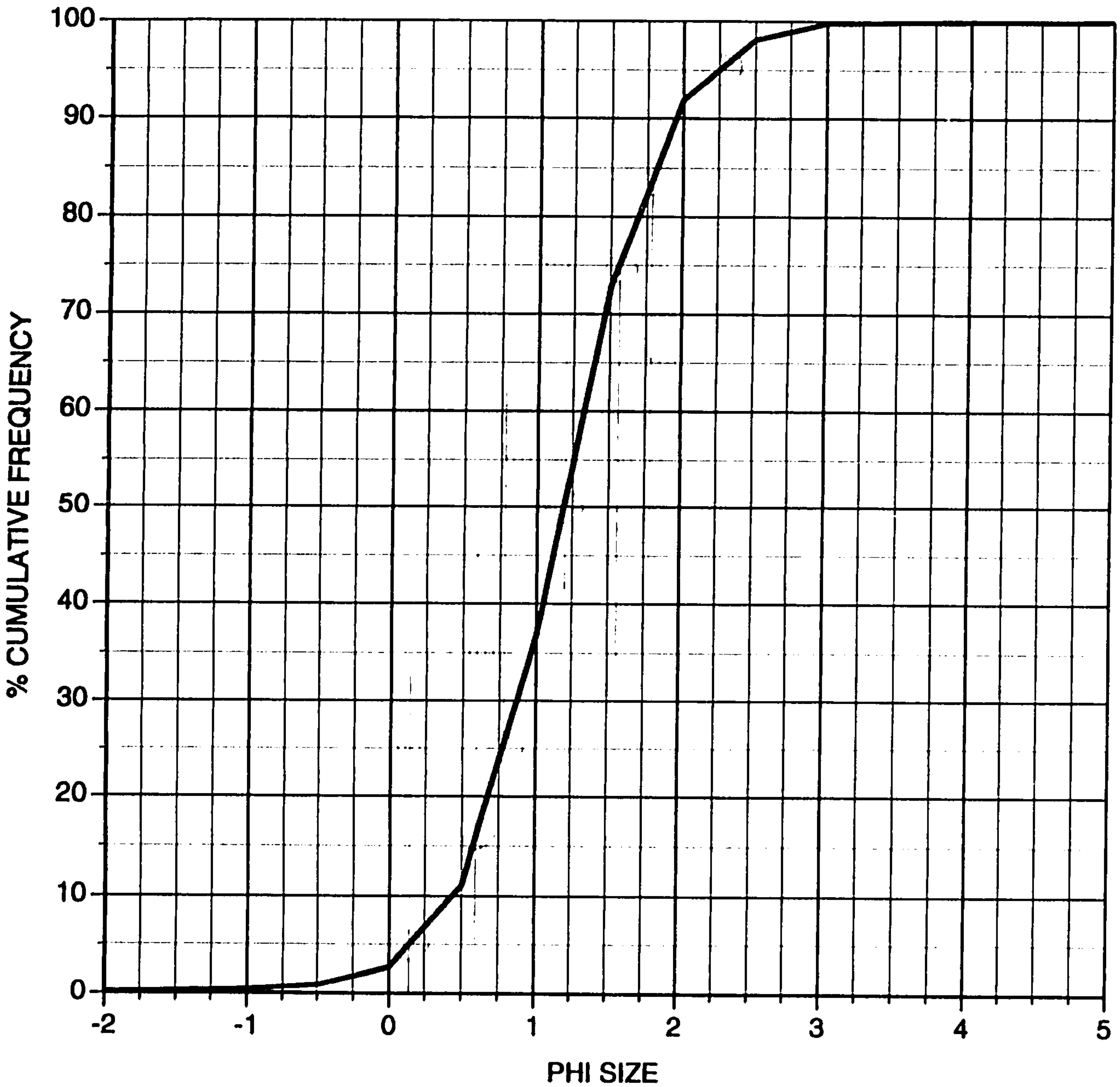
AUGUST 3, 1996.
LINE 1
40.0 METRE



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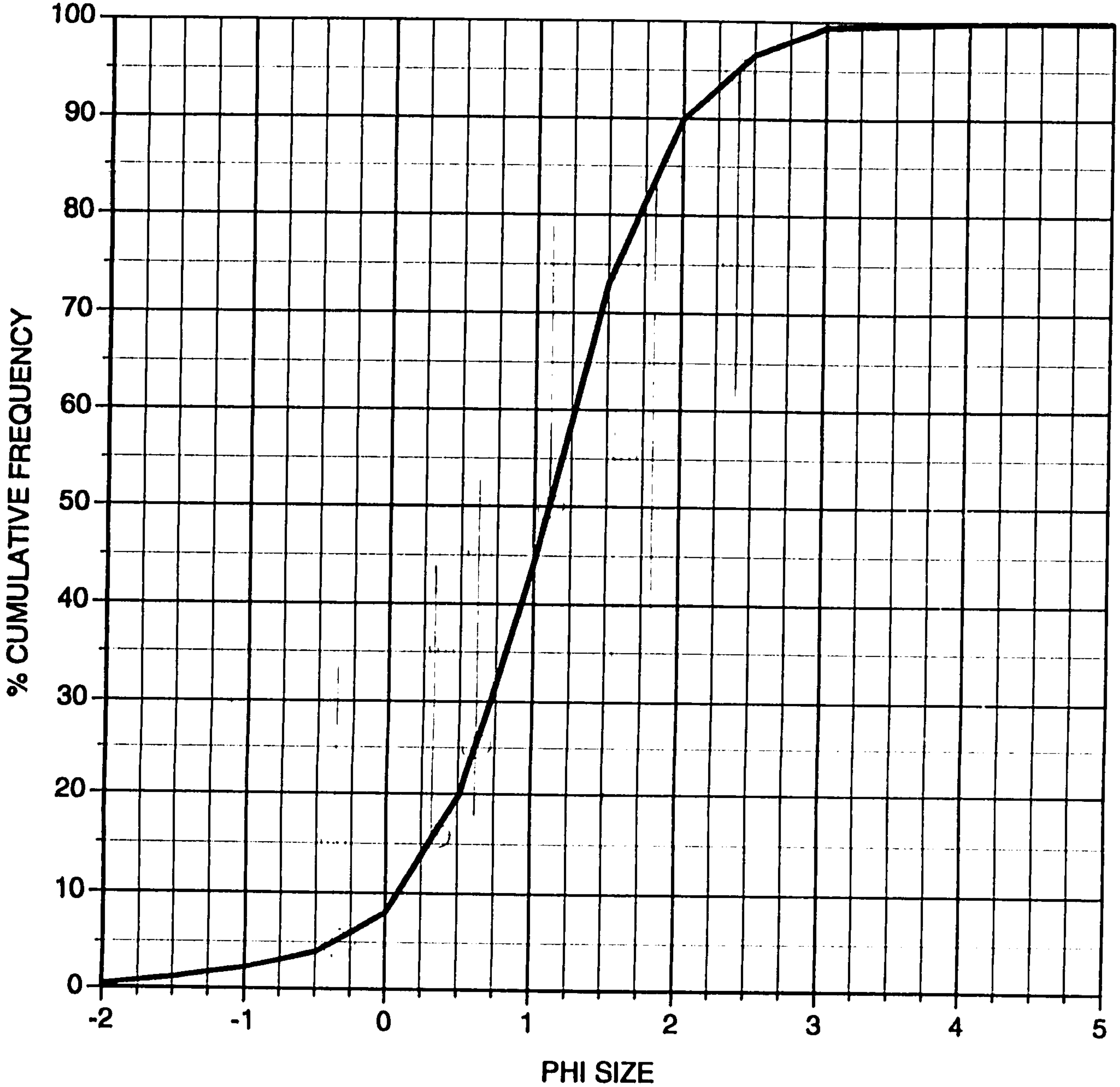
KILCOURSIE BEACH
AUGUST 3, 1996.
LINE 1
45.0 METRES



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Appendix C: Mineralogical Sediment Analysis

Beaver Dams Line 4					
Profile Distance	Grain Size (Phi)	Mineralogical Composition % Organics	% Granitic	% Darks	% Garnet
10.0 m	-2.0	100	-	-	-
	-1.5	88	12	-	-
	-1.0	73	27	-	-
	-0.5	12	84	4	-
	0.0	21	75	4	-
	0.5	1	96	4	-
	1.0	1	83	10	6
	1.5	-	92	7	6
	2.0	-	76	10	5
	2.5	-	65	24	11
	3.0	-	61	25	14
	3.5	2	61	24	12
	4.0	5	65	23	8
15.0 m	-2.0	100	-	-	-
	-1.5	-		-	-
	-1.0	7	80	13	-
	-0.5	3	93	4	-
	0.0	-	96	4	-
	0.5	-	96	4	-
	1.0	-	83	11	6
	1.5	-	88	8	4
	2.0	-	83	13	4
	2.5		55	32	13
	3.0	-	56	30	15
	3.5	-	61	29	10
	4.0	-	65	25	10
20.0 m	-2.0	-	100	-	-
	-1.5	29	71		
	-1.0	2	93	5	-
	-0.5	3	88	9	-
	0.0	1	93	7	-
	0.5	94	5	1	-
	1.0	-	89	7	4
	1.5	-	91	6	3
	2.0	-	78	18	4
	2.5	-	59	25	16
	3.0	-	60	25	18
	3.5	3	56	33	7
	4.0	2	69	23	6
25.0 m	-2.0	20	80	-	-
	-1.5	7	87	7	-
	-1.0	5	88		-
	-0.5	4	92	4	-
	0.0	1	93	5	-
	0.5	-	95	5	-
	1.0	-	93	5	4

Beaver Dams Line4					
Profile Distance	Grain Size (Phi)	Mineralogical Composition			
		% Organics	% Granitic	% Darks	% Garnet
	1.5	-	87	8	1
	2.0	-	82	13	5
	2.5	-	60	25	15
	3.0	-	62	27	12
	3.5	-	67	24	9
	4.0	-	78	20	5
30.0 m	-2.0	15	70	15	-
	-1.5	7	76	17	-
	-1.0	2	88	10	-
	-0.5	5	87	8	-
	0.0	-	96	4	-
	0.5	-	92	7	1
	1.0	-	92		1
	1.5	-	84	10	6
	2.0	-	77	16	7
	2.5	-	52	28	20
	3.0	-	56	25	16
	3.5	-	63	27	10
	4.0	-	68	25	
25.0 m	-2.0	67	33	-	-
	-1.5	40	40	20	-
	-1.0	-	88	3	
	-0.5	3	86	11	-
	0.0	-	96	4	-
	0.5	-	95	3	2
	1.0	-	92	5	3
	1.5	-	89	7	4
	2.0		81	14	5
	2.5	-	53	28	19
	3.0	-	51	28	21
	3.5	-	65	25	10
	4.0	-	-	-	-
40.0 m	-2.0	-	-	-	-
	-1.5	-	-	-	-
	-1.0	82	9	9	-
	-0.5	12	85	4	-
	0.0	1	93	6	-
	0.5	-	94	5	1
	1.0	-	92	6	2
	1.5	-	93	4	3
	2.0	-	89	6	5
	2.5	-	81	14	5
	3.0	-	78	16	6
	3.5	-	-	-	-
	4.0	-	-	-	-

Kilcoursie Beach Line 1					
Profile Distance	Grain Size (Phi)	Mineralogical Composition			
		% Organics	% Granitic	% Darks	% Garnet
0.0 m	-2.0	100	-	-	-
	-1.5	100	-	-	-
	-1.0	100	-	-	-
	-0.5	98	2	-	-
	0.0	52	46	1	-
	0.5	6	86	6	2
	1.0	-	86	9	3
	1.5	-	78	17	5
	2.0	-	68	22	10
	2.5	-	52	28	20
	3.0	-	44	37	19
	3.5	1	40	41	18
	4.0	5	41	39	15
5.0 m	-2.0	81	19	-	-
	-1.5	100		-	-
	-1.0	63	33	4	-
	-0.5	61	35	4	-
	0.0	19	71	10	-
	0.5	[illegible]	92	[illegible]	2
	1.0	-	89	9	2
	1.5	-	85	12	3
	2.0	1	66	26	7
	2.5		53	31	16
	3.0	-	43	32	25
	3.5	2	40	41	17
	4.0	4	45	39	12
10.0 m	-2.0	60	40	-	-
	-1.5	100			
	-1.0	76	24	-	-
	-0.5	54	40	6	-
	0.0	-	12	83	5
	0.5	4	86	9	1
	1.0	-	87	9	4
	1.5	-	85	11	4
	2.0	-	61	26	13
	2.5	-	47	30	23
	3.0	-	40	36	24
	3.5	2	44	40	14
	4.0	4	55	31	10
15.0 m	-2.0	100	-	-	-
	-1.5	99	1	-	-
	-1.0	70	30	-	-
	-0.5	46	49	5	-
	0.0	14	75	11	-
	0.5	15	73	12	-
	1.0	-	87	8	5

	1.5	-	78	16	6
	2.0	-	60	24	16
	2.5	-	42	38	20
	3.0	-	38	36	26
	3.5	-	40	40	20
	4.0	1	50	34	15
20.0 m	-2.0	77	23	-	-
	-1.5	40	40	20	-
	-1.0	50	38	12	-
	-0.5	15	73	12	-
	0.0	5	88	7	-
	0.5	1	89	9	1
	1.0	-	84	13	3
	1.5	-	80	16	4
	2.0	-	51	32	17
	2.5	-	42	38	20
	3.0	-	35	42	23
	3.5	-	33	48	19
	4.0	2	41	40	17
30.0 m	-2.0	69	31	-	-
	-1.5	28	[illegible]	10	-
	-1.0	7	80	13	-
	-0.5	13	[illegible]	12	-
	0.0	5	88	7	-
	0.5	1	[illegible]	11	3
	1.0	-	86	13	3
	1.5	-	82	12	[illegible]
	2.0	-	58	28	14
	2.5	-	51	31	18
	3.0	-	40	38	22
	3.5		44	[illegible]	14
	4.0	-	48	38	12
35.0 m	-2.0	78	22	-	-
	-1.5	56	44	-	-
	-1.0	26	63	11	-
	-0.5	8	80	12	-
	0.0	4	82	13	1
	0.5	1	90	6	3
	1.0	-	84	10	6
	1.5	-	75	17	8
	2.0	-	60	26	14
	2.5	-	48	35	16
	3.0	-	41	42	17
	3.5	-	43	38	19
	4.0	-	49	36	15
40.0 m	-2.0	70	30	-	-
	-1.5	30	60	10	-
	-1.0	18	65	17	-

	-0.5	16	75	9	-
	0.0	3	89	5	3
	0.5	-	90	7	3
	1.0	-	89	7	4
	1.5	-	76	18	6
	2.0	-	60	31	9
	2.5	-	49	37	14
	3.0	-	41	40	18
	3.5	1	45	39	15
	4.0	1	58	33	8
45.0 m	-2.0	99	1	-	-
	-1.5	-	-	-	-
	-1.0	-	66	33	-
	-0.5	-	77	19	4
	0.0	-	90	8	2
	0.5	-	90	8	2
	1.0	-	88	9	3
	1.5	-	85	12	3
	2.0	-	83	13	4
	2.5	-	78	18	4
	3.0	-	58	30	12
	3.5	-	50	36	14
	4.0	-	-	-	-

Kilcoursie Beach Line 4					
Profile Distance	Grain Size (Phi)	Mineralogical Composition			
		% Organics	% Granitic	% Darks	% Garnet
0.0 m	-2.0	100	-	-	-
	-1.5	100	-	-	-
	-1.0	100	-	-	-
	-0.5	88	10	2	-
	0.0	58	35	7	-
	0.5	3	88	8	1
	1.0	-	86	10	4
	1.5	-	84	11	5
	2.0	-	70	21	9
	2.5	-	70	22	8
	3.0	3	47	35	17
	3.5	3	41	40	16
	4.0	10	58	26	6
5.0 m	-2.0	83	17	-	-
	-1.5	69	19	12	-
	-1.0	47	50	3	-
	-0.5	25	67	8	-
	0.0	12	77	11	-
	0.5	2	89	6	3
	1.0	-	90	7	3
	1.5	-	80	15	5
	2.0	-	75	19	6
	2.5		54	29	17
	3.0	-	63	26	11
	3.5	1	41	36	22
	4.0	6	50	33	11
10.0 m	-2.0	18	82	-	-
	-1.5	2	90	8	
	-1.0	3	78	19	-
	-0.5	-	83	17	-
	0.0	-	92	8	-
	0.5	-	90	9	1
	1.0	-	87	11	2
	1.5	-	83	12	5
	2.0	-	68	25	7
	2.5	-	66	24	10
	3.0	-	60	26	13
	3.5	-	52	32	15
	4.0	2	53	35	10
15.0 m	-2.0	4	83	13	-
	-1.5	-	86	14	-
	-1.0	-	93	7	-
	-0.5	-	88	12	-
	0.0	-	89	11	-
	0.5	-	92	6	2
	1.0	-	86	11	3

Kilcoursie Beach Line 4					
Profile Distance	Grain Size (Phi)	Mineralogical Composition			
		% Organics	% Granitic	% Darks	% Garnet
	1.5	-	83	13	4
	2.0	-	77	19	4
	2.5	-	70	23	7
	3.0	-	57	18	18
	3.5	-	49	35	16
	4.0	-	49	38	13
20.0 m	-2.0	83	17	-	-
	-1.5	60	40	-	-
	-1.0	27	68	5	-
	-0.5	13	81	6	-
	0.0	3	88	8	2
	0.5	-	86	11	3
	1.0	-	86	10	3
	1.5	-	68	26	6
	2.0	-	65	29	6
	2.5	-	44	38	18
	3.0	-	41	39	20
	3.5	-	49	35	16
	4.0	-	[illegible]	[illegible]	16
30.0 m	-2.0	100	-	-	-
	-1.5	-	-	-	-
	-1.0				
	-0.5	6	76	18	-
	0.0	[illegible]	92	[illegible]	-
	0.5	-	84	15	-
	1.0	-	78	17	1
	1.5	-	85	11	3
	2.0		82	11	1
	2.5	-	35	41	24
	3.0	-	22	47	30
	3.5	-	25	56	20
	4.0	-	-	-	-

Kilcoursie Beach Line 7					
Profile Distance	Grain Size (Phi)	Mineralogical Composition			
		% Organics	% Granitic	% Darks	% Garnet
0.0 m	-2.0	100	-	-	-
	-1.5	100	-	-	-
	-1.0	100	-	-	-
	-0.5	99	1	-	-
	0.0	65	32	3	-
	0.5	8	88	3	1
	1.0	4	86	7	3
	1.5	-	86	10	4
	2.0	-	75	18	7
	2.5	-	58	28	14
	3.0	2	52	34	13
	3.5	2	41	42	15
	4.0	5	47	38	10
10.0 m	-2.0	100	-	-	-
	-1.5	100	-	-	-
	-1.0	100	-	-	-
	-0.5	90	8	2	-
	0.0	17	70	13	-
	0.5	7	87	6	-
	1.0	2	88	7	3
	1.5	-	72	21	7
	2.0	-	65	25	11
	2.5		53	26	20
	3.0	-	41	36	23
	3.5	2	35	42	21
	4.0	10	45	37	21
15.0 m	-2.0	100	-	-	-
	1.5	100			
	-1.0	85	15	-	-
	-0.5	54	41	6	-
	0.0	20	70	11	-
	0.5	[illegible]	87	12	-
	1.0	-	90	7	3
	1.5	-	82	15	3
	2.0	-	72	21	8
	2.5	-	49	34	17
	3.0	-	39	39	22
	3.5	3	43	39	15
	4.0	5	50	35	10
20.0 m	-2.0	100	-	-	-
	-1.5	100	-	-	-
	-1.0	82	11	[illegible]	-
	-0.5	31	62	8	-
	0.0	[illegible]	81	14	-
	0.5	1	91	7	-
	1.0	-	84	11	5

Kilcoursie Beach Line 7					
Profile Distance	Grain Size (Phi)	Mineralogical Composition			
		% Organics	% Granitic	% Darks	% Garnet
	1.5	-	80	13	7
	2.0	-	70	23	7
	2.5	-	52	27	21
	3.0	1	50	28	21
	3.5	2	40	42	16
	4.0	5	47	38	10
25.0 m	-2.0	60	30	10	-
	-1.5	17	69	14	-
	-1.0	16	71	14	-
	-0.5	10	82	8	-
	0.0	2	83	15	-
	0.5	2	82	14	2
	1.0	-	81	14	5
	1.5	-	78	15	7
	2.0	-	62	25	13
	2.5	-	40	39	21
	3.0	-	40	42	18
	3.5	-	43	44	13
	4.0	2	54	36	8
30.0 m	-2.0	100	-	-	-
	-1.5	100	-	-	-
	-1.0	99	1		
	-0.5	45	46	9	-
	0.0	7	95	7	-
	0.5	2	93	4	1
	1.0	-	86	11	1
	1.5	-	80	17	3
	2.0		67	24	9
	2.5	-	40	35	25
	3.0	-	36	40	25
	3.5	2	40	44	14
	4.0	6	44	40	10
35.0 m	-2.0	75	25	-	-
	-1.5	67	33	-	-
	-1.0	18	68	14	-
	-0.5	2	81	17	-
	0.0	-	90	10	-
	0.5	-	92	7	1
	1.0	-	89	7	3
	1.5	-	83	12	5
	2.0	-	-	-	-
	2.5	-	-	-	-
	3.0	-	-	-	-
	3.5	-	-	-	-
	4.0	-	-	-	-

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