'Wind and Sand on the South Coast'

Environmental Control- ARCH 332

Dan Eves

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INTRODUCTION

The South Coast of Wellington is renowned for its rugged beauty and picturesque views. However, coinciding with this ruggedness is the exposure to nature's elements. A common site during a typical southerly is people leaning hard into a strong wind, coming in and out of focus amongst clouds of sand streaming off the beach and onto the streets. It is this phenomenon that I will be attempting to address through programme of wind shelters. Though a problem throughout the south coast the research will focus on Lyall Bay, as it is currently the most vulnerable environment.

The research will investigate:

- The study of wind patterns on the south coast
- The study of appropriate wind shelters that provide protection in the areas most vulnerable.
- The designing of wind shelters that are sensitive to the aesthetic of the context (ie do not distract from the natural beauty)
- To investigate a wind shelter design that also addresses the issue of sand transportation.

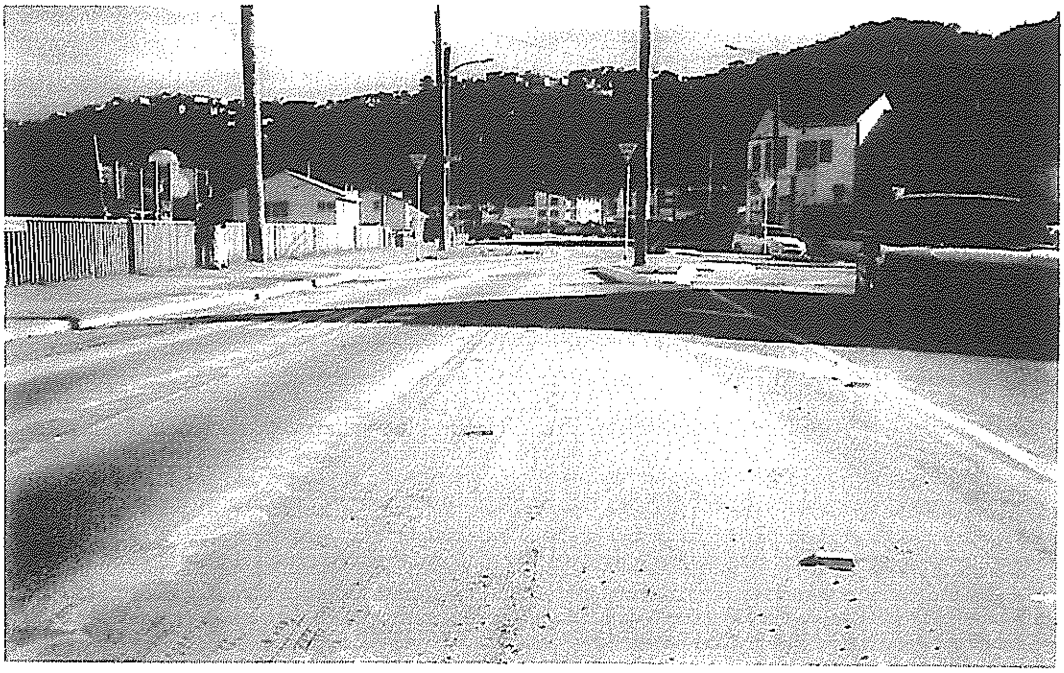
The Urban development in this area has caused significant beach erosion and it has also removed the natural wind shelters created by the original sand dunes.
The need to retain the sand and to reduce the transportation throughout the residential area is paramount.

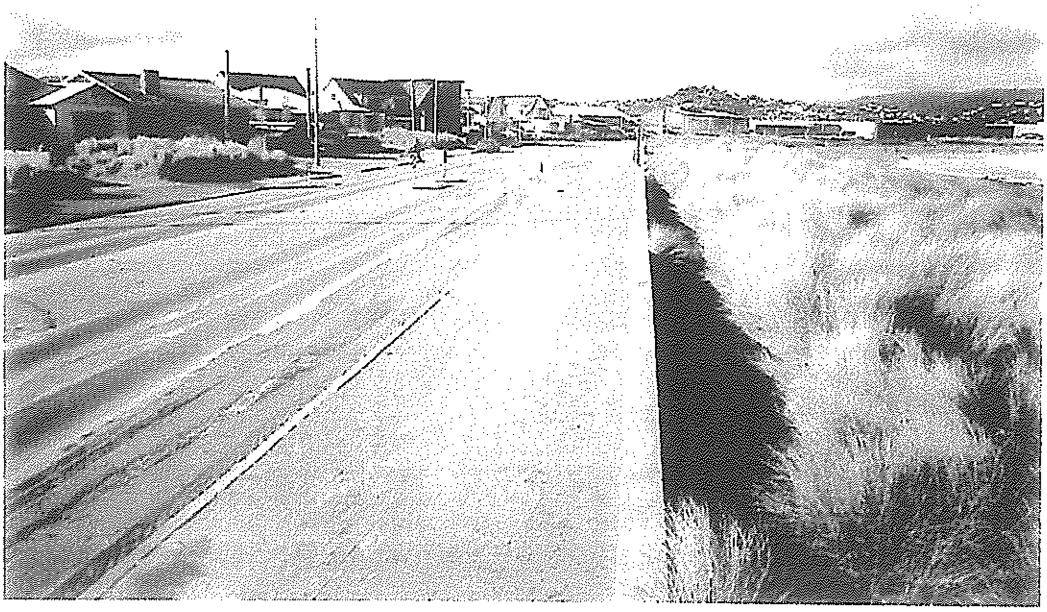
I seek to design a wind shelter that promotes a more enjoyable interaction with the coastline, in a manner which is appropriate to the natural characteristics of the area, and one which will aid in the sustaining of the environment we now have.

The goals of this research will be to design a wind shelter, which though designed for Lyall Bay, could potentially be implemented throughout the south coast, addressing sand transportation and pedestrian protection

To achieve this I intend to:

- Research the history of Lyall Bay beach
  - -Understanding it's ecological background
  - -The effects of urban development
  - -The residential history of wind and sand problems
  - -The rehabilitation processes.
- Investigate the design parameters set by the south coast plan (WCC)
- Investigate wind shelters, and research information that may be appropriate to sand transport reduction.
- Understand the climatic conditions and prevailing wind patterns of Lyall Bay (South coast)
- Design a number of appropriate wind shelters, seeking to maintain natural aesthetic and relationship to the coastline.
- Test the above designs to see there effectiveness in a simulated environment (Eg. wind tunnels or computer programme.)





SAND - POST STORM - SEP 03

HISTORY OF LYALL BAY

Lyall Bay beach is located in the eastern suburbs of Wellington City, and is easily recognised with the International Airport running down one side.

It is a beach loaded with history, having provided over a century of pleasurable experiences for local Wellingtonians and passing tourists, with fun in the surf and sand. A beach, which has created so many memories, but one whose history is clouded with controversy, residential dissatisfaction and disregard for the natural state of the bay. Original beach users described the beach as a beautiful area, providing excellent picnicking and safe swimming[1]. In time Lyall Bay was developed into a suburb with roads, buildings and concrete sea walls, turning the natural coastline into one with a distinct urban character.

Chronological History

In 1897 Crawford, a keen developer of the surrounding area, subdivided a section of land he had acquired at the western end of Lyall Bay. Again the subdivision was initially unsuccessful, but would eventually become known as the Maranui Township. [2]

In the early 1900's, Lyall Bay became recognised as Wellington's newest watering place with crowds flocking in the weekend. A place to be seen, people wore top hats, bow ties, dress boots in fact all the fineries one could muster. Baches and beach houses began to be developed along the waterfront, slowly filling the gaps of the recently subdivided Maranui Township. (Press)

In 1911 the tram service was extended from Kilbirnie to Lyall Bay [3]. The result, an almost instant influx of people buying and developing sites. The Morrah Land Company quickly subdivided land they owned making the most of the sudden interest of living in Lyall Bay[4]. The western end of Lyall Bay had become an urban coastline, with the development of roads, houses and entertainment facilities. This was the first major urban intervention on Lyall Bay beach.

The development of Maranui was carried out right over the well-established sand dunes, with the houses and roads being built right to the beach edge. The sand hills were levelled prior to each major subdivision. The authorities demanded that sites to be surveyed, be provided with amenities such as roads and drainage and then be approved by the City Engineer before being actioned by the Land Title Office. This was to ensure that the land being sold was appropriate in order to meet with official requirements.[5] The levelling of these sand hills was the beginning of the undoing of Lyall Bays' natural sand ecosystem.

The values these early pioneers had were firmly based on a European example. Their aim was to develop 'the wilderness' into something dignified, something that was more familiar, and something that began to reflect their heritage. Therefore, they devised a scheme for the 'improvement' of Lyall Bay, which consisted of transforming the sand hills into an attractive resort for picnickers. These values were reflected in the following newspaper article. "It is amusing to notice the alarm that this intelligence has created in the mind of at least one of the habitants of Lyall Bay. His dismay at the prospect of the reserve being 'improved'. He was terrified at the idea of the present primitive wilderness being replaced by lawns, gardens, promenades, band rotundas and that sort of thing.

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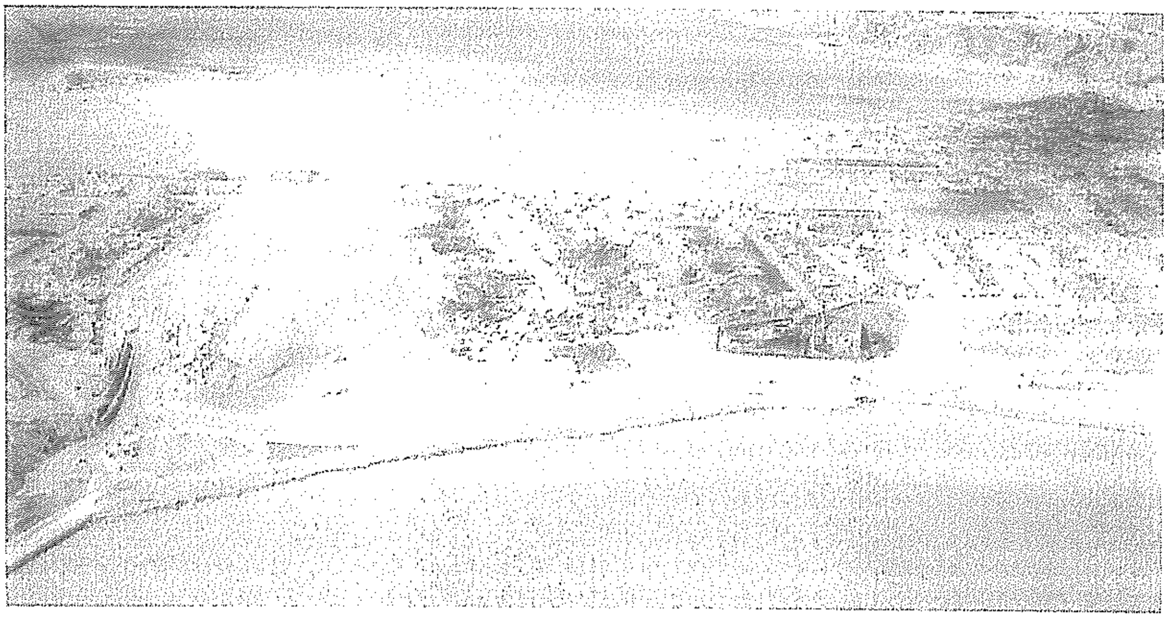
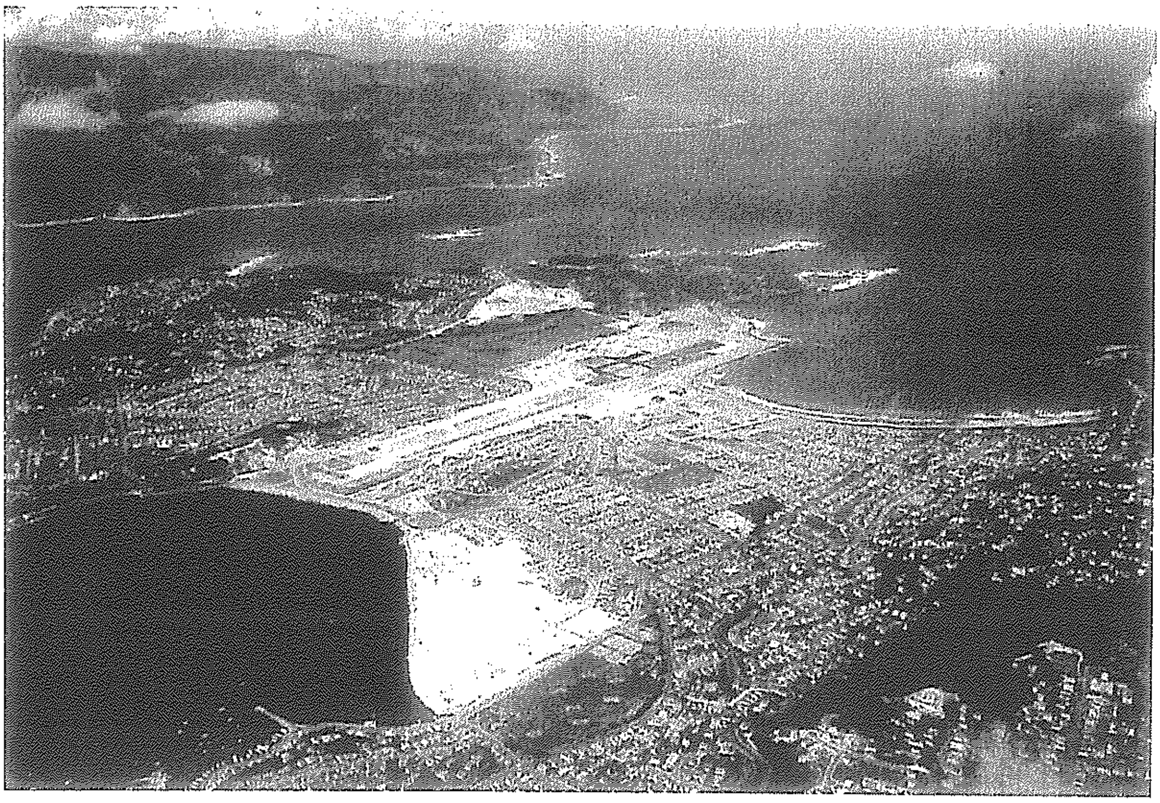
[1] McGill. D, pg 14, 1985
[2] Kenneally, JM &BM pg 14, 1984
[3] Kenneally, JM &BM pg 13, 1991
[4] Evening Post 17th August 1963
[5] Humpheris, Adrian



Early development- Lyall Bay



Development - airport and residential

One is inclined to sympathise with the correspondent in his antipathy to lawns, promenades and band rotundas." [6]

The power of the sea, aided by neglect and the removal of sand from the dunes, saw the end of this ideal. By the 1920's, the picnic shelters were removed, followed by the children's bathing shelters. The Lyall Bay beach of this period no longer thrived in the weekends as it once did. [7]

Mid 1920's – The sand dunes which had provided much shelter from the winds were removed and the bay became more exposed. 'Progress' in this case had a detrimental effect on the local beach amenities. By mid 1920's wide-open space was gradually replaced by high-density housing, usually financed by Government loans.[8]

1926- A solid concrete sea wall was established between Onepu Road and Queens Drive, with the aim of reducing sand drift thus protecting the road from erosion.

1928 - The Council decided to raise a loan of 10,000 pounds for the purpose of levelling, claying and rolling a portion of the land for an airport.

The Prime Minister was against the idea of giving money for expenditure on the construction of a civil or private aerodrome, but as Defence had considerable rights over this area he agreed. The Government provided labour, on the condition that government planes could use the facility free of charge. ***436 acres of sand dunes were levelled*** *at the eastern end of Lyall Bay, the object to provide work for men who would otherwise be unemployed.*

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[6] Free Lance 11 February, 1911

[7] McGill. M pg 35, 1985

[8] Keneally. JM& BM, pg 35, 1991

THE SAND DUNES OF LYALL BAY

In 1930 Lyall Bay Parade was developed, removing the last of the sand dunes and therefore ending the natural eco-cycle and the natural buffer zone that they created.

The sand dunes at Lyall Bay have been referred to as a wasteland, a hilly barren and the eyesore of Wellington. All comments which in their time carried a degree of validity, but comments that lack an understanding of the process which sand dunes represent. To remove a beach of its sand dunes is, in essence removing an integral part of the beach ecosystem.[9] A system, which ensures the coastline, is sustained. The New Zealand coastal dynamics and associated wind and wave action can shift huge quantities of sand into the sea or onto the land, often over a short time. In Lyall Bay alone, there is an estimated 106,000 cubic metres of sand movement per year.[10] Sand dunes are created through the transport of sand. The wind speed near the surface changes whenever there are changes in topography, the amount of vegetation, or some other barrier to sand transport. Any irregularity or barrier will cause turbulence and potentially result in deposition of transported sand grains. Plant stems and leaves are very effective in modifying wind flow, reducing wind speed and causing sand deposition. [11]The erosion of these established dunes was part of the overall sand cycle. With development, the natural buffer zone that the sand dunes created was removed and as a result erosion of the foreshore urban structure occurred and the beach it self depleted to a point where at high tide the beach was about 5 meters from wall to sea.

The Parade was 20 metres wide and built to the edge of the sand dunes. The associated sea wall and footpath encroached another 10 metres onto the beach. The solid concrete sea wall was designed to protect the road from the sea and also to trap the sand from transportation. The design included a curved lip, thought to act as a sand trap, did nothing to reduce the flow, instead, threw the sand higher and thus allowing it to travel further. The gaps in the wall for pedestrian access, worked as a funnel increasing the volume of sand leaving at those points. Moreover, sand that would normally feed back onto the beach during the periods of beach accretion can not do so, as its passage is blocked by the sea wall. Instead, this sand blows across Lyall Bay Parade to form low dunes on the landward side. This sand unless physically re-deposited onto the beach is now lost permanently from the Lyall Bay beach circulation system.[12]

This solution to erosion involving armouring the beach with rock and concrete walls not only destroys the natural character of sand dunes, it also seriously impacts on the amenity use and aesthetics of the beach.

1947
A large storm struck the south coast, creating widespread sand drift. A large part of the problem was associated to the gaps in the sea wall. The build up of wind blown sand was so deep a resident could not open their car door.
The Lyall Bay Residents Association asks for the removal of sand. The sand is removed and a temporary baffle was used to combat sand drift between sea wall openings[13]

1961) 26/1
-Sand drift was recognised as a problem, costing big sums each year in the clearance of roads and footpaths. The concrete sea wall was built with a curled lip to send sand back to beach. This proved to be no great success and sand removal was the easiest option reducing excess sand drift, but left minimal beach.

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[9] Hesp, Patrick, pg 2, 2000
[10] Pickrill, R.A, pg 12, 1979
[11] Hesp, Patrick, pg 4, 2000
[12] Gibb, Jeremy, pg 12, 1991
[13] City Voice, 20th February 1947

1975
A new wall is constructed, reinforcing included where previous erosion had occurred.
"Lyall Bay used to be one of Wellington beautiful expanses of water, but beauty has been partly destroyed by the building of the airport .Now a crude concrete wall is being erected without plan or skill. Another permanent monument to inefficiency and our utilitarian outlook on things, erected by people obviously blind to the beauty around them."[14]

Redevelopment

The early developments of sea walls at Lyall Bay were significantly detrimental to the natural eco system, and over 60 years Governments have continued to invest vast sums of money into restrengthening and replacing the walls, rather than address the actual issue.

A growing awareness of environmental issues saw trial dunes established in the far east end of Lyall Bay. After successful trialing and continued pressure from local residents, the re-establishment of the sand dunes continued along the foreshore. By the mid 90's the dunes were constructed in the middle of the bay and by 2000 sand dunes were established along the whole beach east of Onepu Road.

Today the results of the sand dune rehabilitation programme can be seen, successfully reducing any further damage to the sea walls, reducing the quantity of sand being lost and providing a more natural aesthetic for a predominantly urban beach.

Despite the positive attribute of these dunes, the lack of space for a rear dune accumulation means sand transportation is still a considerable issue, both for pedestrians and for residents.

[14] Evening Post, 11th August 1975

CLIMATOLOGY OF LYALL BAY

Lyall Bay Beach is located on the south coast of the North Island, defining one of the edges for the narrow isthmus that separates Lyall Bay from Evans Bay.
The surrounding country is very hilly, but the exposed edge is unobstructed being over the water of Port Nicholson from the north and Cook Strait from the south. As Cook Strait is a relatively narrow gap between the mountain ranges of the North and South Islands, winds are considerably reinforced orographically in the Wellington area and are channelled strongly in the north/north westerly and southerly directions. There is also some local north-south channelling of the surface winds at Lyall Bay owing to the hills running perpendicular to the beach edge.

The unobstructed passage for wind from the south means the turbulence rating for Lyall Bay is Class I: the wind flow is relatively unimpeded as predominantly smooth surfaces.

Due to the funnelling effect of the break in the mountain chains between the North and South Islands, strong winds occur relatively often at Lyall Bay. Maximum gusts of 84 knots from the north and 101 knots from the south have been recorded since 1959 at Wellington Airport.

Strong southerly winds are most common in winter and are usually associated with ridges over the South Island and lows over or east of the North Island. Southerly winds occur approximately 35%[15] of the time, with most of Lyall Bays wind coming from the predominate north/ northwesterly quarter. The situation is very different in the case of winds averaging over 30 knots, when southerlies are about 30 percent more frequent than the northerlies. The most severe winds experienced are usually from the south and are commonly associated with deep depressions over or east of the North Island with a strong ridge over Canterbury.
Brief periods of very strong southerlies occur with the passage of line squalls in strong southwesterly airstreams. They are potentially hazardous because of the intensity and suddenness of wind changes to the south, sometimes gusting to at least 50 knots in a matter of seconds from near calm conditions. The period of strongest gust usually persist for less than half an hour before the wind settles. Southerly winds gusting 60 knots or more may be expected on about 3 days per year.

[redacted]

To initiate a significant movement of sand, winds speeds only need to reach 10m/s (approx). The occurrence of these conditions Lyall Bay is approximately 15 %[16] of the time. The above information, along with the history of residential complaints, provides substantial evidence of the need for some form of remedial action to occur along the urban edge of Lyall Bay beach. Ultimately to provide some form of pedestrian shelter and to reduce the effect of sand transportation within the urban landscape. The most vulnerable area of the bay seems to be the section east of Onepu Road to the Bowling club entry (the central zone of Lyall Bay beach. The wind patterns seeming to be more focussed in this area and are probably due to the funnelling effect of the hills and the provision of some protection to other areas of the bay by the hills and coastal points. This was seen in the recent southerly (September 03), with sand build up significantly deeper in this area compared to the rest of Lyall Bay Parade. Residents interviewed also commented on the regularity of this pattern, with some reflecting on the physical strength difference, which was sometimes notable.

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[15] Reid Steve, NIWA
[16] Reid Steve, NIWA

Lyall Bay Beach- funnel created by surrounding hills

WIND BREAKS

The use of wind breaks to provide shelter in both rural and urban situations has been well researched and studied, with basic principles for their design readily available. However it is important not to assume that one design is appropriate for all situations. The need to consider the context and conditions of a given location is paramount to designing a windbreak that performs effectively for its intended use. To research an appropriate solution for Lyall Bay the basic principles of wind shelters, snow fences and sand control will be investigated.

Basic principles[17]

A requirement of any windbreak is a fairly continuous impediment placed to provide wind protection or other benefits. The most important factors in windbreak design for wind protection are height, opacity, orientation, and length.

POROSITY

Height — Windbreaks reduce wind speeds up to 30 times their height (H) downwind.

Porosity— All windbreaks, except solid fences or walls, let some wind through. Dense windbreaks stop more wind by having a greater proportion of solid area to open area, but density is not always good. As wind is deflected up and over a windbreak, low pressure on the downwind side draws the wind back down. This low pressure is stronger in dense windbreaks, drawing the wind down quickly and reducing the protected area size. Letting some wind through reduces the low pressure and results in a larger protected area.

Designing with Porosity (rules of thumb)

- High protection is provided with 25% porosity
- Low protection 50% porosity
- Wind- breaks with Porosity higher than 80% provide little wind reduction.
- It is advisable to ensure that the porosity of the windbreak is as even as possible to avoid locally uneven or unpleasant effects.
- Wind breaks in an open country region can be expected to shelter a 20-30% greater area than those erected in a town or suburb because of the greater turbulence experienced in these latter locations.
- Progressively increasing the porosity of an already porous screen, from 0.2 to 0.5 over the last 10m before the ends has the same effects on the turbulence in the area and increases the areas of all levels of protection by 25%.
- Horizontal or vertical gaps in an otherwise dense windbreak will funnel wind and locally increase wind speeds.

Orientation — Windbreaks should be oriented at right angles to the prevailing wind direction to protect the greatest land area. In hilly areas, locate windbreaks just upwind of the hill crest for greatest benefit. Placing a windbreak on the crest will result in a small-protected area because of extreme low pressure and turbulence created on the downwind and downhill side.

[17] www. Forestry extension.utu.edu

SAND CONTROL

The most effective form of sand control is through the maintenance of the natural eco system provided by sand dunes. (Refer to history of Lyall Bay) For a context such as Lyall Bay where the dunes are not complete, little information is available on how to reduce sand transportation. By researching what is understood about sand movement and sand control it is hoped some of the characteristics can be employed in designing a solution to this problem.

Sand transportation

Wind-flow over a sandy surface such as a beach will experience friction with the sand, and therefore the wind speed will decrease closer to the surface. The wind applies a force to sand grains, which can be increased either through an increase in the velocity of the wind, or through an increase in the roughness of the surface of the sand. A few loose grains of sand will be moved in this method, and will travel by a method of saltation. Saltation in the process of sand grains being flicked up by the wind and carried forward a certain distance, before the grains return to the surface. As the sand grains return to the ground they impact into the surface, this results in many more grains being flicked up into the air. Wind-flow and sand combine to produce sand transportation.

Sand control Fences

Companies in America have produced snow and sand control fencing, however these solutions are often aimed at a more temporary situation, or do not seem to take aesthetics into consideration.
They are made of UV stabilised high-density polyethylene and is international orange in colour.

Mesh size 4" x 1" (10cm x 2.5cm). In rolls of 1.22m, x 15.24m, (4' x 50') and 1.22m, x 30.48m,(4' x 100').

The positive characteristics of this type of fencing is it is durable, non corrosive and the company prescribes to
50% porosity for maximum drifting.

SNOW CONTROL

The need to control snowdrift is an international problem, and has been studied in-depth to try to reduce the effect of snow build up on roads, railway tracks and farms. Windblown snow has a similar characteristics to wind blown sand, though being lighter it is more difficult to control.

Principles of wind and snow control[18]

* When high-velocity air blows over a rough surface, it swirls and loses both energy and velocity.
* As high-velocity air strikes an obstacle, the air pressure increases on the upwind side, and a slight vacuum is created on the downwind side.
* When high-velocity air passes through a constriction, its velocity increases.
* High-velocity air can hold more snow in suspension than low-velocity air.

Types of snow breaks

In open areas wind, lifts, carries, and deposits snowflakes just as it does soil particles. By modifying wind flow, blowing snow can be distributed over a field or deposited within a given area. [19]

Solid Fences

As wind slams into a solid fence, it is either forced up and over the obstacle or around it. Air pressure increases on the upwind (windward) side, and a slight vacuum is created on the downwind (leeward) side. As the wind is forced over the top of this solid barrier, its velocity increases. After crossing the top of the barrier, the vacuum created on the downwind side causes air turbulence which dissipates the wind's energy. The wind no longer retains enough energy and velocity to carry a snow load; therefore, the snow drops out.
Wind drops the snow in two places: (1) on the *upwind* side of the fence at a 45-degree angle for a distance of about one-fence-height, and (2) on the *downwind* side for a distance equal to about five times the fence height (Figure 1). The distance of snowdrop on the downwind side is not directly proportional to fence height, and the effect is somewhat less than five times the height for very high fences. The area of wind and snow protection for a solid fence, then, extends from about five to fifteen times the fence height downwind.

A solid windbreak is usually built adjacent to the area it is designed to protect, since snow accumulation does not usually extend out far from the fence

Porous Fences

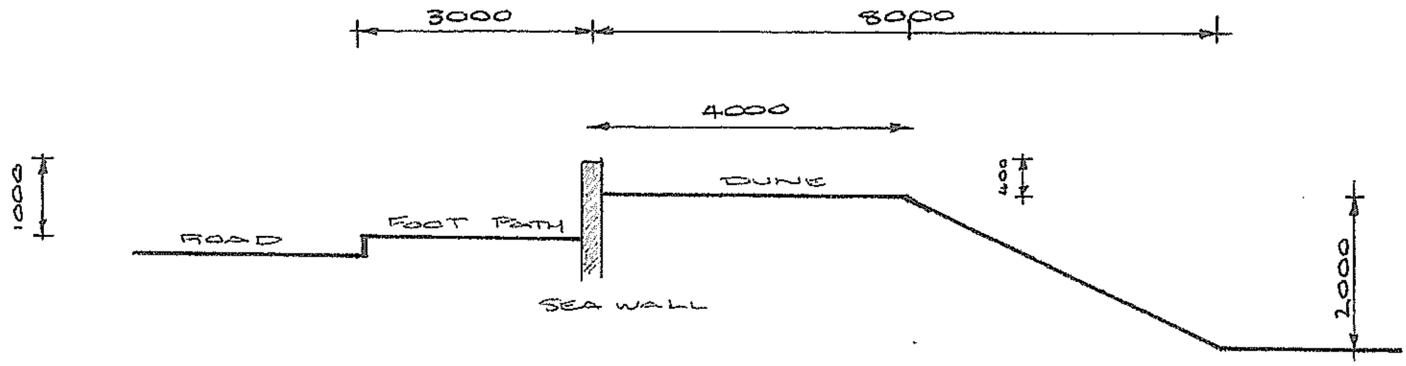
A fence designed for snow control, which is porous, will result in a larger sheltered area, as with normal windshelters, and a resulting even spread of snow over a large area, rather than, thick layers and drift build up.

[18] Don D. Jones and William H. Friday

[19] http://www.ianr.unl.edu/pubs/forestry/ec1770.htm

DESIGN- PARRAMETERS

The research established thus far has confirmed the need for some form of sand control and pedestrian shelter at Lyall Bay. Due to the central area of the bay appearing to be more vulnerable the design of the sand control fence and pedestrian shelter will be focussed in this area.



Pic- current sand dune and sea wall dimensions.

One of the design difficulties observed is the limited space in which the reduction of sand transportation can be carried out. The need to leave the lower half of the dune untouched is necessary to ensure a buffer zone is provided for large storms. This leaves approximately 6 metres for which to try and control sand. This problem of space is augmented by the restricted height plane created by the need to maintain a vista for all pedestrians and residents over looking the beach.

Another design parameter to consider is the south coast strategy plan, a specific report aimed at maintaining the natural character of this area. The report focused on caring for the ecological, resource, heritage and use values, recreation and leisure, coastal erosion control, and beautification guidelines.

An applicable clause states: The addition of new structure to the area is to be reduced to that which is necessary for the enjoyment or management of the coast or are necessary for the functioning of the city infrastructure. Where a new structure is supported, its design should be directed at enhancing the coastal character. The structure should be seen as an extension of the coastal character of the immediate area, rather than an intrusion into it. [20]

The policy also stipulates specifics such as the use of materials, recommending materials should be selected that have a coastal look.[21] An example of this could be seen in the rest area walls constructed around the south coast, with the choice of natural stone, keeping to the requirements of 'a coastal look'.

The coastal strategy plan places further parameters on the design of the wind shelters, ensuring a holistic solution is found, one that considers the overall potential effects of the design, the impact for beach user and the aesthetic appropriateness to the context.

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[20] Wellington City Council, Draft Plan for the South Coast, pg 34 , 2001
[21] Wellington City Council, Draft Plan for the South Coast, pg 49, 2001

DESIGN- THE PROCESS

The concept of sand control and pedestrian wind protection has direct benefits to local residents, pedestrians and the Wellington City Council. Moreover, the secondary benefits though not obvious will benefit the beach users of today and more importantly those of tomorrow.

Through establishing a shelter system at Lyall Bay, access to the sand dunes is restricted, controlling the passage of movement from road to beach to that purely of designated paths. Currently the unfenced dunes are trampled upon and utilised for activities beyond there purpose. The protection of the dunes at Lyall Bay is very important. Dunes are sensitive to disruption in general, the small size and vulnerability of the dunes at Lyall Bay makes their protection paramount. The combination of sand dunes, sand control and council maintenance would hypothetically reduce the sand loss currently occurring at Lyall Bay, resulting in a healthier beach and one that is potentially sustainable for future generations.

DESIGN-CONSTRUCTION

The need to construct the screens in a manner that appears light and unobtrusive is fundamental to the desired coastal aesthetic. To achieve this I would envisage a glass and steel construction. The of use steel enables a frame to be created that has an exceptional strength to weight ratio and as a result would appear as slender structure. The impact of the harsh and corrosive environment on the steel structure will need to be considered.

Galvanised or a brushed stainless steel. so would need to be specified if the natural qualities of steel are to be maintained The context which these screens will be cited also effects the type of glass to be specified. The glass will need to be of a toughened variety to prevent sand blasting and more importantly to reduce the effects of intentional vandalism.

CONCEPTS

The concepts I will be investigating are based on the following principle ideas:

- In snow control, a solid fence will create snow piles in a confined area The potential for this methodology to be used to reduce sand movement, provides excellent potential, especially given the especially the restriction on space.
- Gandemers design of a ventilated base 'K' wind break. A design tested and said to work " particularly well for sand control.[22]
- Ship construction – where a tilted panel of steel guides wind upwards and creates an air bubble to protect the occupant of the bridge from oncoming wind.
- Gandamers use of this theory to create a pedestrian wind break for a coastal situation. However the design of his wind breaks require great height and a solid construction. It is hoped that by using the general principles, a slender more appropriate solution could be found with similar results.

[22] 231 Hand book pg 84

METHODOLOGY

To investigate the most appropriate solution for wind and sand control , parametric testing of different fence configurations will be orchestrated. Wind tunnel testing will asses the performance of the screens using smoke stream visualisation techniques to create a 3 dimensional understanding of the wind flow patterns. The models will be built at a scale of 1:20, a scale appropriate to ensuring that no more than 5 % of the wind tunnel mouth is blocked. A digital video camera will provide a record of the tests and allow for future reference and analysis. (refer to attached CD)

TEST 1: FILE 'ORIGINAL"

The first trial assessed the wind flow over the current arrangement of sand dune and sea wall. This established a benchmark for which the trial tests could be compared and also allowed a greater understanding of why the problem of sand transportation existed.

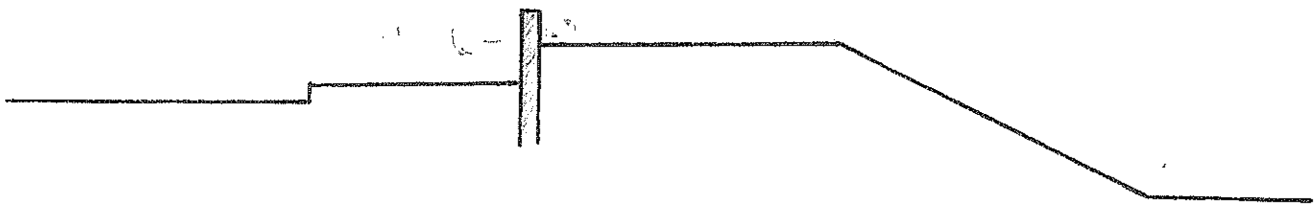

Fig 1- current situation.

Smoke in the first test stayed low travelling unimpeded from the 'sea' over the dunes and finally over the sea wall. A small vortex was observed on the seaward side of the wall, this created an air bubble which tended to lift the airflow higher sending the smoke further over the road. A negative pressure behind the sea wall was also observed creating a down ward flow and explaining the build up of sand on the footpath after most storms. However, the minimal size of the exposed face meant that the predominate flow was lifted over the wall by the air pocket and out onto the street.

TEST 2: FILE 'K' FENCE

The second test used the 'K' fence (1400mm tall) in an attempt to disperse the wind flow in a manner which would be positive for sand control. Research suggests the placement of the sand control fence at halfway down the sand dune. This will allow space for the coastal buffer zone, moreover, it will reduces the availability of exposed loose sand for transportation and most importantly a vista will still be maintained.

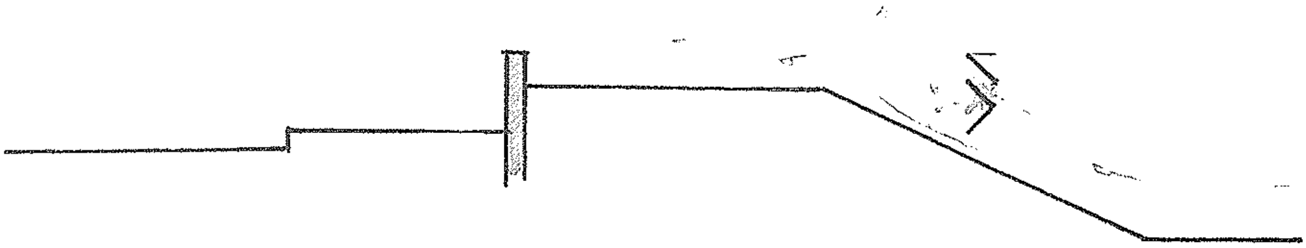

Fig 2- K fence

VORTICES

The K-fence effectively broke up the direct wind flow over the sand dune, reducing significantly the velocity at which the air passed over the sea wall. Vortex's could be seen on the leeward side created by the flow of air through the fence. This negative pressure represents a lowered wind pressure and as a result, an opportunity for sand to be deposited. However the ventilated base reduces this pressure difference behind the fence and thus the potential sand catchment is reduced. Moreover, the ventilated base allows a strong flow of air at ground level, the area most vulnerable to sand transport. The K-fence did dissipate the airflow successfully however, its application appears to suit an environment where a larger area for sand catchment is available.

TEST 3: FILE 'SOLID FENCE'

The third test used a solid wall (1400 mm high) also place halfway up the dunes height. It was hoped by using a wall with no porosity that a strong downward force behind the wall would be established and thus a large catchment area.

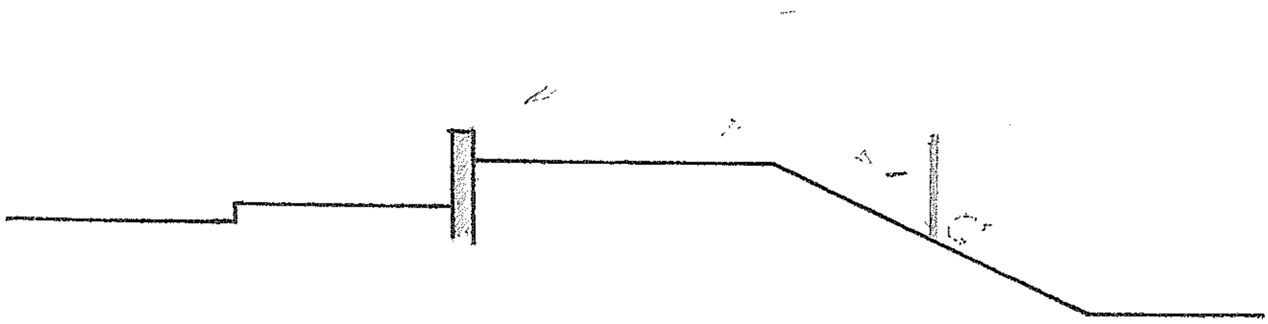

Fig 3- solid fence

The analysis of test showed this theory in practice. The smoke was lifted over the solid fence by the vortex on the seaward side, but then quickly dipped into the negative pressure zone behind the fence. This is caused by the tendency of air to flow from a positive pressure to a negative one. The analysis showed the negative pressure to be covering a large area of the dune, which hypothetically means a larger area for sand catchment. The predominate flow showed the air travelling closest to the lip of the windbreak was the air pulled down into the negative pressure. This is a positive scenario as it is assumed that most of the sand transportation would be contained in these lower strata of wind flow.

TEST 4: FILE: 'PEDESTRIAN

The fourth test involved creating a wind break to provide shelter for pedestrians and other users. By adding a glass structure to the top of the seawall (500mm high) a combined exposed face height of 900 mm is created. The height of the fence reflected a desire to maintain a vista to the sea for most users. The front face of the model had another panel attached creating a linear funnel. It was hoped that the 'funnel' would create a significant vertical wind flow, which would result in a protective air pocket for the footpath user.

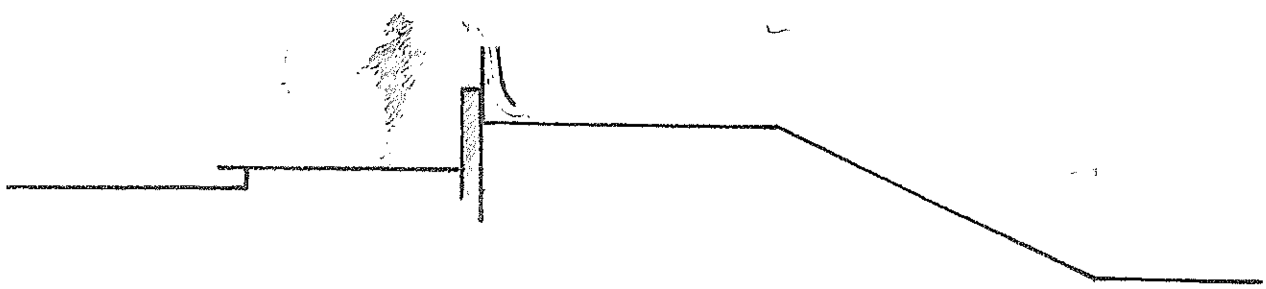

Fig 4

To ascertain whether the screen actually worked, wind tunnel tests were carried out with just the pedestrian fence. Analysis showed that even with the small face the fence created enough vertical flow to provide a significant protective pocket where pedestrians could walk. A high level of turbulence was also observed, and was the result of the combination of the upward flow and the downward pull of the negative pressure zone behind the sea wall. However this was on the road and thus does not become a significant factor.

The establishment of solely the pedestrian fence in this context, though successful in protecting the pedestrian, would not address the fundamental problem of sand control. The following tests sought to assess how well the pedestrian fence responded in combination with the two sand control fences. The question being raised as to whether the disturbed airflow created by the sand control system would have detrimental effect on the performance of the pedestrian fence.

Analysis of both situations showed a substantial protective air pocket was still created, and in a position which would be beneficial to pedestrian users. Though the flow of air appeared more dispersed before the pedestrian fence it did not appear to effect the process adversely.

CONCLUSION.

The report ' wind and sand on the south coast' sought to investigate:

- whether a solution to sand transportation could be found that suited the dynamic of Lyall Bay Beach
- The provision of a pedestrian environment that would be comfortable during southerly wind conditions.
- The ecological, urban and aesthetic impact of the wind breaks on the area, ensuring a more holistic approach to the design of the shelters.
- Whether the climatology of Lyall Bay reflected an environment where the investigation and development of sand control and pedestrian shelter is warrantable.

I consider the investigation of sand control to be an important aspect of the continued rehabilitation and maintenance of Lyall Bay beach. The need to establish methods to control sand from being transported off the beach is important for the beaches maintenance today and the preservation for users of tomorrow. The climatology of Lyall Bay is such that conditions, which lead to sand transportation, will occur 15 % of the time, making for a convincing argument of the current need to address beach depletion.

Lyall Bay beach has progressed through a series of urban developments, many detrimental to the beaches existence. These developments have created the need to rehabilitate the beach back to a more natural condition, however the fundamental reality is that Lyall Bay is still very much an urban beach. Therefore, I find the potential for development of a pedestrian shelter to be one which will greatly add to the useability of the parade, provide further protection for the dunes and if designed sensitively, could become an exciting visual dynamic for the coastal edge.

Test conclusions:

That the positioning of a solid fence half way down the dune showed the most promise in sand control. The solid fence effectively created a large negative pressure on the leeward side, providing an area of low wind speed where air borne sand would be deposited.

The pedestrian fence successfully provided a sheltered air pocket for pedestrians, proving adequate with each of the concepts tested.

In conclusion, I find that the impact of sand transportation can be reduced at Lyall bay. I recommend the use of a dual system, where a solid fence configuration is used to control sand in combination with the pedestrian fence to provide a more useable beach environment.

These findings establish an excellent foundation for which further research and development could be carried out to refine the correct response for Lyall Bay beach. Furthermore it is hoped that the report could be used as a base to begin similar investigations to other vulnerable areas within the south coast.

FUTURE DEVELOPMENT

If Further development and research were to occur within the bounds of this report, I would recommend the following considerations.

- To test the impact of sand build up in front of the sand control fence, to see its effect on the negative pressure zone and to observe how sand transportation responds to this build up.
- To investigate what is the most appropriate method for the removal of sand build up behind the sand control fence and the redistribution back on to the beach.
- Further more to investigate how sand redistribution could be implemented through natural processes rather than manual labour.
- If wind shelters are to be established over a continuous stretch of the beach, how is the problem of beach access to be addressed with its previous history of creating sand funnels?

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