4 ANALYSIS OF EXISTING DATA

4.1 Analysis of Aerial Photography and Historical Shoal Mapping

The shoal patterns and island configurations within the study area have been mapped from aerial photography captured in 1979, 1986, 1987, 1990, 1993, 1996 and 2001. The resulting maps have been presented in Appendix D, along with other figures that have been referred to in this section. Aerial photographs from 1961 and 1965 were also examined to gain a broader perspective of the underlying processes in Swansea Channel during the last half century.

The aerial photographs of the study area, from 1961 (Figure D8), 1965 (Figure D9) and 1979 (Figure D1) show the deepest part of the channel running along the eastern foreshore of Swansea Channel then diverging into two main channels. The dominant situation before 1979 is shown on Figure D10. One channel continues to the north along the western edge of the spoil island within Swan Bay and past Marks Point while the second channel, also referred to as the 'Airforce Channel' flows westwards to the north of Pelican Island. The depth of the Airforce Channel has been slowly decreasing since 1979. The 1996 aerial photograph (Figure D6) shows that the Airforce Channel has been blocked by a large shoal moving upstream towards the lake. The 2001 aerial photograph shows that this shoal has tended to move northwards into the main channel (refer Figure D11 for comparison). The origin of the sediment for both of these shoals is most likely from further downstream.

Previous studies undertaken by the New South Wales Public Works Department (1976) using current meter readings identify three main discharge channels to Lake Macquarie. The first channel ran along the shoreline of Coon Island maintaining a depth of 1 m along its length. The second channel (Airforce Channel) was located along the northern shoreline of Pelican Island with an average depth of 4 m. The third channel (Main Navigation Channel) was located in the area immediately west of Pelican Point, with a channel depth of approximately 3.0 m, decreasing to less than 2 m in some sections. Aerial photographs apparently show that the main channel carries a greater portion of water through the drop-over. This main channel has been maintained by periodic dredging since about 1960. It was surmised that the relatively straight alignment of the third channel was unnatural and that it would not remain stable to a significant navigable depth without continued maintenance (PWD 1976).

The aerial photographs from 1961, 1965 and 1979 indicate a clear navigational channel into the northern entrance of Swan Bay from Lake Macquarie. The tidal dropover had been growing eastwards at approximately 0.8 m per year, and northwards (into Lake Macquarie) at approximately 10.5 m per year at this location. By 1993 the shoal had moved across the northern entrance, blocking the channel to Lake Macquarie.

Comparison of the aerial photographs from 1979 to 2001 show a significant change in the islands within the study area. Elizabeth Island appears to have gained its current plan form between 1979 and 1986. From aerial photographs it can be seen that it took some time for vegetation to establish on the island, indicating that further spoil had been placed on the island during the 1980's. The 2001 aerial photograph indicates that the island is fully covered with vegetation. The shape of Elizabeth

Island has changed only slightly over the years (Figure D12). The northern foreshore of the island appears to have become flatter and receded (since 1979). Erosion appears to have occurred along the eastern foreshore of the island and accretion appears to have occurred on the north western foreshore.

Pelican and Spectacle Islands are situated north of Coon Island. Pelican Island has eroded significantly between 1996 and 2001 reducing the surface area by approximately half. Prior to this, aerial photographs indicate that the island has generally remained the same size. This change appears to be related to the development of a secondary channel into Lake Macquarie that follows the eastern and northern foreshores of Spectacle Island. Prior to this development, Spectacle Island had remained a similar size over the years.

The Spoil Island in Swan Bay were established in 1958 during dredging of the main channel. Prior to re-establishment of the southern entrance to Swan Bay the Spoil Island comprised a continuous chain of islands punctuated by occasional small channels linking Swansea Channel and Swan Bay. The Island extended from Naru Point across the mouth of Swan Bay to Pelican Point. A smaller island was located to the east of the Pelican. This smaller island seems to have slowly shrunk over the years. Significant erosion has occurred along the western shore of the Spoil Island and the 1993 aerial photography indicates the presence of shallow areas along the western foreshore, which have potentially been created through the erosion of the western foreshore of the Spoil Island. The size of the Spoil Island has slowly decreased over the years and the 2001 aerial photograph shows a significantly smaller island in both width (probably caused by erosion) and length (mainly from dredging of the southern entrance) in comparison with the 1979 aerial photograph.

Only one of the aerial photographs shows the complete opening of the second entrance, which also shows a significant increase in the size of a small inlet around halfway along the island (Figure D13). This increase has probably been caused by erosion of the western foreshore of the island causing a decrease in resistance to flow through the split in the Spoil Island, which in turn has increased the flow, resulting in erosion of the gap. Prior to 1996, this area tended to undergo cycles of slight erosion and accretion over the years.

The shoreline of Swan Bay has not experienced significant recession. Coon Island has experienced some erosion (30 m from 1979 to 2001) on the northern tip of the western shore, which has occurred gradually over this time. This erosion appears to coincide with the development of a channel to the north of the island which has become a more favourable hydraulic path into the lake with the recent constriction of the two main channels as shown on Figure D11.

The shoals in the study area have changed significantly over the years, the most notable change is the increase of the main dropover shoals protruding into Lake Macquarie. There are essentially four of these shoals (Figure D14):

1. The shoal north and west of Marks Point. This shoal has increased in width and length from 1979 to 2001, approximately 4 m/yr in width and approximately 6 m/yr in length. The shoal has grown around Marks Point and the 2001 aerial photograph shows that the shoal has encroached upon the northern entrance of Swan Bay. From the 1996 aerial photograph it can be seen that dredging has occurred on the shoal to improve navigability within Swansea Channel.

2. The shoal situated between Elizabeth and Pelican Island has spread south by 30 m between 1996 and 2001. During the period prior to 1996 the shoal had been relatively stable, consequently the increase in the size of the shoal could be related to a recent tendency for more flow through this area, and associated sediment transport and deposition on the dropover. The depth of the shoal has been slowly decreasing, and in the 2001 aerial photograph the area appears to be very shallow.

3. The third shoal occurs between Pelican and Spectacle Island, the shoal has grown progressively into Lake Macquarie by a total of approximately 152 m from 1979 to 2001.

4. The fourth shoal situated between Spectacle and Coon Island has changed shape from 1979 to 2001, (Figure D15). From 1979 to 1986 the shoal appears to have eroded along its western edge but accreted along its northern extents. From 1986 to 2001 the shoal accreted further to the west by a varied amount(refer Figure D16).

4.2 Analysis of Hydrosurvey Information

Ten Digital Elevation Models (DEMs) were created using the hydrosurvey data outlined in Section 2.1.3. The dates of the DEMs are as follows:

- 1996;
- March 1999;
- June 1999;
- July 1999;
- November 1999;
- May 2000;
- November 2000;
- March 2001;
- August 2001;
- January 2002.

These DEMs were compared against each other, in order to identify areas of erosion and accretion. Figures E1 to E9 in Appendix E shows the comparisons. It should be noted that there are some small irregularities in the comparisons, particularly at the edges where two sets of survey data meet, however, overall patterns of erosion and accretion can be identified. Importantly, it should be noted that the changes in bathymetry within the eastern extents of Swan Bay are based upon an estimated progress of dredging works derived using verbal information provided by the dredging contractor. Actual post dredge survey information was not available for the Swan Bay dredging operation.

The comparison of March 1999 and 1996 DEMs (Figure E1) shows a large amount of erosion occurring inside the southern entrance of Swan Bay, which is due to the removal of material during

dredging to re-establish that entrance. Within the mouth of the southern entrance there is also a significant amount of accretion occurring in the area to the north of Naru Point, which is probably due to the opening of the second entrance encouraging tidal flows (and sediment transport) into Swan Bay. When flood tidal currents enter Swan Bay, they are slowed and the capacity for sediment transport is reduced, resulting in deposition in the mouth of the southern entrance of the Bay. The Figures E2 through E9 show a small amount of progressive accretion in the entrance to Swan Bay. Erosion has also gradually occurred along the western edge of the Spoil Island in Swan Bay. This has been accompanied by accretion at the western edge of the navigation channel adjacent to these islands. Small areas of accretion occurring along the western edge of the island in some comparisons e.g. November 1999 and July 1999 (Figure E4) and August 2001 and March 2001 (Figure E8) are due to irregularities in the digital elevation models where different sets of survey data meet.

An overall comparison was also undertaken between January 2002 and 1996 (Figure E10) and August 2001 and March 1999 (Figure E11, which excludes the effects of the most recent maintenance dredging). Areas in which erosion is actively occurring are along the foreshore of Pelican Flat in the vicinity of Pelican Marina, the western foreshore of the Spoil Island in Swan Bay, and inside the entrance to Swan Bay. The remaining areas where erosion has been identified, are within Swan Bay and at the drop over to Lake Macquarie, which is due to dredging in the area.

From Figure E10 it can be seen that the main areas of accretion occur within the main channel, adjacent to Swan Bay. A significant amount of accretion is also occurring on the western side of the navigation channel adjacent to Pelican Marina. Progradation of the western shoals into navigation channel at this location is resulting in a substantial deepening (erosion) of the navigation channel, as noted above. Accretion is also occurring at the drop over to Lake Macquarie, this process has been identified in a review of historical information and aerial photographs (Section 4.1).

The comparison of August 2001 and March 1999 (Figure E11) was carried out in order to understand more recent erosion and accretion patterns, without the effects of dredging. Figure E11 shows that there is a build up of sediment at the entrance and from Figure E2 to Figure E8 it can be seen that this process has been taking place gradually over the three year period. Figure E9 shows limited change as it is based on the post dredge survey for recent maintenance dredging, which was not very extensive.

4.3 Analysis of Bed Sediments

4.3.1 Previous Studies

Previous studies where sediment sampling and testing was undertaken include PWD (1976), Resource Planning Pty. Ltd (1988) and PWD (1992). The sampling locations from those studies that are relevant to this investigation are presented in Figure 4-1.

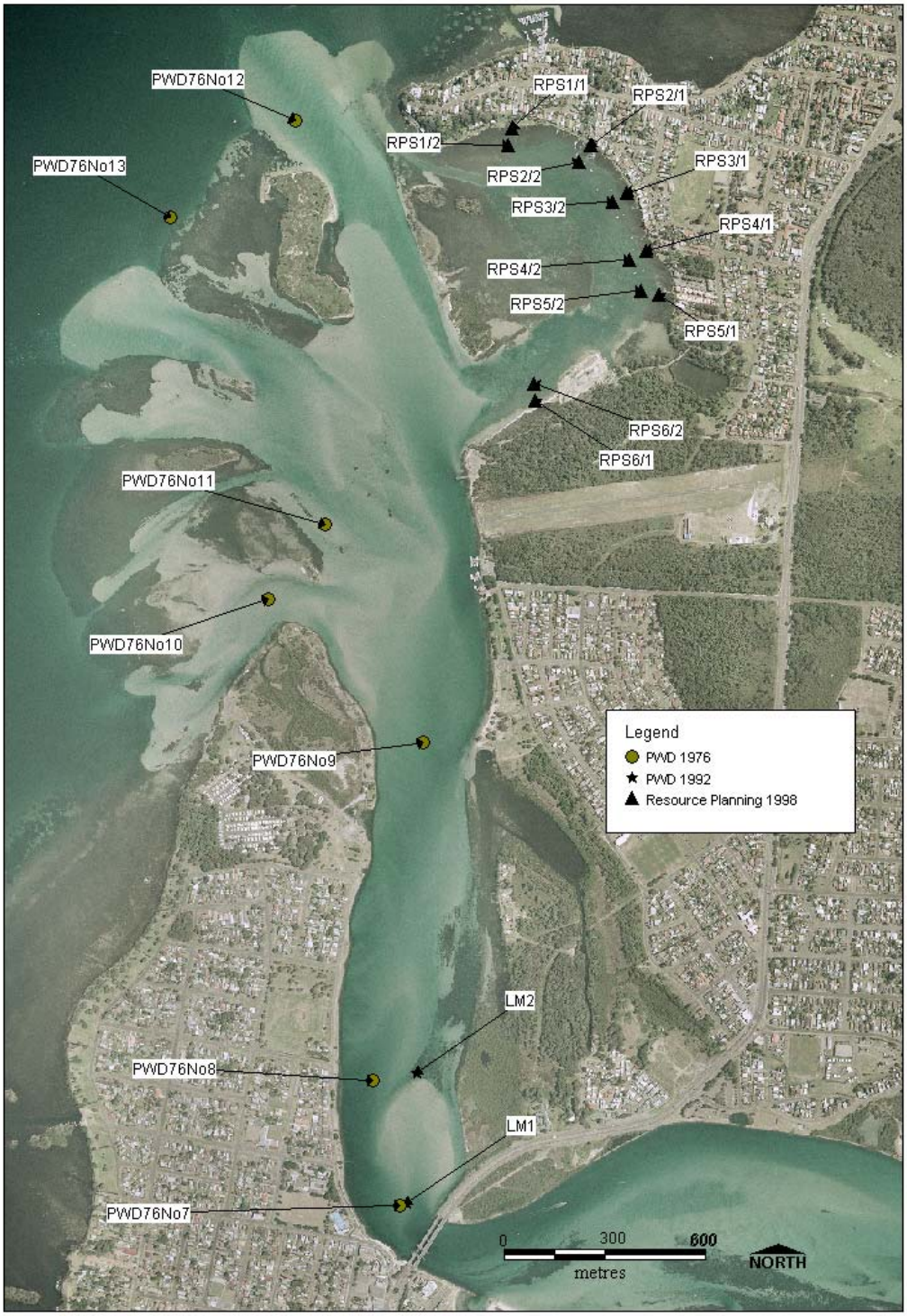

Figure 4-1 Locations of Previous Sediment Sampling

The results presented in the various studies are provided in Appendix C.

PWD, (1976) Waterways Planning Study results indicated that the material showed a slight trend towards finer material with distance upstream. This was correlated to the magnitude of the tidal flow which reduces with distance upstream. The effective size reported by PWD (1976) was D_{10}, (i.e. the size that 90%of the material is larger than). The report cites Hjulstrom, (1939) as indicating that the most readily eroded particles are medium sands (0.25 to 0.5 mm) which can be moved by currents of about 0.15 m/s.

In order to assess the commercial quality of the sand, 24 samples were collected from 11 locations in Swan Bay by Resource Planning (1988), as shown in Figure 4-1. Samples were taken at 0.5 to 1.0 m depth and 2-3 m depth for all 11 sites. The sediment was shown to be principally fine grained and suitable for marketing as a fill material. Resource Planning, (1988) classified the sediments within Swan Bay as clean, well sorted, quartzose marine sands. It was found that grain size varied from fine to coarse with some small pebbles and shells and a mean grain size of 0.29 to 0.33 mm. Colour varied from light to white with most samples having a speckled appearance due to the presence of darker lithic grains. It was noted that Swan Bay forms part of a drowned dune sheet that has formed behind the coastal barrier dunes between Redhead and Swansea.

Sediment sampling was undertaken by PWD on April 10, 1992 for the Salts Bay Erosion Study. Within the study area samples were extracted at LM1 and LM2 (refer to Figure 4-1 for locations), from the shoal immediately upstream of Swansea Bridge. Both samples were shown to have a mean grain size of approximately 0.39 mm but the sample from LM2 had a more significant spread across various grain sizes.

Overall, it was concluded that the sediments in the downstream reaches of Swansea Channel:

> "..showed clean, well sorted quartzose marine sands varying from light grey to white in colour. Beach samples ranged from medium to coarse grained. Dune samples were finer, ranging from fine to medium grained sands." (PWD, 1992)

4.3.2 Sampling for this Investigation

As discussed in Section 2.3.2, 40 surface sediment grab samples were collected from the study area. An analysis of the sand size fraction was undertaken of each sediment sample and the results are provided in Appendix C.

Overall it can be seen that the sediment within the study area can be predominantly classified as Medium Sand (0.25 – 0.5 mm) that is, 50% or greater is medium sand. There are four locations within the study area however, where this is not the case. These locations tend to have a large portion of very coarse sand (0.5 mm-2 mm) and are as follows:

- Location 14, situated west of Coon Island. The sample was taken on the edge of a reasonable active shoal, which has moved 30 m to the west since 1996. The sediment sample has a small percentage of fine sand (0.12%), consequently it can be postulated that there are large currents experienced at this site;

- Location 20 situated at the south entrance of Swan Bay. Since the opening of the entrance this area has become very active, a large current flows through this area moving from the south (during a flood tide) into the bay to the east, then changing directions a small distance inside the Bay towards the west and continuing north alongside the Spoil Island. Shells were detected in the sample, which could be due to recent maintenance dredging activities and would also reflect the large currents experienced through the area. There was 7% of Gravel/Organic Matter > 2 mm found in the sample.
- Location 13, situated on the north tip of Coon Island, next to a shoal that has been quite active over the past 22 years. A relatively deep channel runs along the eastern and northern foreshores of Coon Island and then westwards were it deposits sediment at the dropover into lake Macquarie. Location 13 is situated where the channel depth is slowly increasing with distance along the channel, therefore large sediment tends to drop in this area whereas finer sediment remains suspended. This sample also contained traces of shell;
- Location 3 is approximately 400 m upstream from Swansea Bridge, and is located in the main flow channel of Swansea Channel. The location has similar percentages of Very Coarse Sand (42%) and Medium Sand (48%) but with a small amount of fines (3%). The area is highly active, due to the large current and significant turbulent characteristics of the flow through the area, which is capable of effectively entraining finer sediment grains above the bed of the channel.

Only three locations have greater that 20% of Fine Sand (0.063 – 0.125 mm) and those samples have greater than 50% Medium Sand. These location are:

- Location 38, situated north of Marks Point on the shoal that is protruding west. Due to the percentage of fine sediment this area would be fairly stable, representing an area where flow slow and fines settle out of the water column. The relative stability of this area is also reflected in the identification of organic matter in the sample (<2%).
- Location 28, situated south of Elizabeth Island, over recent times this area has become progressively shallower and subsequently is not subject to fast flowing currents at present. The sediment characteristic identified in this area show that it is now relatively stable, due to the presence of fines and organic matter (<5%).
- Location 27, situated approximately 450 m south of Elizabeth Island and is just west of the 1996 location of the main flow channel (prior to the opening of the south entrance to Swan Bay). The sediment sample was taken from a location were the shoal is fairly stable, hence there is a presence of fine sediment and organic matter (<5%).

The four samples collected on the dropover shoals protruding into Lake Macquarie, Locations 12, 33, 34 and 37, all show the presence of organic matter, which indicates that areas of these shoals which are not subject to active deposition are fairly stable.

4.3.3 Summary of Sediment Samples and Analysis

Since 1976, the pattern of channels through the study area has changed significantly. In addition, the samples taken from Swan Bay prior to ventilation dredging may not be representative of what currently exists at the bed, as the removal of material has altered the bed characteristics of Swan Bay.

The most recent sediment samples cover the entire study area and are considered to be representative of the area at present. The sands within the area are predominantly medium grained (0.25 to 0.5 mm) with localised variations due to the specific localised environment of certain samples.

4.4 Analysis of Other Data

4.4.1 Wind Data and Wave Climate

Changes in the wind wave climate at Swan Bay were assessed based on hydrosurvey information. The 1996 hydrosurvey was compared with the most recent hydrosurvey (January 2002). This comparison was undertaken in order to determine whether the removal of material from the entrance of Swan Bay has prompted wind-wave erosion along the shoreline. The assessment utilised standard empirical methods, developed by the US Army Corps of Engineers.

Three locations were chosen within Swan Bay and are shown on Figure 4-2. For each location wind waves coming from a number of direction were assessed:

- Location 1: North, North West and West;
- Location 2: South West, West and North West;
- Location 3: North and North West.

For the analysis the 1% exceedance wind speed was used which is approximately 12.2 m/s. The results are presented in Table 4-1.

Table 4-1 Results of Wind Wave Analysis

Location	Direction of wind	Wave Height Pre Dredge (m)	Wave Height Post Dredge (m)	Wave Period Pre Dredge (sec)	Wave Period Post Dredge (sec)
1	North	0.12	0.12	1.03	1.06
1	North West	0.20	0.20	1.45	1.45
1	West	0.25	0.25	1.69	1.69
2	South West	0.13	0.22	1.10	1.54
2	West	0.16	0.16	1.23	1.24
2	North West	0.15	0.15	1.21	1.21
3	North	0.14	0.14	1.16	1.16
3	North West	0.21	0.21	1.52	1.52

From the results it can be seen that Locations 1 and 3 have not been affected by the creation of the southern entrance. At Location 2, there has been an increase in the wave period and wave height for waves from the south west, as well as an increase in wave period for waves from the west. The increase in wave height is consistent with anecdotal reports of increased erosion occurring in the vicinity of location 2.

Figure 4-2 Location for Wind Wave Climate Analysis

4.4.2 Tidal Planes

Tidal planes have been presented in a number of reports, most recently in the Lake Macquarie Estuary Management Study (Volume 1, WBM, 1997). These tidal planes are reproduced in Figure 4-3. The tidal planes show a steep gradient between the normal tidal range in the ocean and the small tidal range in the lake.

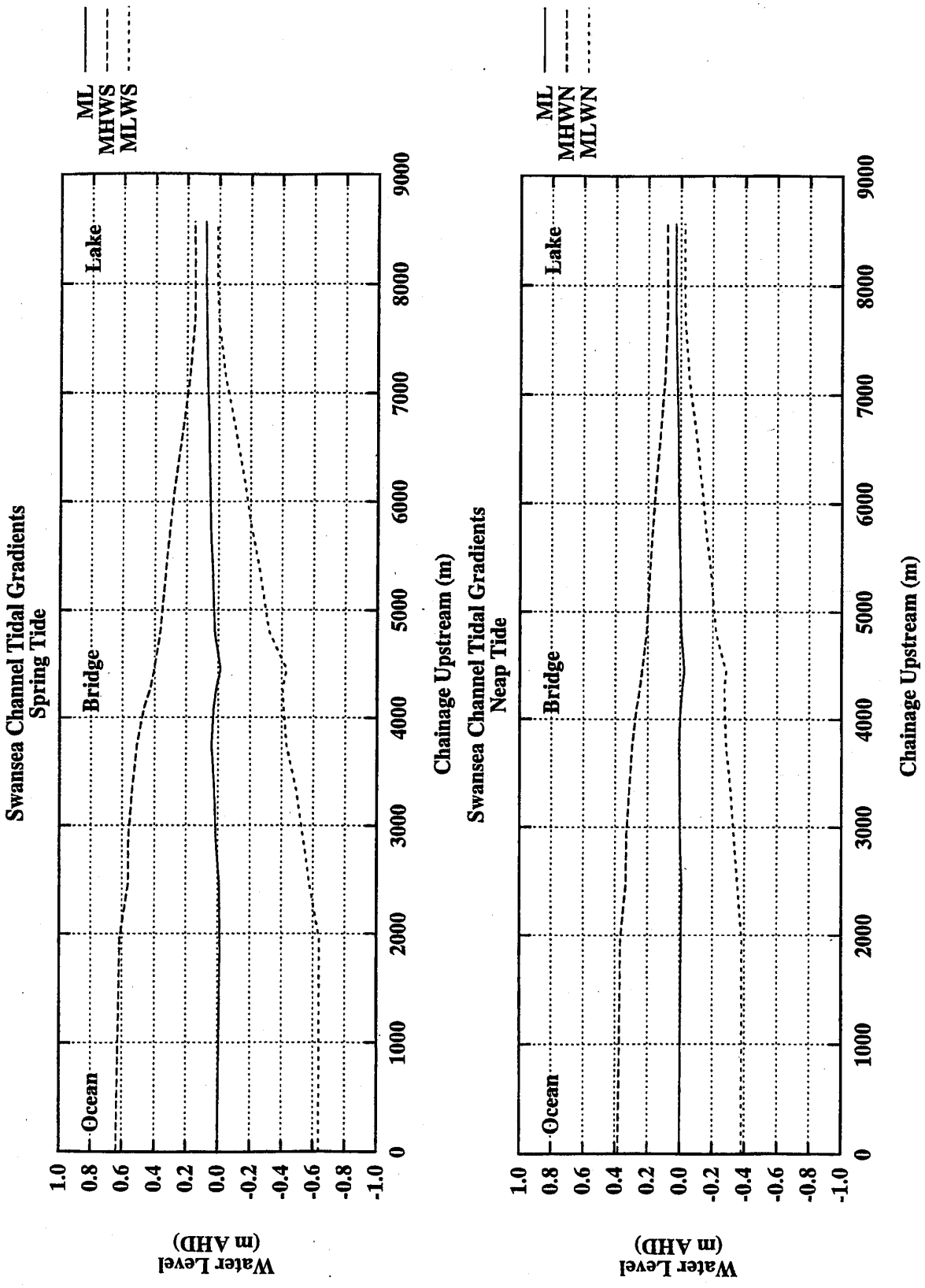

Figure 4-3 Swansea Channel Tidal Gradients (WBM, Figure 3.3, 1997)

The tidal envelopes for the high, low and mean water levels are presented, from the ocean to the lake for a mean spring tide and a mean neap tide. For the spring tide, there is a steep decrease in high tide levels between the ocean and the lake and a steep increase in low tide levels. Similarly, this pattern is reflected in the neap tide event but the difference between the ocean and lake is not as large.

Steep water surface gradient and high velocities are experienced at the bridge, due to the constriction of flow at that location. This effect has been amplified due to the increase in the efficiency of the ocean entrance by training works (WBM, 1997). In 1976 the Public Works Department commented that the tidal gradients were generally steeper between Swansea Bridge and Pelican Flat.