Using anthropogenic geomorphological change associated with historic maritime infrastructure to predict the location of coastal archaeological sites in Queenscliff, Victoria

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This paper examines the relationship between anthropogenic and coastal geomorphologic processes in relation to archaeological site formation processes for foreshore maritime infrastructure such as piers and baths. The natural and cultural history of Queenscliff, a nineteenth-century Victorian township, is explored to understand the historical reasoning for the development of many diverse types of coastal architecture associated with use of the sea in the area. The effects of environmental processes on these structures are demonstrated, along with the role these structures play in subsequently shaping the environment. It is demonstrated that changing coastal dynamics play a major role in shaping the final locations and condition of archaeological maritime infrastructure sites. By understanding these processes it is possible to make predictive statements about the, often unexpected location and integrity of these sites.

INTRODUCTION

This paper explores the role environmental determinants play on cultural landscape evolution and vice versa. Despite a long history of shipwreck investigation, Australian archaeology has only recently begun to explore the field of inter-tidal and coastal infrastructure sites associated with shipping and the general use of the foreshore environment. This field is evolving as new characterisations of largely unexplored sites types are observed. The potential scope for archaeological research is enormous, as the location and types of marine infrastructure offer observations into the diverse range of activities being undertaken on the coastal fringe, providing valuable insights into the interconnectivity between the terrestrial and maritime spheres.

The foreshores on which many of these structures were located are among the most dynamic environmental regions on earth, subject to constant change and reshaping. In order to understand the meaning and evolution of coastal architecture over time, it is also necessary to investigate the effects of environmental influences on their placement and construction. Furthermore, as this paper will demonstrate, the installation of maritime infrastructure can also have significant effects on the geomorphology of local foreshore regions. A sound understanding of these cyclic interactive processes may therefore offer alternative interpretations for predicting the current archaeological locations and condition of maritime infrastructure sites.

Queenscliff, Victoria lies at the confluence of several major shipping routes of local, national and international significance, where vessels pass through the dangerous passage into Port Phillip Bay (Figs 1, 2). The growth of the township was heavily reliant on the development of several

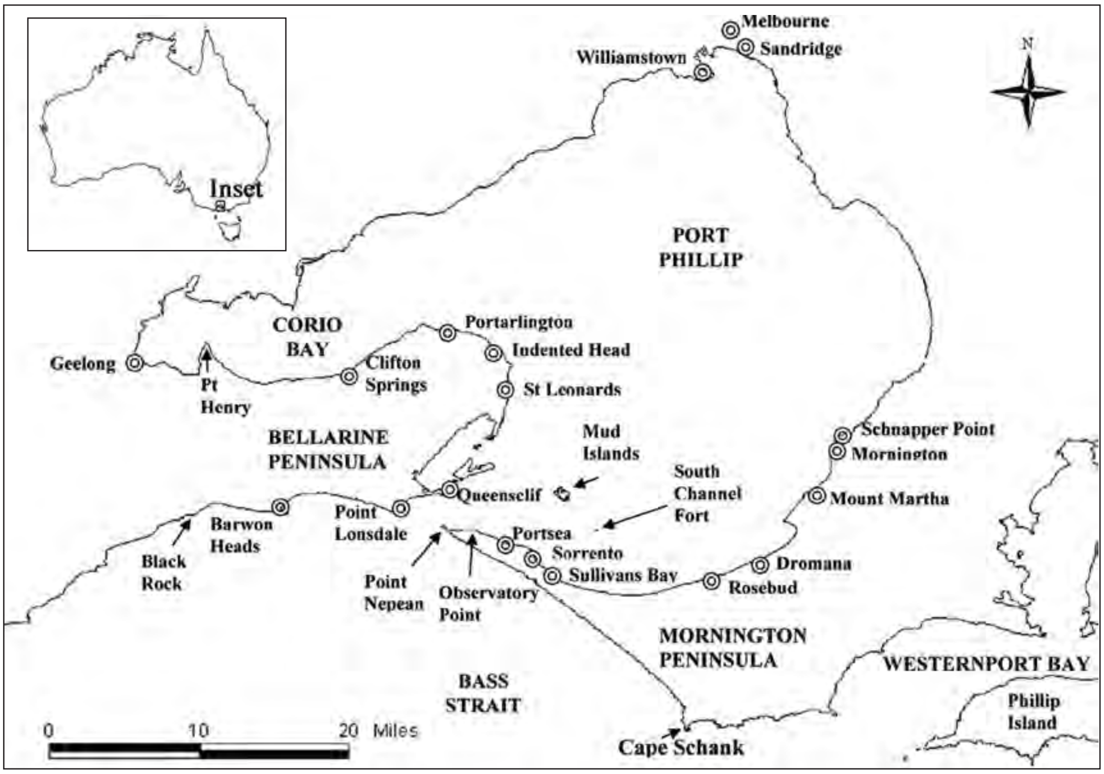

Fig. 1: Map of Queenscliff in Port Phillip Bay. Map by B. Duncan

administrative maritime services, which together with the beginning of many extractive and commercial industries, led to the installation of a vast range of supportive maritime infrastructure. Queenscliff presents an ideal setting in which to examine a range of maritime activities and explore the interactions between maritime infrastructure and the coastal environment. It will be shown that while the geography of the ‘natural’ environment shaped the location and types of activities being undertaken in the region, these cultural influences actively shaped and reshaped the environment.

The first section of this paper outlines the methodology developed for the investigation of coastal landscapes, initially undertaken as a component of the author’s doctoral research (Duncan 2006). Following this the results are presented in three parts. Part one provides a brief historical overview of maritime activities and the placement of maritime infrastructure around the Queenscliff foreshore to demonstrate the extent of cultural influences in the maritime realm. The effects of coastal dynamics on these structures (and vice versa) are presented to demonstrate the interconnectivity of geomorphological and anthropogenic, derived from human activities, processes. Finally, the implications of these observations are considered with regards to the archaeological investigation and cultural heritage management of coastal regions.

METHODOLOGICAL APPROACHES

This research required the development of several (at the time) innovative approaches towards critical analysis of documentary, oral and archaeological resources. As an evolving methodology, the approach is documented here in further detail.

Documentary Sources

Documentary records were initially consulted to establish a chronological historical overview of local maritime industries and their associated infrastructure. Regional and broad thematic historical syntheses provided potted and specific histories of the several local maritime industries. Where summary overviews were unavailable, incomplete or unreliable, they were supplemented with primary data to generate comparative chronologies for specific coastal industries, infrastructure development and other local events. Primary documentation included official governmental records such as sailing directions and warnings, charts and plans, Harbour Masters records, mariners log books, parliamentary papers, summary contracts books, Royal Commissions and other official correspondence. Furthermore, where official documentation was lacking, primary anecdotal evidence from published oral histories and local recollections in newspapers and memoirs, along with unpublished personal diaries provided additional insights into issues affecting coastal foreshore movement and infrastructure development. Further information was gleaned from private histories, trade directories, newspapers advertisements, and historical society collections. Historic photographic collections played a critical role in the verification of infrastructure development and demolition dates, as did aerial imagery where available. All these sources were used to identify the location of potential archaeological sites and their possible signatures through descriptions of the types of infrastructure and coastal foreshore processes.

GIS and Geo-referencing

Historic cartographic sources and aerial images which evidenced different coastal infrastructure were scanned and then overlaid onto modern GIS coverages of the Queenscliff area to compare their past positions in relation to the modern coastline. Using a common GIS process called geo-referencing, historical cartographic sources were superimposed onto modern primary cadastral and/or hydrographic coverages, and an algorithmic process then transformed (or geo-referenced)

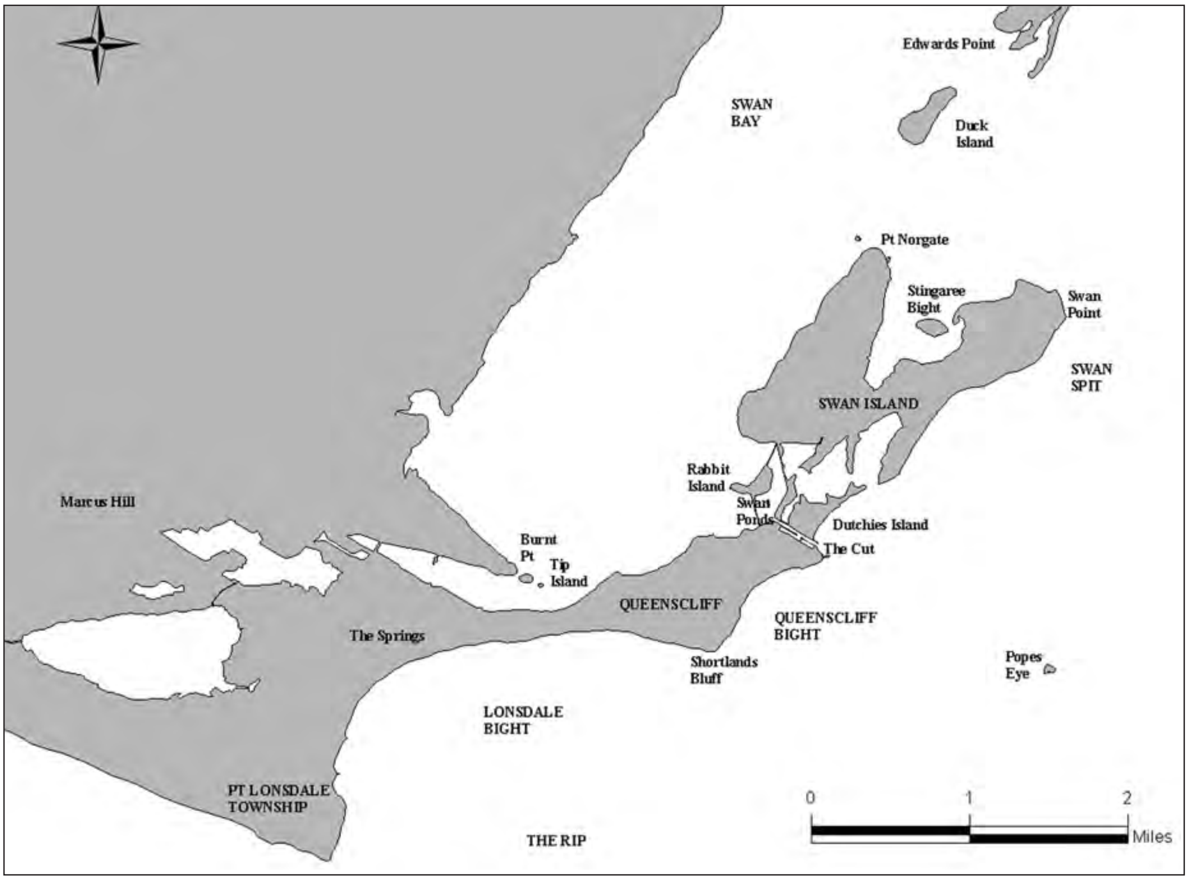

Fig. 2: Map of Queenscliff and Point Lonsdale foreshores. Map by B. Duncan

the historic map into a modern projection system to create a new GIS image coverage of the original cartographic source (Duncan 2006:72).

The resultant GIS image coverages were digitised (electronically traced) and relevant information entered into an attached database, enabling the actual geographical coordinates for former historical feature locations, such as maritime infrastructure sites and environmental coastlines, to be extracted from the GIS.

This method has been used by other archaeological and historical studies to identify former use of a planned excavation area, or to document the accumulated history of a given region (e.g. Johnson 2003), but it is possibly the first time (to the author's knowledge) that it had been used to physically identify and locate potential underwater archaeological sites. The author has also subsequently applied it to numerous other projects around Victoria with similar success (Duncan 2002, 2003a, 2003b, 2004), as has Souter (2003) using historic aerial photography.

Time slice analysis, the process where the differences in a sequence of geo-referenced historic maps and charts are examined (e.g. Hastenstab and Resnick 1990; Mather and Watts 1998), was also applied to identify chronological changes in seabed and shoreline geomorphology around Queenscliff and Port Phillip Bay. When correlated to other historical and oral sources it was possible to identify the effects of infrastructure on local coastal geomorphology over time, and consequently the probable location of maritime archaeological sites as shorelines prograded (encroached forward) or eroded.

Local Oral History/Folklore Interviews

Oral accounts were clearly an important method of transmission of local histories within the Queenscliff township and often provided information not available through other sources of historical documentation. Numerous long-term Queenscliffe (borough) and Geelong residents were interviewed to determine the existence of a body of direct and/or informally transmitted knowledge of a range of maritime industries and services still retained within the community. Most of the local participants interviewed were between the ages of 70 and 90, which meant many informants had first-hand memories of most of the events, themes and sites being investigated. However, some younger participants were included where they had strong collective knowledge based on familial ties, or where they were directly involved in a major maritime industry that exposed them to the cognitive landscapes and collective knowledge of non-family members in those services. Local historical museums also held extensive oral history collections, whose informants had long since passed away. These recordings enabled the oral history approach to access personal recollections dating in some cases back to the early 1860s.

Queenscliff and the surrounding areas proved a fertile ground for oral histories, as many residents could often trace their familial origins back to five generations and in some cases with as many generations in the same industry. Each informant was interviewed with a set of standard predetermined questions and were asked to draw on a local chart/map the locations of various areas which were either used by them or their families, along with prominent landmark features, names, archaeological sites or other relevant information such as coastline change. In some cases, informants possessed detailed local knowledge of the effects of the installation of maritime infrastructure on coastal formation processes, along with the location of previously unrecorded archaeological sites. This information was converted to GIS coverages (layers) which enabled comparison with other data sources.

Most informants clearly recognised the existence of previous maritime sites in the Queenscliff Bight area, both from their own personal experience or from oral traditions within the township. Several people recalled many of the major infrastructure sites and, even though they had long since disappeared, they could still envision them standing at their former locations. The local population also possessed a clear understanding of the numerous coastal processes which generated a changing foreshore and led to the demise of many infrastructure sites.

Archaeological Investigation and Ground Truthing

The coordinate positions of the geo-referenced historic sites, as well as those places indicated by oral histories and other sources, were extracted from the GIS coverage layers and programed into a hand-held GPS (satellite navigation) unit to ground-truth the possible existence of archaeological sites. A series of ground-truthing inspections were undertaken, both on land and below water, between 2001–2005. The process allowed for not only the location and identification of sites and features, but also comparisons between the data sets and recognition of ambiguities, as well as the exploration of the effects of changing environmental conditions on maritime activities (and vice versa). This process was constantly evolving as new sources were discovered and entered into the GIS database.

NATURAL ENVIRONMENTAL HISTORY AND ITS EFFECTS ON SHIPPING

In order to understand the reasoning behind the locations of maritime infrastructure around Queenscliff, a consideration of the local environmental conditions is warranted. Port Phillip Bay, locally known as 'the Bay', was formed when the Pleistocene coastal plain and tectonic depression was flooded to form a semi-encapsulated bay over 60 km wide at its extremities (Bird 1964:35). A horseshoe-shaped underwater chasm up to 95 m deep straddles the entrance to Port Phillip Bay and is locally known as 'the Wall'. The area was originally strewn with isolated uncharted pinnacles which often rose to within a few metres of the surface. These pinnacles were usually discovered by vessels striking them, and were often removed upon discovery by blasting so as to construct a safe channel through the heads (Anderson 1997:7–8).

A series of sand and mud banks form a delta from the former archaic Yarra River mouth beginning approximately 5 km north of 'the Rip', extending in a 5 km radius (Fig. 3). The reduction in current velocity and subsequent deposition of waterborne sediments associated with tidal changes and channel narrowing at the Rip have produced an extensive sandbank delta. These banks are interspersed with up to six naturally occurring channels, cut by the former river course and tidal influences. The sediment in this area is highly dynamic, and only two channels of sufficient width, the West and South Channels, offer reliable courses for safe navigation; a third, the Coles Channel, is navigable only through regular buoyage updates (Bird 1964:138).

The Point Lonsdale to Queenscliff shoreline consists of broad shore platforms cut in Pleistocene dunes faced by rugged cliffs. Shallow lagoons lie inland between dune calcarenite ridges. Swan Bay is characterised by a shallow landlocked tidal marine region connecting to Port Phillip and is partly enclosed by spits and barrier islands and bordered by an extensive salt marsh. Edwards Point is a recurved sand and shingle spit (a deflected river/estruary mouth entrance spit

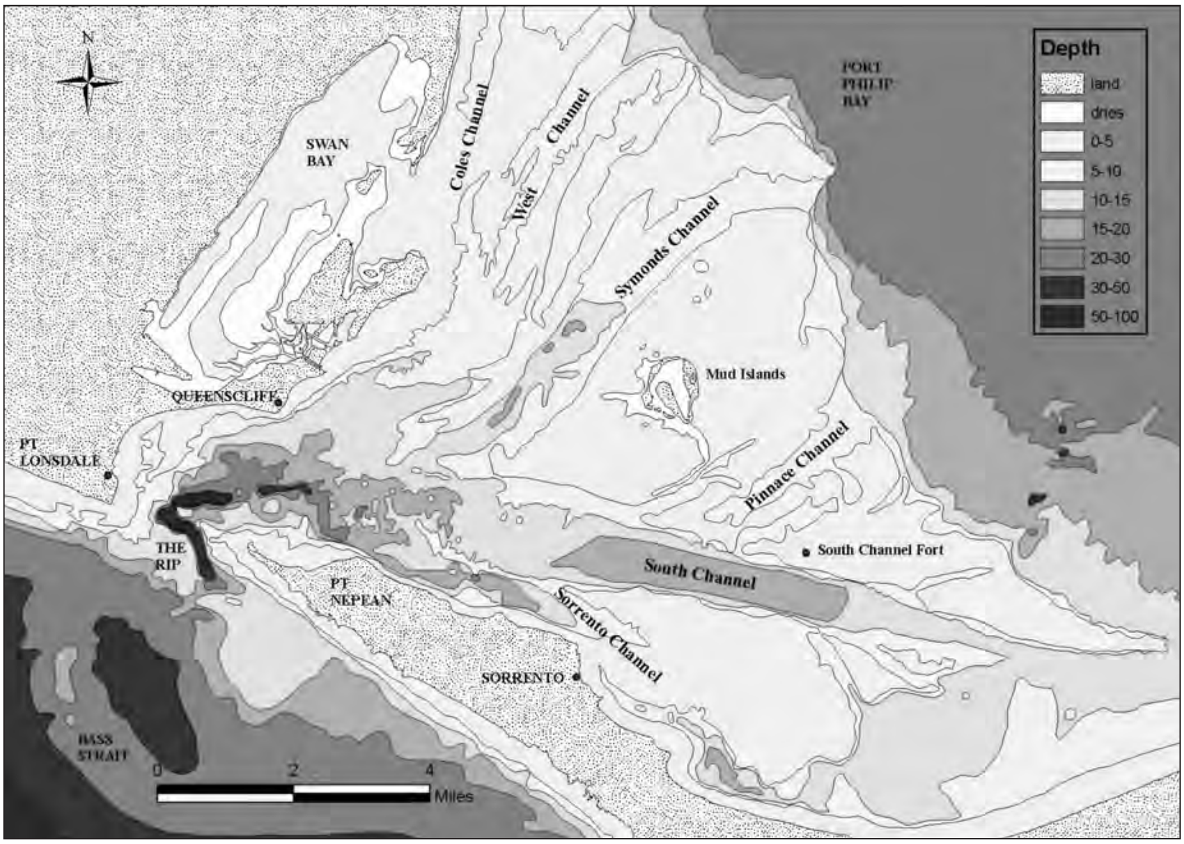

Fig. 3: Bathymetry and channels of the study area. Map by B. Duncan, after Australian Chart 143

caused by the actions of longshore drift and onshore waves) lined with salt marshes, shallow lagoons and fringing sandy recurves. Swan Island is characterised by a large mobile sandy foreshore and spit, which is known for its constant deposition and erosion. The Point Nepean to Observatory Point (Portsea) foreshore is similar to Point Lonsdale but also with parallel dune ridges on the inside of the bay and steep rugged cliffs fronted by shore platforms on the exposed ocean precincts (Bird 1977:52, 56).

The Port Phillip heads area is known for its often unpredictable conditions and is considered extremely dangerous. The semi-enclosed topography of the heads entrance constricts the tidal water flow either outside or inside the inlet, dependent on high or low tides, leading to a disparity of water levels in the Bay and the ocean outside the heads (Bird 1964:9). The tidal influx is delayed by the narrow entrance, as only a restricted amount of water can flow through the inlet at any one time, a similar situation to bath water at the plug hole. The water levels inside the Bay are therefore alternately higher or lower than the ocean sea level outside, dependent on the tide. The water flow continues until equilibrium is achieved midway between high and low tides, when currents slow and reverse to produce the period known as 'slack water'. However, slack water at the Heads actually occurs midway through the oceanic tidal stream, usually three hours after the tidal change, and this is the opposite of the generally expected rule where slack water occurs concurrent with the change of tide (Anderson 1997:7).

Furthermore, water flowing through the entrance to Port Phillip Bay is funnelled through a mile wide entrance, the Rip, resulting in a severe tidal current of up to 7 knots. Tidal waters are further disturbed by the effects of underwater topography and localised climatic effects on winds and waves, resulting in unpredictable eddies and whirlpools and currents directed towards the shore. The tidal flow also runs slightly athwart the entrance with great force, which is constricted for at least half of its width by shoal reefs and pinnacles on either side, all contributing to a confused sea and tidal rip. When sailing vessels attempted to navigate the Rip against a strong ebb tide they were often swept against the eastern peninsula. The difficulty of this situation was intensified as the oceanic wind frequently eased off as the tidal water was reached, leaving the vessels unmanageable. The combination of the tides with a shallower approach reef outside the Heads, and a very deep chasm inside, meant the Rip is often subject to highly unpredictable seas, especially in a southwest gale (Yule 1876:271, 305). Although ocean swells do not enter Port Phillip due to the narrowness of the entrance, as is normal in other more open coves, wind generated waves are a constant danger within the Bay (Bird 1964:13, 14).

DEVELOPMENT OF MARITIME INFRASTRUCTURE IN QUEENSCLIFF BIGHT

The following historical overview provides the context for the European settlement and maritime use of the Queenscliffe area, with special focus on the development of infrastructure. Queenscliffe refers to the local borough and includes the towns of Queenscliff and Point Lonsdale.

Queenscliff lies close to the entrance of Port Phillip, the gateway for the ports of Melbourne and Geelong (Fig. 1). It is predominantly a maritime-based community and was established to assist mariners through the treacherous environment described above. The site of the future township was first settled by private commercial pilots in 1839, who launched boats off the beach below the Bluff, and by staff of the first lighthouse established there in 1842 (Noble 1979:8, 9, 42; Cuzens 1912:1). The Shortlands Bluff settlement was built on the tip of a narrow peninsula which was approached by a narrow track through shifting dunes. It was located approximately 50 km by sea from Melbourne and 30 km from Geelong, the nearest large town. This settlement was initially isolated from the nearby farming districts by flood tides and heavy rains which often inundated the sole land route into the community, leading to a reliance on maritime transport (Dod 1931: 50; Perry 1973:41).

The peninsula proved to be an early popular tourist haven for wealthy Victorians. The township was established in 1853, when allotments were surveyed and many blocks were sold to well-off merchants, speculators and graziers as the sites of future holiday homes. The settlement was renamed Queenscliff at this time, with the name Shortlands Bluff reserved for the prominent headland on the southeastern side (Dod 1931:8–9).

Despite the increasing maritime traffic, the only sheltered anchorage for small vessels based at the township was inside a small inlet formed by a sandy peninsula, Chinamans Point on one side, and the southern extremity of Swan Island on the northern side (see Figs. 5 & 6). This bar entrance to Swan Ponds was difficult to navigate, as it moved seasonally with the natural re-deposition of sediments caused by the tidal currents, and was often too shallow or silted up for boats to pass through (pers. comm. Cec Anderson and Harry Mouchmore).

Queenscliff Jetty and Sea Baths

Around the time of the first land sales, the construction of a public pier or wharf was mooted to facilitate seaward access to the town. Known as the Queenscliff Jetty, the pier was constructed from unturned raw logs in 1856 and extended to an offshore water depth of 12 feet (3.65 m) (GA 27/11/1855:2; Bluelight 1912). This structure acted as the gateway to the township where early steamers delivered both supplies and passengers. In 1857 a plank road was built that traversed a marshy area up the northern foot of the main settlement (Cuzens 1912:1; Allom Lovell 1985:161). Although the pier was built in the lee, or sheltered side, of Shortlands Bluff away from the prevailing south westerly winds, it was still subject to strong tidal influences associated with the narrow confluence of the Port Phillip Heads (the Rip) only 5 km away.

Queenscliff Jetty was quickly adapted as the base for the early fishing industry by the early 1860s. At this time the pier extended 150 m seaward with a small extension arm to the south (Cox 1863). Fishing boats were moored in Swan Ponds after crossing the bar entrance at Chinamans Point (Figs 5, 6), and in stormy weather were taken into the sheltered bight, Stingaree Bay, on the north side of nearby Swan Island. Several other facilities, including a lifeboat and shed, tidal gauge and tramway were constructed in the period up to 1863 (Fanning 1892b; VPRS 2143:58/101, 60/68).

Fortifications

The onset of the Crimean War (1853–1856) led to calls to fortify the heads to deter any potential Russian attack. Concerns were expressed that a hostile ship could easily hold Geelong or Melbourne to ransom (Sutherland 1888:461; Brownhill 1990:634–636). An increasing world-wide arms race in the nineteenth century eventually led to the installation of a network of coastal batteries around Port Phillip, including coastal fortresses at Queenscliff (1862) and Swan Island (1882) (VPD 1862:420, 718; Tate 1982:55; Kitson 1987:6.2). The supply requirements for these facilities placed further pressure on the need for reliable pier facilities, leading to the installation of a railway in 1879 which markedly improved the viability of the fishing industry as fish catches could then be easily transported to Melbourne and Geelong (Perry 1973:41).

Health and Pleasure

Early nineteenth-century medical practioners regularly espoused the therapeutic benefits of taking in the fresh air of seaside regions. It was thought the pure cool air and a salubrious climate combated germs and poisonous miasma which supposedly cause sickness (QS 19/7/1884; Wells 1982:43; Inglis 1999:22). Seaside excursions became popular activities and as early as 1842 pleasure trips were being undertaken to 'the Bay' (Day 1992:286). Health resorts and sea baths sprang up around Port Phillip to take advantage of the perceived health benefits and for cleanliness (Cooper 1931:160–161; Duncan 2003a:282, 317, 359, 383, 384, 385, 408). Sea baths were usually large areas of open ocean enclosed by picket fences (often acres in size). This restricted poor swimmers to shallow water but also protected them from strong tides and sharks (Duncan 2006: Appendix D–1).

Queenscliff quickly grew into a seaside resort patronised by wealthy tourists from Melbourne, Ballarat, Bendigo and the Western Districts (QS 22/7/1893; Inglis 1999:72). Many tourist vessels arrived from Melbourne and Geelong. In the early 1850s a bathing facility, located at a natural rock cut pool known as the governor's hole, was added to the southern side of Shortlands Bluff (Fig. 5). It soon proved to be too dangerous for the weaker swimmers of this time, with several drowning in the notorious currents that swept by its exposed position (McWilliams 1865; QS 25/3/1893, 2/11/1907; Dod 1931:12). By 1863 a new enclosed bathing facility, the Queenscliff Bathing Company Baths, was built to the south of Queenscliff Jetty and replaced the earlier facility (GA 22/5/1862:2).

By 1864 a second pier, known alternatively as the Boat Jetty or Doctors Jetty, was built to the south of the Queenscliff Baths to assist in transferring the health officer, pilots, customs and other government maritime officials (Dod 1931:9; McWilliams 1865; VPRS 2143: 64/288, 65/92, 65/159). With the arrival of regular Bay steamer passenger services from the 1870s the Queenscliff Jetty was extensively used for the tourist trade (Duncan 2006:Appendix D–1–4). Several extensions and upgrades were undertaken between 1870 and 1875 to accommodate increased tourist traffic arriving on the large Bay steamer ferries (VPRS 2143:61/157, 70/123, 72.3/192; GA 21/7/1875:2). A new bathing facility available to both men and women was constructed in 1871 and had segregated bathing times for each sex (GA 2/10/1871; 27/9/1871). The original Queenscliff Bathing Company Baths grew into a much larger facility by 1875 as a direct result of the increased tourist trade (SGO 1882).

Building New Piers

Numerous repairs were undertaken on the Queenscliff Jetty in 1881–1882 (VPRS 2143: 81.2/13, 82.3/4). A lifeboat shed mounted on the northern side of the pier, on the west side of a 60 m northern extension (SGO 1882), had been removed by 1883 (Norgate 1883). When the water around the jetty proved to be too shallow to service the new, deeper drafted bay steamers, the New Pier was built. It was almost twice as long as the original jetty and was designed to accommodate larger vessels. It was erected to the south, on the site of the Queenscliff Bathing Company Baths (SGO 1882; QS 22/6/1889; Duncan 2006: Appendix D–1:9). The Queenscliff Jetty then became known as the Fishermens Pier as it continued to be used predominantly by fishers (QS 19/7/1884). The demolition of the original baths saw the building of another structure exclusively for men. It was built between the second bathing facility, then known as the ladies' baths and the boat jetty (Fig. 4), and became known as the men's baths (Norgate 1883; QS 2/11/1907).

Fig. 4: Maritime infrastructure in Queenscliff Bight. Boat jetty and pilot station (foreground and left), ladies' baths (centre), remains of Queenscliff Bathing Company Baths being dismantled and Fishermens Pier (at top) c. 1882. Photo PH 292, Queenscliffe Historical Museum Collection

The 702 feet long (214 m) New Pier, also known as the Steamer Pier, was constructed in 1884–1885 (VPRS 2143: 84.5/257). Further extensions were undertaken between 1886 and 1888, when 500 feet (152 m) were added, and included a new dogleg extremity, lifeboat and shelter sheds and a tramway (QS 3/4/1886; VPRS 2143:86/209; 87/12, 87/210, 87/133, 87/298; COPW 1888). By 1889 the New Pier had started to fall out of use, as despite its ample L-shaped loading facilities and being twice the length of the Fishermens Pier, the water depth at its extremity proved to be the same. The older pier continued to be used in pref-erence to the new one, due to its shorter length for passenger disembarkation. A new deepwater pier was proposed in 1889, to the south of the boat jetty under Shortlands Bluff, as a replacement for both the Fishermens and the New Pier but was never built (QS, 22/6/1889). In 1889 a lifeboat shed was built on the New Pier, on one of the landing stages on the southern side, to house a davit-mounted lifeboat (VPRS 2143: 94.5/196; Allom Lovell 1985:161).

In 1911 a new 300 feet (91 m) L-shaped breakwater extension was built at the New Pier and breakwater planks were installed along the pier to provide better protection for fishermen's boats moored between the two piers during rough weather (QS 17/9/1910; pers. comm. George Werry). Prior to this the fishermen had to shelter their boats behind Swan Island in bad weather (QS 19/8/1911).

The Fishermens Pier was lengthened in 1914 when a 210 feet (63 m) long seaward extension was added (Stewart 1914), along with a dogleg extension by 1915 which aligned with a similar component on the New Pier (Raison 2002:24; Barrett 1916). An island pier (dolphin) was built between the two pier doglegs to provide additional shelter for the fishing fleet in bad weather (Larkin 1928; Allom Lovell 1985:162; pers. comm. Les Irving-Dusting and Peter Ferrier). Boats could now be moored between the piers in most conditions but still had to be taken to shelter in the north during gales (pers. comm. Harry Mouchmore; Raison 1987:25). Sometime between 1914 and 1923 the men's baths were extended eastwards into deeper water (Stewart 1914; Larkin 1928).

Fishermens Pier was again extended between 1926–1928 when the L-shaped dogleg arm was lengthened to provide an enclosed safe breakwater haven for the local fishing fleet. A new lifeboat house was constructed between the Fishermens Pier dogleg to house the new lifeboat *Queenscliffe*, along with a slipway for hauling fishing boats out of the water for rough weather storage on the pier. Despite the installation of breakwater planks on both piers fisher's boats were still often forced to shelter in Stingaree Bay (Larkin 1928; Allom Lovell 1985:162; pers. comm. George Werry).

The need for a new sheltered anchorage was sorely felt by the fishermen, whose constant vigilance was required to avoid damage to their boats. After severe storms in late 1934, which caused extensive damage around Port Phillip, work began the next year to install a permanent channel through Queenscliff Bar into Swan Ponds (Raison 1987:25). The new 80 m long canal, lined with timber training walls, known as 'the Cut', was dug through the Queenscliff Spit at Chinamans Point (Fig. 6). Access to Swan Bay still proved problematic even after the work was completed. The area inside the new channel was referred to as 'the Creek', a name previously applied to the entrance through Queenscliff Bar.

The next three decades saw the removal of many major maritime infrastructure sites from Queenscliff Bight. A new lifeboat shed and launching ramp was built at the extremity of the New Pier in 1949 to replace the former facility on the Fishermens Pier (pers. comm. George Werry). The ladies and gents sea baths were demolished by the Australian army using explosives in the 1950s (pers. comm. Gus Rogers and George Werry). After Fishermens Pier became unusable in 1963, some sections were demolished (Raison 2002:24; pers. comm. John Patrick). The New Pier's dilapidated dogleg was removed in 1979 (GA 4/12/1979).

In 1960 all civilian access to Swan Island military base was discontinued when the army assumed command (pers. comm. Les Irving-Dusting). This prevented its use as an emergency fishing boat harbour. A new boat harbour basin was dug on the southeast side of the Cut, along with rock training walls to direct water through the new eastern entrance channel. A slipway was built at the western extremity of this basin in 1964 to replace the previous slipway located on the Fishermens Pier. A second slipway was added by 1972. The basin was extended to its present size between 1975 and 1982.

The introduction of a large cross-strait car ferry led to the construction of a major wharf in 1987 at the eastern end of the Fishermens Basin. In 1993 this wharf was again lengthened to the east and a basalt breakwater installed at its extremity (Allender 1997:7, 41–49).

COASTAL GEOMORPHOLOGY AND MARITIME INFRASTRUCTURE SITES

Bird (1976:73) and Wheeler (2005) have succinctly demonstrated the effect of maritime infrastructure on coastal shorelines. When a structure is placed perpendicular to a shoreline, especially in areas of high tidal currents, it will slow longshore drift and suspended sediments carried by the tide. The sediment will be deposited alongside and around the piles of the structure on the side of the direction of the current. This principle has been successfully utilised worldwide in the construction of sand groynes, small jetties built into the sea, to encourage beach accretion in tourist areas. However, as the current will be deficient of suspended sediment downstream of the groyne there is a tendency for scouring and further erosion in the lee of the structure. With these observations in mind it is useful to re-examine the effects of major maritime infrastructure along the Queenscliff Bight shoreline.

The historical, oral and archaeological evidence strongly supports that the evolution of the modern Queenscliff's coastline can be partially attributed to the various periods of pier, baths, harbour and channel construction, both locally and within the Rip. The installation of these maritime facilities began a cycle of dynamic geomorphological change that was to affect and dramatically reshape the entire coastline of Queenscliff. Beginning in 1855 with the construction of the first pier, current-borne sediments were slowed producing sand accretion around the extremities of the piers and baths. As further extensions were added, along with two additional piers and two bathing complexes, the velocity of the current in the area was reduced to the extent that all these structures verged on becoming unusable (QS 8/6/1876, 2/11/1907, 30/11/1907).

Coastal Shorelines Changes and Infrastructure in Queenscliff Bight

The installation of the Fishermens Pier led to the gradual accretion of sand around its piles. Early charts show that by 1863 (Fig. 5) sand accumulation had already buried the inshore sections of the pier, resulting in the need for its first extension in 1860 (VPRS 2143: 60/68). Combined with the extension of the nearby Queenscliff Bathing Company Baths facility, which filtered and slowed water passing through its partially fenced-in sides, the dropping of suspended sediment caused a pronounced bulging of the shoreline eastwards, along with further sand accretion between the baths and the Boat Jetty.

The installation of further bathing facilities between 1875 and 1883, resulted in the need to extend the Fishermens Pier into deeper water, in the lee of the flood current, and to construct the New Pier to access deeper water in 1885. These works were intended to provide adequate berthing facilities for the larger vessels servicing the Bay steamer tourist ferry trade. The construction of the latter pier appears to have further exacerbated the situation because it acted like a sand groyne by accumulating sediments on one side. The proposal to construct a new fourth pier, to the south of the Boat Jetty on the southeastern side of Shortlands Bluff near permanent deep water (QS 22/6/1889), was probably as a direct consequence of the depth limitations associated with siltation experienced further north. It was also noted locally that the construction of the Swan Island Fort, from 1882 onwards, further contributed to silting in the area (QS 10/4/1886).

By 1906 the shoreline had prograded (sanded up) out halfway along the length of the ladies baths and Fishermens Pier, to the extent that surveys were undertaken to assess the water depth directly seaward of the pier (Smith 1906). Silting was a serious problem in 1907, when it was reported that several hundred tons of sand had accumulated around Fishermens Pier, severely inconveniencing fishermen and local trading vessels (QS 20/4/1907, 2/11/1907). By November, plans were being made to cut and blast away the 'forest of (old disused) piles' left under the pier and to remove pier landings. The dredge *Pioneer* was employed to remove silt to a navigational depth alongside the Fishermens Pier from 1907 until February 1908. Further works were undertaken then at both piers to remove piles to encourage scouring underneath the piers (QS 30/11/1907; 29/2/1908). In 1908 the problem became so acute that fishermen were forced to offload fish among the tourist traffic at the New Pier. Despite work on both piers to reduce siltation, piles were removed and lateral beams attached to encourage scouring, the approaches to Fishermens Pier continued silting up, as did the whole bay. A suggestion was made to extend the older pier 200 feet (61 m) to the edge of the seaward channel where tidal influence would keep the approaches clear but this was rejected (QS 21/11/1908).

By 1911, although breakwater planks had been installed on both major piers, plans were made to open two bays of planks on both piers to alleviate further siltation problems (QS 17/9/1910). By 1914, the sand accretion was so extreme that the baths required constant excavation to provide sufficient water depth for swimmers. Diminishing water depth around the men's baths necessitated the construction of an additional enclosed bathing paddock further out to sea. An extension was added to Fishermens Pier to reach deeper water after the shoreline threatened to engulf the dogleg arm of the pier (Stewart 1914). An L-shaped extension arm was also added to the New Pier at its extremity to act both as a breakwater for fishing craft and to enable adequate berthing depth for large steamers. Encroaching shallow water depths under the lifeboat shed on this pier also threatened the launches, leading to the construction of the new motorised lifeboat at the extremity of the Fishermens Pier in 1926 (QS 26/4/1919; Boyd and Roddick 1996:3).

The removal of obsolete structural elements of the piers (QS 30/11/1907) and the raising of the baths paddock fences in winter to encourage scouring alleviated the sand accretion to some extent but problematic access to the pier was only solved by localised dredging after they were extended to facilitate access for large vessels (QS 21/11/1908, 17/9/1910, 25/5/1912). This further altered the dynamics of the region, allowing sea swells to approach closer to the shoreline, which caused local scouring at the rear of the fishermen's houses located on the beach to the north of the Fishermens Pier (pers. comm. John Patrick). After several unsuccessful attempts to alleviate the problem with timber groynes and stone walls, a former defence hulk (HMVS *Lonsdale*) was deposited in the area as an erosion control measure (Larkin 1928; pers. comm. Harry Mouchmore and Margaret Wright).

Problems were also experienced along the edge of Swan Island, where the shoreline began to erode and fill up Queenscliff Bight (Yule 1884:313). This threatened the foundations of the fort and beacon, leading to the installation of two hulks to stop the erosion. Groynes were also later installed around the island, in particular at the Swan Island Beacon/Fort and at the Swan Point, along with a submarine hulk at the latter. This was sunk on top of a barge to give it more height (pers. comm.

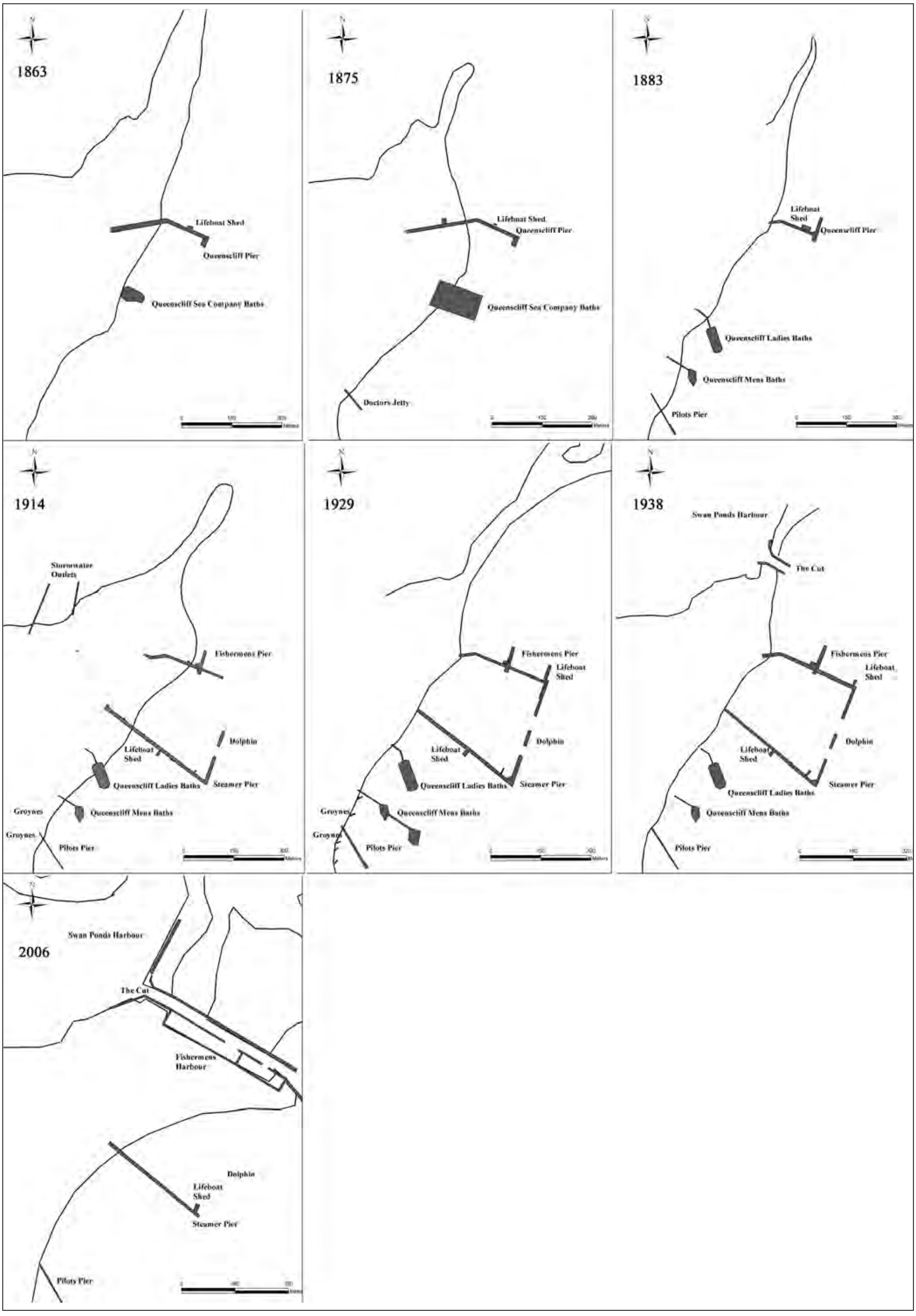

Fig. 5: Changes in the Queenscliff shoreline 1863–2006 taken from geo-referenced cartographic sources. Map by B. Duncan

Les Irving-Dusting). Until this time the water depth at Swan Point was such that large ships could moor in a gutter close to the point (pers. comm. Peter Ferrier).

The Effects of the New 'Cut' Channel

The opening of the Cut in 1935 further complicated the geomorphological conditions. Although a permanent training wall had been installed to keep the channel open, silting remained a problem. The mobile nature of the bar peninsula meant that a natural entrance was constantly being formed through which the waters of Swan Bay emptied. A training wall consisting of a breakwater, sheet piling and stone causeways was designed to permanently close the natural channel. It was later added across the inshore edge of the former northern end of the Chinamans Point Spit and Swan Island to force water through the Cut and prevent water from breaking through the sand spit to form a new entrance. However, this caused an embayment in the interior of Swan Bay and Swan Ponds which slowed waterway borne sediments to settle. These regions gradually began to silt up, therefore limiting the size of watercraft that could be used and moored in the inlet. The blocking of the former bar entrance also caused major problems on the Fishermens Flat residential area, as water from Swan Ponds could not escape fast enough through the Cut. This resulted in major flooding and subsequent scouring threatened to wash away the Fishermens Flat backyards and houses on the northern end of the Flat on Beach and Bridge Street, leading to the construction of stone walls and groynes to try to alleviate the problem (pers. comm. John Patrick).

The building of the Cut and breakwater structures dramatically altered the coastal dynamics of the area. The mobile nature of the natural bar entrance prior to this installation allowed water to scour along the natural channels of the entrance, creating deep water channels in Swan Ponds suitable for large sailing craft. The area inside Swan Ponds subsequently began to silt up as suspended sediment exiting from Swan Bay dropped as it was funnelled and slowed at the Cut.

To further complicate the issue, the western foreshore of Swan Bay had been subject to intense deforestation associated with lime burning, bark and firewood harvesting, and farming since at least the 1850s (Duncan 2006:91). The installation of the Cut then allowed a constant stream of silt-laden run-off water to permanently flow out at the same location between Swan Island and Queenscliff. Previously it had created its own natural channels through the bar and any given area could become choked with sediments. This produced an increased deposition of suspended sediment in the area outside the permanent entrance, as the heavily silt laden waters from Swan Bay slowed down when they met the sand burdened tidal waters of Port Phillip Bay. As a result coastal sand accretion in these areas produced up to 500 m of new land to the east of the old entrance between 1935 and 2000 (Fig. 6).

The introduction of dredging to keep the seaward ends of the Cut channel open probably further accentuated the problem, as fluidised sand flowed back inside the Cut and Swan Ponds with every tidal change to form a flood tide delta accretion. Similar observations were made at Lakes Entrance, Victoria (Wheeler and Peterson 2005:6–8). Further problems were also experienced along Swan Island. Here extensive erosion was attributed to the effects of decreased sediment transportation caused by being in the lee of the piers, acting as groynes, and to the cessation of seasonal water-borne sediment replacement along the beach. Formerly the sediment had exited via the natural bar entrance but was consequently blocked by the new Chinamans Point/Swan Island breakwaters.

These conditions led to the removal of the lifeboat shed from the Fishermens Pier to deeper water on the New Pier in 1949, after the former location began to silt up (pers. comm. John (Jack) Beazley; Raison 2002:28). By the mid 1950s sand accretion had buried almost half of Fishermens Pier, which became unusable by the 1960s (Raison 2002:24; pers. comm. John Patrick). Further south, the removal of the sea baths piles in the 1950s also cancelled the groyne-like protection they afforded. This resulted in the construction of two new seawalls at Queenscliff Bight Beach in the 1950s (pers. comm. John

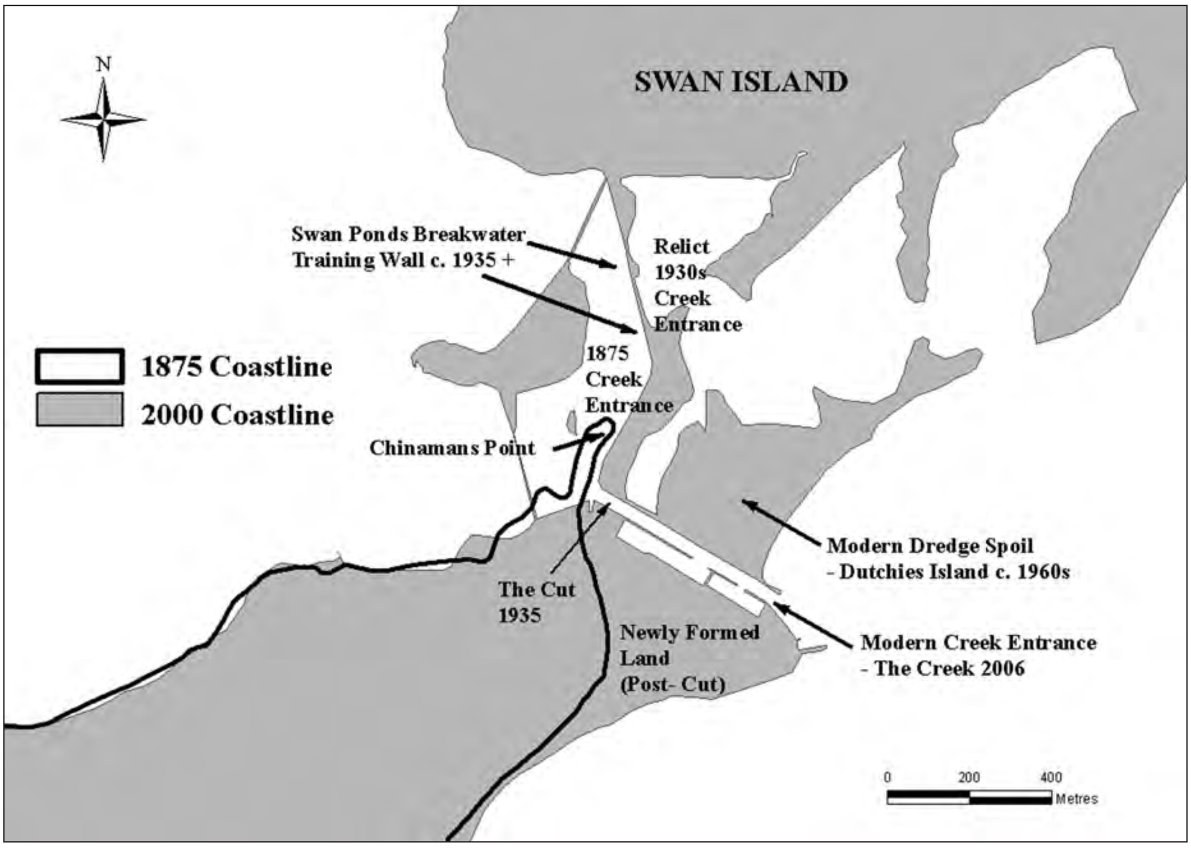

Fig. 6: Comparison of 1875 and 2000 coastlines derived from geo-referenced historic plan and modern aerial image. Map by B. Duncan

Patrick), and another below the Shortlands Bluff cliffs in the 1960s to prevent further erosion (pers. comm. Peter Ferrier).

By the 1960s siltation around the Cut's seaward entrance had prograded the area of land to the east on the southern side of the Creek, into which the new Fishermens Basin was later dug. The sand excavated to create this new harbour was pumped into the area north of the new rock training walls, which acted as pseudo groynes by encouraging further sand accretion east of the entrance. Furthermore, spoil from continuous dredging to alleviate this problem was also pumped into this northern area and created a new sandbank atoll called Dutchies Island (Allender 1997:5).

The extension of the Fishermens Basin wharf in 1987 and 1993 to accommodate the car ferry further encouraged sand accretion in the region from ebb tides which began to silt up Queenscliff Bight. The scale of deposition in these areas is evidenced by extensive silting under the New Pier which has rendered almost one third of its length unusable to maritime traffic within the last two decades (author's own observations).

The fluvial plume from dredged spoil at the entrance to the Fishermens Basin, along with the groyne-like effects of the new ferry terminal, were responsible for massive sediment deposition along the Queenscliff Bight since 1993. This created a 60 m wide strip of accumulated land from the seawalls between the New and Pilots Pier, site of the former Boat Jetty, and up to 500 m of prograded and densely vegetated land north of the New Pier (Fig. 6).

Other factors have contributed to extensive silting and erosion (pers. comm. Cec Anderson and Jocelyn Grant) that has shaped the Queenscliff and Swan Bay coastlines. These include: the construction and deepening of channels at the Heads from 1909–1935, local guano mining, the introduction of feral animals (e.g. rabbits and goats), other extensive extractive industries (e.g. sand and shell mining, firewood and bark cutting, farming), and artificial channels dug along the coast of Swan Bay (Duncan 2006:Appendix G–3).

ARCHAEOLOGICAL IMPLICATIONS OF COASTAL GEOMORPHOLOGICAL CHANGE AT QUEENSCLIFF

The observations outlined above have relevance for the predictive modelling and relocation of coastal/littoral archaeological sites. The accelerated deposition of sand along the Queenscliff Bight coastline not only inconvenienced shipping and other maritime activities but also potentially buried archaeological structures, sites and deposits associated with maritime infrastructure. This study concluded in 2002 that some former underwater/intertidal sites would now be located under prograded land (Fig. 7) and other former terrestrial sites, such as Chinese fisher hut sites were now underwater (Duncan 2006:328, in prep,).

This forecast was substantiated in 2005 when a number of predicted sites were uncovered during redevelopment of the area. Most notable was the Fishermens Pier. It was found in a remarkable state of preservation in the exact location and orientation forecast (Figs 8, 9). Despite the installation of several utility pipelines through this area, the majority of the service facilities were diverted over or under the structure, and hence much of the pier was discovered intact (Hewitt 2006). The degree of integrity of this site also suggested that multiple intact horizons of formerly submerged archaeological artefact deposits associated with the pier's use would be discovered on former seabed levels below the current ground surface. The extent of preservation of this timber structure was unique in

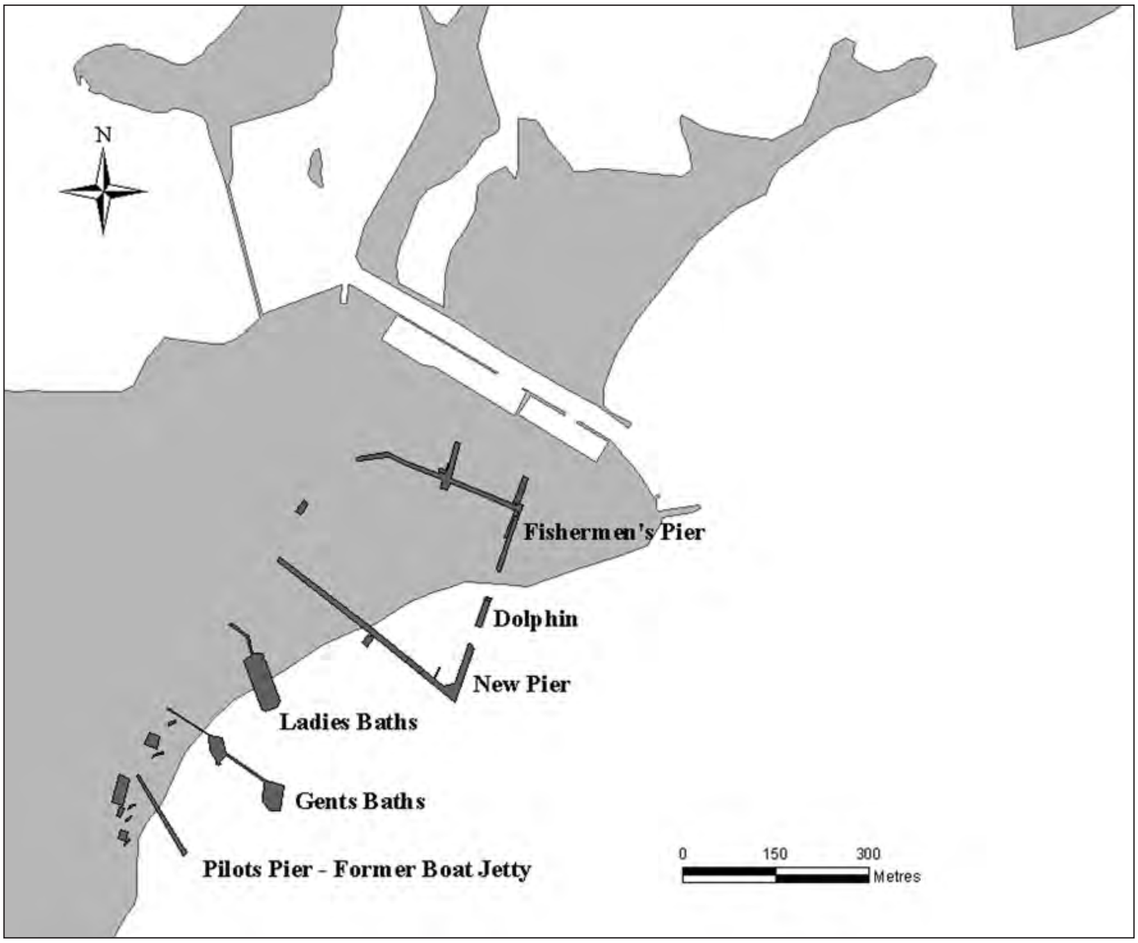

Figure 7: The current location of 1929 maritime infrastructure sites shown against the modern shoreline. Note the potential for archaeological sites buried under shoreline progradation. Map by B. Duncan

Figure 8: Queenscliff Fishermens Pier excavation 2005. Photo B. Duncan

Victoria and was accordingly recognised by the National Trust as a site of State significance.

Unfortunately, most of the upper superstructure of the central sections of Fishermens Pier were demolished as part of construction works associated with a marina development in 2005/2006, although part of the inshore and outer segments of the pier still exist under a local museum/government offices and the current beach shoreline respectively. Despite the loss of this highly significant site, the observations and experiences of this process offer valuable lessons to be heeded and considered for future planning and management studies of similar coastal regions. Because of the complexity of these environments this research should be undertaken well in advance of any potential development.

Other structures have been uncovered up to 500 m inland from the present day shoreline during development of the Queenscliff harbour precinct: a timber sand groyne; the hulk of the HMVS *Nepean*, also used as an erosion control device; and stone breakwaters. Important in identifying these sites was the accuracy of oral history predictions for the location and probable condition. Despite an understanding by the local community of the regional geomorphological processes, the discovery of the intact structure of the Fishermens Pier came as a surprise to many archaeologists. They had not anticipated that an oceanic structure would be completely subsumed by land progradation in such a short time period, less than 30 years. The veracity of this information raises further issues about past perceptions of local knowledge networks and the

Figure 9: Location of Fishermens Pier against an aerial photograph, showing the extent of the prograded land area. Map by B. Duncan

value of collecting oral histories during archaeological research but this discussion is beyond the scope of this paper.

Although the deposition of new areas of land around Queenscliff Bight and the Cut is an example of a natural progradation process, the process itself was undoubtedly artificially induced, or at least influenced through the introduction of maritime infrastructure into the local environment. This situation varies markedly from other archaeological remains of pier and jetty (solid stone structures) sites identified under prograded coasts around Port Phillip Bay (Duncan 2003a, 2004 for further discussion). In these cases the encroachment of the historical shoreline can predominantly be attributed to land reclamation practices associated with more appropriate use of shallow unusable areas of water which were marginalised as vessel draughts increased over time.

Another aspect raised by this study is the consideration of the effects of communal activities evident in more subtle archaeological aspects, where the joint effects of individual group actions were revealed through an understanding of the evolution of the environmental landscape. The creation of channels and management of waterways represent significant archaeological evidence of maritime environmental exploitation which might normally be referred to as natural landscape changes if we did not know the historical basis for their development. The combined modification of the marine and estuarine environments by many different maritime groups in this region produced dramatic coastline changes which also represent tangible archaeological signatures of maritime and coastal cultural activity.

The local geomorphological dynamics of Port Phillip and Swan Bays were influenced by:

- Many artificial alterations and constructions: piers, baths, defences, bridges, breakwater and harbour construction; channel deepening and dredging; erosion control devices.
- Extractive industries: sand and shell grit extraction; firewood and bark cutting; guano mining; farming.
- The introduction of domestic animal species which became feral, e.g. rabbits and goats.

The environmental effects of these activities were potently revealed through comparative analysis of spatial and temporal historic coastline changes using geo-referencing of historic cartographic sources to modern cadastral GIS coverages (Fig. 5). These analyses revealed a cyclic pattern, whereas coastal shorelines altered ‘naturally’, often as a result of the stimulus of construction of maritime infrastructure, the resulting geomorphological change led to the extension and/or replacement of these same maritime structures with new/improved versions. The environmental changes in themselves demonstrate powerful alternative tangible evidence, and sometime the only substantiation of the former presence of individual and/or combined maritime industries, particularly where the original structures that caused the change were subsequently removed. Therefore, the communal development and use of Queenscliff Harbour region and the Rip can also be traced through the various environmental changes and other relict erosion control devices installed in the area. These alterations in themselves represent important archaeological signatures of past landscapes and historic landscape modifications.

Studies of the effects of geomorphological change on coastal infrastructure sites also offers a bridge between the worlds of maritime and historical archaeology. It demonstrates that although the environmental medium in which the site exists may change, the site itself essentially remains the same. Sites in this context therefore offer exciting new possibilities for inter-disciplinary investigation, linking terrestrial and maritime studies across the land/sea interface.

CONCLUSION

These discoveries prompt a reconsideration of the perceived actual locations and nature of former coastal infrastructure sites. Clearly, the installation of coastal structures dramatically changed the original Queenscliff shoreline. The resulting artificially-induced coastal geomorphological processes in turn radically altered the shoreline which buried many maritime archaeological sites and eroded others. This ongoing interactive cycle has the potential to both disguise and preserve large archaeological deposits of former maritime structures to an extent which was previously unexpected. Indeed, anthropogenic environmental shoreline encroachment/erosion has subsequently been observed in several other areas statewide (Duncan 2003a, 2003b, 2004, 2007; Bader and Hewitt 2007).

These observations therefore clearly form significant archaeological characterisations of both former maritime infrastructure sites *and* community landscapes, and provides an important basis for the identification of such sites. It is postulated that these impacts (e.g. evidence of prograded/eroded shorelines) demonstrate tangible archaeological evidence of maritime industries and associated infrastructure which are no longer extant. Therefore, it should also be possible to trace the development of other harbour and maritime/coastal activities elsewhere through analysing the history of the various environmental changes and erosion control devices installed in dynamic coastal locations. Furthermore, through consideration of the effects of historic foreshore infrastructure sites on the geomorphological processes in an area, archaeological research can contribute to the understanding of speed, nature and location of environmental change and aid in the reconstruction of past natural coastal landscapes or alternatively the impact of natural change on coastal archaeological sites.

The results of this study suggest that the field of environmental archaeology, which has been successively applied to explore numerous Indigenous prehistoric contexts, can also provide a functional approach for the investigation of historic sites. Indigenous archaeological research has been much more conscious of environmental change over a longer time frame, where the effects of human activity on the physical landscape have been well documented (e.g. Dodson 1992; Flood 1995). In the last decade the focus of environmental studies has turned to the impact of European settlers on land clearance (e.g. Flannery 1994). This study has demonstrated that it is possible to identify quite significant coastal change as a result of anthropogenic factors over a relatively short period during historic times. This reinforces the possibilities for further environmental archaeological research for tracking human impacts on the maritime fringe which are not really currently addressed in maritime archaeological studies.

The use of the GIS geo-referencing process in conjunction with historical documentation and local oral histories provides a predictive characterisation or method for coastal maritime infrastructure sites which has yielded dramatic results. While other sites may not yield the startling state of preservation discovered at Queenscliff it should be seen as a possible scenario. Future planning studies for coastal regions and/or piers, and other inter-tidal infrastructure developments should seriously consider the archaeological potential of neighbouring inshore areas well in advance so as to adequately identify the coastal heritage of a place. These observations have relevance for identification of the current locations of archaeological places, as some former underwater sites are now located under prograded land, and terrestrial sites are now submerged. These alterations represent potent archaeological signatures of past landscapes and landscape modification. Given the demonstrated extent of artefact deposits previously discovered at other historic pier and bath sites (e.g. Garratt 1990; McCarthy 2002; Richards and Lewczak 2002; Rodrigues 2002; Weaver 2001), the archaeological potential of buried maritime infrastructure sites is enormous. It may be time that we recognise that not all previously 'wet' maritime sites are out to sea but may be literally right under our feet.

ACKNOWLEDGEMENTS

My thanks go to the people of Queenscliff who graciously took me under their wing and told me the stories of their township and its proud history. In particular, I am grateful to the staff and members of the Queenscliffe Historical Museum and Queenscliff Maritime Museum, along with numerous other local residents (too many to name) for their kindness. James Cook University, Heritage Victoria, Tasmanian Parks and Wildlife Service, West Coast Diving and PADI Aware all contributed to the project financially, through either direct or in kind sponsorship. I would particularly like to express my appreciation to my supervisors, Dr Martin Gibbs and Dr David Roe, for their tireless efforts in guiding me through to completion of the thesis.

ABBREVIATIONS

COPW	Commissioner of Public Works
GA	*Geelong Advertiser*, newspaper, Geelong, Victoria
QS	*Queenscliff Sentinel*, newspaper, Queenscliff, Victoria
SGO	Surveyor Generals Office
VPD	Victorian Parliamentary Debates
VPRS	Victorian Public Records Service, State Archives of Victoria

PERSONAL COMMUNICATIONS (2001–2005)

Cec Anderson, ex-hotelier, Queenscliffe Historical Society volunteer, 17/9/2003 and 27/7/2004.

Gus Rogers, Port Traffic Controller, Pt Lonsdale Lighthouse/ex-PMA diver, 17/9/2003.

George Werry, Queenscliff resident/Queenscliff Maritime Museum volunteer guide, 3/9/2003 & 16/6/2004.

Harry Mouchmore, ex-fisherman, Queenscliff Maritime Centre volunteer, various interviews 6/11/2001–27/7/2004.

John (Jack) Beazley, 30/11/2001, ex-pilot and boat builder.

Jocelyn Grant, President, Queenscliff Historical Society, 9/11/2001, 29/11/2001.

John Patrick, Queenscliffe Historical Society and former local resident, various interviews 8/7/2004–23/2/2006.

Les Irving-Dusting, President, Queenscliff Maritime Centre, 30/9/2002 & 28/8/2003.

Margaret Wright, Queenscliff Historical Society, 8/11/2001, 2/10/2002& 4/10/2002.

Peter Ferrier, Queenscliff Maritime Museum committee member, various interviews 5/11/2001-6/9/2005.

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