50 Years of Seawall and Nourishment Strategy Evolution on the Gold Coast

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Abstract
In the 50 years since the 1967 erosion events coastal management on the Gold Coast has evolved significantly with improvements in coastal management knowledge, tools and technology. The paper reviews the history and evolution of coastal management on the Gold Coast, with the two keystones being terminal seawalls and nourishment.

The 1967 erosion forced the Gold Coast to value and protect its beaches and coastal development. The 1st priority was protection of public and private assets. Erosion measures varied considerably and included dumped sand, clay / shale, sandbags, concrete and old car bodies.

Construction of engineered rock seawalls designed by the Qld Co-ordinator Generals Department started in late 1967 along public foreshore areas. Subsequently, the 1970 "Delft Report" provided the first erosion management plan. This report recommended mass nourishment with structures such as groynes to stabilise the wider beaches. A Scheme of Works was gazetted in 1972 by the State for implementation by Council. The first mass nourishment commenced in 1974.

Council recognised the need for a continuous terminal wall to protect property while the nourishment was progressively funded and implemented over a long-time frame. Supporting policies to encourage private participation were introduced by Council and after 50 years, methods and policies have been evolved and implemented using IENCE (Infrastructure to Enhance the Natural Capacity of the Environment) principles. The strategy of mass nourishment seaward of terminal seawalls has proved successful as has been demonstrated again recently in the large swells in June 2016 that caused widespread erosion along the east coast of Australia. Further major nourishment works are proposed for 2017.

This paper reviews the evolution of coastal management on the Gold Coast with improvements in coastal management knowledge, tools and technology.

Keywords: Gold Coast, seawalls, nourishment, coastal management, IENCE

1. Introduction

Fifty (50) years ago, the Gold Coast beaches and the local tourist economy were severely damaged by a series of 7 storms. The Gold Coast only had a small resident population of about 50,000 but with technical support from the State the local Council was able to develop and implement innovative and cost effective (with 75% local funding) coastal management methods that have been adequate to cope with ongoing erosion events and significant sea level rise since that time (about 100mm). The Gold Coast beaches are now one of the City's biggest assets for residents and tourists. With over half a million residents and approximately 11 million visitors annually - spending about $3.1 billion, it is economically important that these beaches continue to be preserved and managed in a sustainable manner for the future [12].

This paper reviews the evolution of coastal management on the Gold Coast with improvements in coastal management knowledge, tools and technology. The keystones developed to date are primarily terminal seawalls and nourishment. The evolution is ongoing and in 1999 offshore reef breakwaters were trialled and, after extensive monitoring, have been added as an additional method suitable for the Gold Coast.

Such evolutions and a sound knowledge base will be necessary for the challenges of the future, including climate change. The seawall performance and design was reviewed in 2014 and a major mass nourishment campaign, building on the present state of knowledge, is planned for 2017.

2. History

Prior to 1967 there was already a realisation of the vulnerability of the Gold Coast beaches to erosion [8]. Protection works up to that time were relatively simple using local resources. Typical early 1900's coastal protection works were log sea walls and groynes using local timber. By the mid-50's improvements in construction plant facilitated

mining, transport and dumping of rock and clay/shale overburden from local quarries. As a result of severe erosion in the 1950's and early 1960's a data collection programme had been set up to collect beach and seabed profiles along the Gold Coast [2]. This facilitated collection of invaluable data and the establishment of a knowledge base during the 1967 storms.

The 1967 erosion events and the associated severe damage to public and private infrastructure along the beachfront and the broader adverse economic impacts to the City and State were the catalyst for implementation of emergency works and a long term coastal management plan.

The 1st priority was protection of public and private assets. Erosion measures varied considerably and included dumped sand, clay / shale, sandbags, concrete and old car bodies [4].

Construction of engineered rock seawalls designed by the Qld Co-ordinator Generals (COG) Department started in late 1967 along public foreshore areas. The design was simple with a primary boulder armour layer, a secondary rock armour layer and a filter layer of clay / shale. The use of clay/shale as a filter layer was a local adaption based on early experiences, but one that worked very well and is still used today.

Subsequently, the 1970 "Delft Report" provided the first recommendations for a comprehensive erosion management plan [3]. This report recommended mass nourishment with structures such as rock groynes to stabilise the widened beaches. The estimated costs (1970 values) were $15 million (2016; ~$165M) of beach replenishment and $13 million (2016; ~$145M) of other works.

A Scheme of Works was gazetted in 1972 by the State for implementation by Council with, at that time, a 20% subsidy. The scheme of works was primarily beach nourishment with no sea walls [1]. However, seawall planning, design and construction using the COG design developed in the late 1960's continued while the technical and funding issues of a major nourishment programme were considered.

Co-operative research between Council engineers and University researchers helped resolve early technical issues and has continued to be a key factor in the successful management of the Gold Coast beaches. Based on research findings, sand transport and erosion rates have been reassessed and the Scheme has been updated at times with additions such as Kirra Point groyne and the Tweed River entrance sand bypass project.

3. Seawalls

Council recognised the need for a continuous terminal sea wall to protect private and public property while the nourishment was progressively funded and implemented over a long time frame. Supporting policies to encourage private participation were introduced by Council. The adoption of an alignment for the seawall, defined as the A-line, in the early 1970's drew a line in the sand for protection that was generally a smoothed line along the surveyed 1967 and, where worse, the 1972 top of erosion scarps.

By 1974, most of the severely eroded public foreshore areas were protected by "COG" design rock walls (Figure 1). Many private properties were unprotected or inadequately protected by the remnants of the emergency works from the 1967 and 1972 erosion events.

In 1982, an alternate seawall design was developed to replace the filter layer with geotextile, as an option for areas where the width available for sea wall construction was limited. In 1984, the policies were tightened and construction of a seawall for any development work over $25,000 became mandatory and all excess excavated sand from building works within 500m of the seawall line was to be used for beach nourishment [4].

In 2014, a design review of the present standard seawall (Figure 1) and alignment was undertaken for the City by Griffith Centre for Coastal Management and International Coastal Management [12].

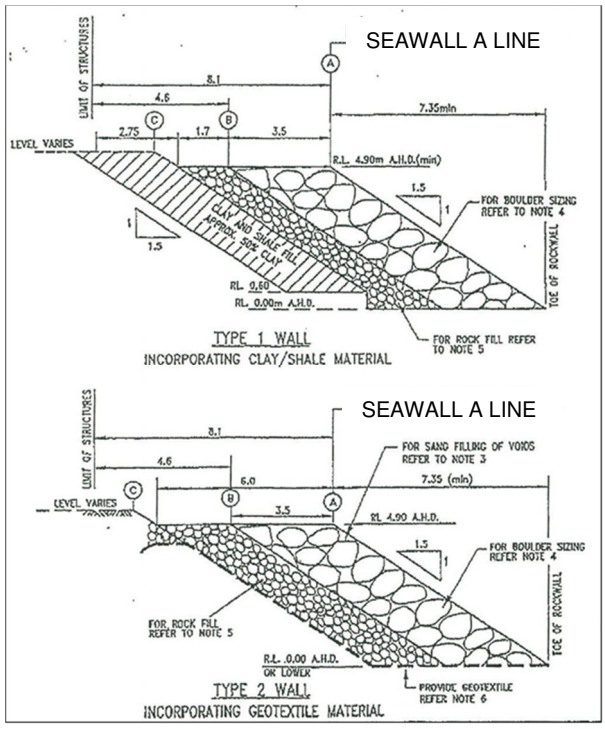

Figure 1: Standard seawall designs

This review included comparison with current best practice and an assessment of the historic changes

to the exposure of the seawall in response to other coastal management works. Consideration was also given to the expected impacts of climate change (primarily in terms of increased sea levels and storminess) on the expected hazard exposure of the Gold Coast seawall. The review found that the standard seawall designs conformed to present standards but required upgrading in the future. The COG design was not difficult to upgrade (Figure 2).

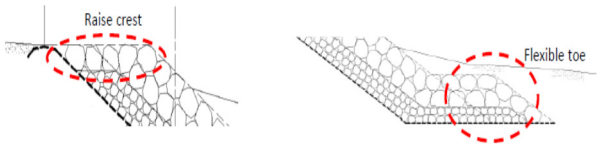

Figure 2: Proposed seawall design revisions

Upgrading of the wall future exposure levels and design conditions were developed along the coastline. It has been concluded that upgrading and completion of a continuous seawall will be required for the future security of Gold Coast beachfront assets. With the uncertainty regarding the rate and extent of changes to sea levels and design wave heights, a staged approach is practical.

Wall construction has evolved and Figure 3 shows a summary of seawall works up to date. The Certified Seawall Lengths to 2014 were [12]:

- Private
  - Certified; 4.5km
  - Uncertified; 4.4km
- Public
  - No Seawall Required (e.g. rocky headlands or non-urban areas); 5km
  - Certified; 1.9km
  - Uncertified; 17.5km (much of which is constructed but uncertified)

Since then a programme to increase the lengths of certified seawalls has been implemented.

With reduction in availability of good quality rock, the development of other wall types, including "sandbags", may become critical in the long-term.

4. NOURISHMENT

After considerable evaluation of practical methods and (heated) discussions regarding funding, the first nourishment on the Gold Coast beaches was undertaken in the 1970s using medium and large cutter suction dredgers pumping through pipes from the Nerang, Currumbin and Tweed estuaries. This was the first major beach nourishment in Australia and many problems were solved by the Council Engineers and hydrographic surveyors working on tight budgets and with only 25% State assistance. The sand was placed on the upper beach and out as far as practical into the surf zone. Placement in this area required beach users to be kept clear as it created hazardous quicksand conditions at the outlet, plunging shore-break waves and required heavy equipment on the beach. Also, the public and media were very quick to claim the expensive sand had been lost after the first storms cut into the nourished visible beach redistributing it over the active profile. This did not help in the funding of ongoing works to implement the Scheme of Works and funds were diverted to other infrastructure projects.

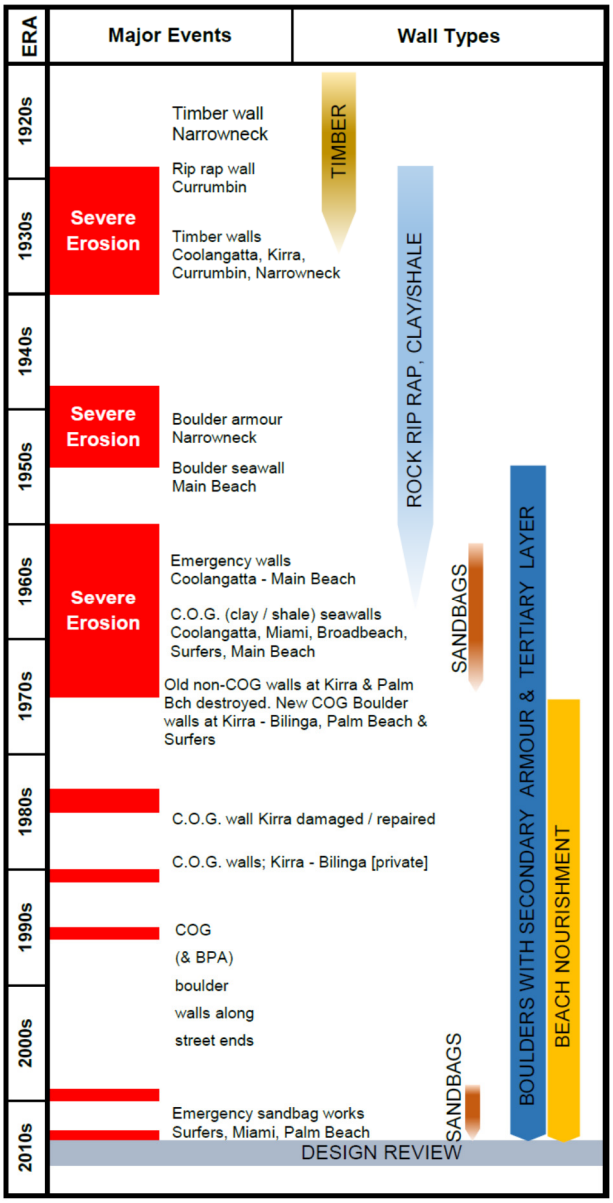

Figure 3: Timeline of seawall works

Studies and works for training of Tallebudgera and Currumbin Creek entrances did continue. In the 1980s, there was a renewed focus on erosion hotspots and the North Kirra erosion was addressed in 1985 when the first sand was pumped from offshore using large trailing suction hopper dredgers (TSHD). It had been intended to truck sand for the relatively small volume, 300,000m^3, but an option in

the tender for offshore dredging proved to be the most economical method.

Conventional practice worldwide was for sand to be pumped ashore or rainbowed. Both are expensive and to avoid costs and the perception of upper beach sand being "lost" it was decided to do a small trial with nearshore nourishment on the North Kirra Beach Restoration Project [5]. Although nearshore nourishment had not been used successfully anywhere else at the time, it was considered low risk if placed shoreward of about 9m water depth as storm bars as detailed surveys showed that the large natural storm bars moved onshore over a period of about 18 months. Surveys confirmed the shoreward movement and accretion of the visible beach inshore of the nourishment. Dyed sand samples were also used to track the sand movement. As a result of the success and significant cost savings, further large scale offshore dredging, deposited nearshore was carried out. This included commencement of the dredging of the Tweed River ebb tide delta in the late 1980s.

Sea level rise and methods to accommodate were first considered in the mid-1980's.

Nourishment in the 1990s was mainly annual maintenance dredging works from Currumbin and Tallebudgera estuaries pumping onto Palm Beach and Burleigh Beaches respectively with medium sized cutter suction dredgers. In 1999, 26 years after the original nourishment of these beaches, 1.1M m^3 of sand was pumped from the Nerang estuary onto the Northern Gold Coast beaches. The dredging widened the eroded beaches and created wider channels required by the increased boating activity resulting from the training and sand bypassing of the Nerang River entrance (a part of the Scheme of Works funded by the State). This nourishment was in conjunction with the Narrowneck reef construction to act as a control point to stabilise the nourishment. Construction of the reef was by a local split hull hopper dredge filling custom locally designed and fabricated mega-sandbags with sand dredged from offshore to fill [9]. This project recognised surfing as a key design criteria for coastal works on the Gold Coast and prompted research [6].

In the 2000s, as well as ongoing routine maintenance dredging of Currumbin and Tallebudgera Creeks, an additional 370,000m^3 of sand was dredged from offshore and placed nearshore at Palm Beach in about 6m water depth by a local shallow draft TSHD.

In the 2010s, as well as ongoing routine maintenance dredging of Currumbin and Tallebudgera Creeks, an additional 125,000m^3 of sand is being dredged from navigation channels in the Nerang estuary to a stockpile for trucking to the eroded Surfers Paradise Beaches.

As well as estuaries and offshore, excess clean sand from building sites must be placed on the dune area. Prior to 1985 this applied to buildings along the beachfront only and some 500,000m^3 of sand was placed on the dune area. In 1985 the policy was rewritten to include all excavations within 500m of the seawall line. This has provided about another 1.5Mm^3 to the dunal areas. This sand has helped create wide dunes over previously exposed boulder walls.

The offshore dredge areas along the whole developed coastal strip have been designated and preserved for beach nourishment only.

After the dredging of the channels for the Northern Gold Coast Beach Protection Strategy, a policy was adopted that dredging of sand from navigation channels in estuaries should be used for beach nourishment. This has secured another source of sand for nourishment only.

The nourishment methods have evolved and to date three deposition options have been used [8]:

- Onshore / Beach:
    - Truck from building sites and dredge stockpile on Spit
    - Cutter suction dredge from estuaries
    - TSHD pump ashore
- Nearshore
    - Small TSHD bottom dumping
    - Larger TSHD rainbowing
- Combination (profile nourishment)
    - Combination of plant and/or methods

All have different impacts, efficiencies and cost implications. About 22Mm^3 of sand nourishment has been dredged to date, not including the sand pumped by the fixed sand bypass systems that do not add any additional sand to the active beaches. Table 1 shows the details of the sand nourishment projects up to 2013 [7].

No major nourishment, other than the ongoing bypassing, has occurred since 2013 but a further 3Mm^3 of nourishment to onshore and nearshore from offshore reserves is proposed for 2017 [11]. Also, top-up of Narrowneck reef "control structure" is proposed for 2017.

Table 1 Sand to Gold Coast beaches by Source

Sand Source	Deposition	Equipment	Mm^3	
Building sites	Beach	Excavator	2.0	9%
Estuaries (& Nerang Seaway construction)	Beach	Cutter suction dredgers	11.2	51%
Offshore	Onshore, nearshore & beach	Trailing Suction Hopper dredgers	10.9	49%
TOTAL			**22.1**	100%

Key findings and lessons regarding nourishment [7] include:

- The Gold Coast beaches have been successfully improved and maintained by ongoing beach nourishment with about $22Mm^3$ to date.
- Alternate strategies and structures, not originally included in the Scheme of Works, to reduce costs and increase the long-term efficiency of nourishments, such as reefs, are being included.
- Considerable experience and expertise has been developed by the growth of the local dredging industry implementing beach nourishment on the Gold Coast. The dredging and deposition methodologies have expanded with experience. This has resulted in competitive dredging rates and allowed innovations in best practice to be developed.
- The practice of monitoring the behavior of the beaches and nourishments with accurate regular surveys, particularly after storms, has provided invaluable long term data and knowledge of the behavior of the beaches. This data has been used to determine the best methods of nourishment placement and to develop sand bypassing systems and alternate strategies such as reefs. The data has also been used to accurately calibrate and validate various numerical models.
- Dredging from offshore and nearshore deposition has proven to be an efficient method of beach nourishment.
- Adequate sand reserves in the coastal zone are vital to ongoing nourishment works and policies are needed to protect these resources for future nourishment and the long-term health of Gold Coast beaches, as there is competition for sand materials for usage for other purposes including land reclamation, land fill, habitat enhancement, landscaping, building materials and other purposes.
- The two sand bypassing systems have been very effective in maintaining the Gold Coast beaches

5. IENCE

The coastal management works on the Gold Coast have always been planned by understanding and working with the natural processes. As well as ongoing surveys of the beaches and seabed at fixed lines along the coast for over 50 years, small scale trials, monitoring and recording (notes, reports and publications) of the behaviour of all major projects have contributed to the local knowledge base and expertise in coastal management.

This pragmatic and low risk approach to a very complex system that does not always conform to theory has been dubbed IENCE (Infrastructure to Enhance the Natural Capacity of the Environment) [10].

There is now a huge volume of data published on the behaviour of the Gold Coast beaches

6. KNOWLEDGE HUB

A key objective of a retrospective look at coastal protection strategies is to learn from past successes and failures. Much of the information related to seawalls and beach nourishment is contained in published papers and technical reports. However, there is also less readily available information in the organisational internal documentation, anecdotal information and the recollection of professionals involved in past activities. The information presented in this paper falls within all of these categories. Acknowledging the importance of historical information, the Griffith Centre for Coastal Management on behalf of the City of Gold Coast commenced in 2013 a project to create a Coastal Knowledge Hub. The Hub has six objectives:

- To ensure that all relevant past literature relating to coastal processes and management on the Gold Coast is accessed and summarised;
- To provide a readily accessible database of accepted state of the knowledge on Gold Coast coastal processes; which can be easily updated for future information;
- To provide a record of justification, timing, scale, and effectiveness of past coastal management actions;
- Provide coastal process information on which to base future development proposals and applications;
- Identify the knowledge limitations in making future coastal management decisions;
- Identify areas of future monitoring, investigations, research required to address any knowledge limitations.

To date over 600 documents have been identified and included in the Hub. Of these, 90 deal with beach nourishment and 34 with the seawall.

Numerous others allude to both of these in terms of more general coastal management or site specific strategies [13].

7. Summary

50 years ago the Gold Coast was in a seemingly impossible technical and financial position with respect to the future of its beaches and tourism economy. However, innovative methods and policies have been evolved in steps and implemented in affordable stages to successfully manage the Gold Coast beaches using collaborative research with university researchers and IENCE principles.

The basic strategy of mass nourishment seaward of terminal seawalls to widen the beaches has proved very successful as has been demonstrated again recently in the large swells in June 2016 that caused widespread erosion along the east coast of Australia. In some other areas, 1967 type erosion was experienced with beachfront homes damaged and emergency walls constructed.

The City of Gold Coast is proactive in protecting its infrastructure associated with beaches based on the knowledge developed and experience gained over the last 50 years. Innovative technology such as the Narrowneck reef has proven successful with on-going top-up maintenance being considered by the City. This year the City also proposes to implement another 3Mm^3 of beach nourishment.

The Gold Coast approach to coastal protection in terms of world-first innovation; commitment to an effective strategy of terminal walls and nourishment, and the maintenance of knowledge provides a model not only for future Gold Coast works but also for other areas.

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