Scoping Study for Extraction of Offshore Sands for Beach Nourishment

Outcomes, Lessons Learnt and Ways Forward

Withycombe, G [1], Walker, J[2], Nielsen, L [2], Pinzone, T [2]and Morrison, C[1]

[1] Sydney Coastal Councils Group, Level 14, 456 Kent Street, Sydney NSW 2000
[2] AECOM Level 11, 44 Market Street, Sydney NSW 2000

Abstract
Sydney beach management and planning issues have arisen due to encroachment of infrastructure into the coastal buffer zone and consequently reducing the available supply of sand for the beach system to naturally respond to seasonal and storm based variability. During coastal storm events, shoreline erosion frequently threatens the stability of seawalls and promenade infrastructure (e.g. Manly Beach), seawalls and car park facilities (e.g. Cronulla) and housing (e.g. Narrabeen/Collaroy). Sea level rise will further threaten existing vulnerable infrastructure, and impact on infrastructure that was previously outside the coastal hazard zone. A migration of the shoreline landward may result in the permanent loss of beach amenity.

Coastline Management Studies undertaken by Local Government assess various options for management of coastal hazards. The approach commonly recommended to protect property from immediate storm damage and coastline recession in the medium-term, is sand nourishment campaigns. At present there are few if any feasible terrestrial sources of suitable sand that could adequately facilitate the endorsed management strategies along the NSW Coast. The only potential sand source identified for nourishment is offshore, contained in the 'Inner Sydney Shelf Sand Body' (Roy, 2001).

To address shoreline erosion in "at threat" sites to a point where decision makers can commit medium-term physical and financial resources, it is essential to understand the environmental, physical, economic and social impacts of using offshore marine sands for beach nourishment.

This project has examined information and data on the environmental, physical, social and economic aspects of utilising offshore marine sands to meet immediate and medium-term requirements of the adopted strategies for these beach environments. This study develops a strategic framework to implement such a formal proposal to Government(s). The study focuses in detail on the application to the proposed case study sites in Sydney and also provides generic consideration of sand applications in other areas of NSW.

Introduction

Along the Sydney foreshore, beach management and planning issues arise due to encroachment of infrastructure into the coastal buffer zone. The encroachments can reduce the available supply of sand for the beach system to respond naturally to seasonal and storm variability. During short episodic coastal storm events, shoreline erosion frequently threatens the stability of seawalls, promenade infrastructure, recreational facilities, car parks and housing (Figure 1).

Evidence of oceanic storm damage to assets and infrastructure along the Sydney foreshore is available in numerous historical photographs and newspaper reports. The most recent large storm events occurred in 1969, 1974 (~100 year storm) and 1978 and caused extensive damage along the NSW coastline. The sea-state since 1978, during the last 30 years, has been relatively benign.

Longer term loss of beach amenity is also evident along the Sydney foreshore. In some cases the loss is due to historical town planning permitting development to the waterline. In other instances loss of sand has occurred along a beach during a storm event and has not recovered to its former state. Sea level rise also threatens the local beach amenity. Sea level rise will generally result in a migration of the shoreline landward and will further threaten existing vulnerable infrastructure and impact on infrastructure that was previously outside the coastal hazard zone. A migration of the shoreline landward may result in the permanent loss of beach amenity.

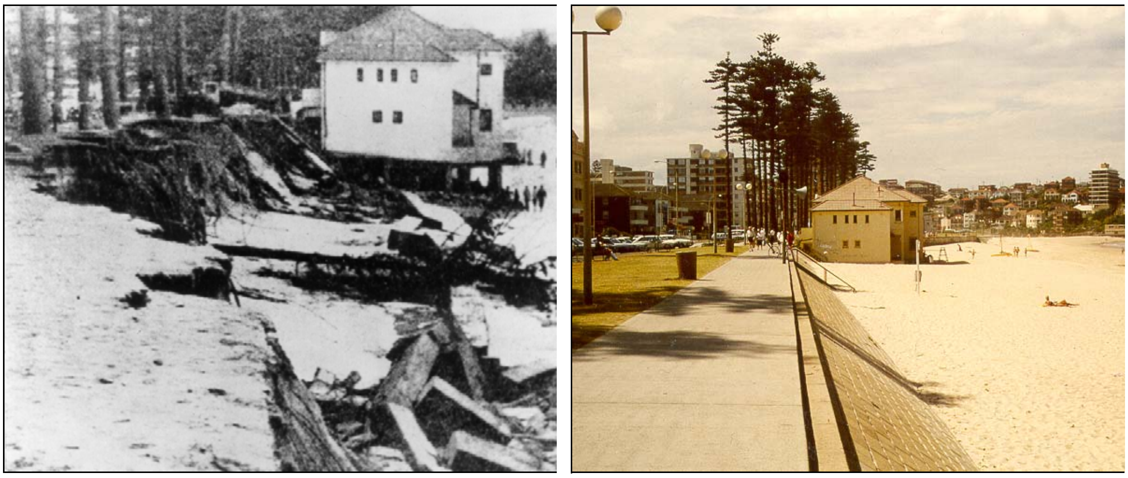

Figure 1 Manly Beach - North Steyne Surf Club (left image: 1950 storm erosion, right image: present day)

Community and business expectations pertaining to development in the coastal zone can be complex and, ultimately, is a balance between environmental, social and economic considerations. In some cases the protection of property has been achieved by the construction of seawalls. In other instances (Collaroy-Narrabeen Beach) the proposal to construct a seawall along the fore dune to protect private property has been met with strong community opposition. Concerns included the perceived loss of beach amenity due to construction of a seawall (including the environmental consequences) and the proposed funding model (i.e. who pays?).

Shoreline erosion and management issues are not unique to Sydney and the general consensus has long been held that beach nourishment is, in many cases, the best long-term strategy to manage them. If sufficient sand deposits are available for nourishment works, hazards associated with storm events and sea level rise can be alleviated.

The primary purpose of the scoping study was to develop the outline of a sand nourishment programme utilising suitable offshore sand deposits for amenity enhancement and to ameliorate increased hazard risk from sea level rise. A key environmental driver for the study is the predicted climate change sea level rise. The scoping study identified potential benefits and impacts of a nourishment program associated with physical, environmental, social and economic issues. It also drew comparisons with the “do nothing approach”.

While the study scoped a nourishment program for the whole of Sydney that is closely aligned to nourishment of all NSW beaches, it case studies three (3) Sydney beaches in more detail. The nominated beaches are Collaroy-Narrabeen, Manly and Bate Bay.

Project Background
For each of the three case study beaches, hazard definition studies have been completed. These studies identify the immediate and longer term hazard threats at each location. Assets valued at close to $1BN are estimated at threat in these three locations over a 100 year planning horizon.

Coastline Management Plans in the three case study sites have assessed various options for management of coastal hazards and concluded with a strategic approach for management of coastal erosion hazards. The approach recommended to protect property from immediate storm damage and coastline recession in the medium to long-term, is primarily the use of sand nourishment campaigns to provide a buffer to offset the immediate storm erosion demand and to restore/enhance degraded recreational beach amenities. There are no apparent feasible terrestrial sources of suitable sand that could adequately facilitate the endorsed management strategies. The only potential sand source identified for use as a long-term source of nourishment material is offshore contained in the 'Inner Sydney Shelf Sand Body' (Roy, 2001).

In early 2007 the Sydney Coastal Councils Group Inc (SCCG) in partnership with its Beach Management Working Group [1](Project Steering Committee) applied for funding support under the Natural Disaster Mitigation Programme to undertake this scoping study. In 2008 the SCCG signed a funding agreement with the NSW State Emergency Management Committee enabling the SCCG to engage a consultant to undertake a scoping study to look at the information and data currently available in relation to the environmental, physical, social and economic aspects of utilising available offshore sands to meet immediate and medium term requirements of the adopted strategies for these beach environments. AECOM was appointed in March 2009 to undertake the study. Detailed assessments of each component of the study can be found in AECOM (2009).

Study Aims

From a broad engineering and logistical perspective the study aimed to address:

1) The location and suitability of sand nourishment sources.
2) The methods of sand extraction and transport to site.
3) The methods of sand nourishment, including volumes and frequency.

Environmental and planning considerations include:

1) The potential environmental impacts of an offshore sand extraction process.
2) The potential environmental impacts of a near-shore sand nourishment campaign.
3) Future environmental studies required to develop an EIS.
4) The planning and approval process for a sand nourishment program.

Social values were addressed with respect to:

1) Who will be impacted by loss of beach amenity and assets?
2) How will they be impacted (culture, recreation, leisure etc)?
3) What is the intangible cost to the community?

The economic appraisal aimed to:

1) Evaluate the costs and benefits of a nourishment program based on engineering, environmental and social considerations.
2) Develop a business plan outline that may fund a nourishment campaign.

---

[1] SCCG Beach Management Working Group includes delegates from the SCCG Secretariat; member council professional staff, State agency technical staff, academia and peak coastal community groups.

Past and Present Climate Change Sea Level Rise Considerations
The volume of sand required on the beaches to maintain the existing amenity in response to climate change sea level rise is dependent on the magnitude of sea level rise and the economic assessment will depend upon the rate of sea level rise. In this study an upper bound estimate of sea level rise of 0.1m/10yrs has been adopted (based on IPCC and DECCW assessments). From a cost/benefit perspective and nourishment campaign frequency approach this is the most conservative assessment. Lower rates of sea level rise will provide a more favourable cost/benefit outcome.

Between 1870 and 2004 the mean global sea level has risen almost 0.2m (Church and White 2006). The approach for the first 10-year sand nourishment campaign would be to accommodate a past sea level rise of 0.2m and a future sea level rise of 0.1m. This would reinstate and maintain beach amenity and some storm protection buffer. Subsequent sand nourishment campaigns are scheduled at sea level rise increments of 0.1m (i.e. each 10 years). The entire campaign considers a 50 year planning period from a cost/benefit perspective, although sea level rise will extend beyond this planning period.

Offshore Sand Sources
There are numerous sand bodies offshore of Sydney that may be suitable for a nourishment campaign of Sydney's beaches. The majority of potential sand sources offshore of Sydney are subject to leases. Sand volumes and compatibility with the native beach sands were assessed.

There is currently a prohibition on offshore minerals extraction due to the effect of the *Offshore Minerals Act (1999*). It would require an amendment to Schedule 2 of the this Act, and the introduction of companion regulations to enable a mining licence to be issued over an area of sand within the 3Nm limit to enable sand to be recovered for beach nourishment purposes.

Beach Nourishment Volumes
For a typical Sydney beach with an equilibrium slope of 1:50 and a depth of closure (the limit of offshore sand transport) of 22m, the active beach width (L) is approximately 1,100m (Figure 2). Applying the Bruun Rule (Bruun 1962, 1983) and adopting a 0.3m sea level rise, $9Mm^3$ of native sand would be required to maintain the recreational amenity of all of Sydney's beaches. This is equivalent to an average native sand volume of $300m^3$/m length of beach. The nourishment sand volume of $300m^3$/m would be distributed over the full beach width of 1,100m (Figure 3).

Using a suitable offshore borrow sand source, $12Mm^3$ of borrow sand would be required. This is equivalent to an average borrow sand volume of $400m^3$/m length of beach. Subsequent nourishment campaigns (each 10 years) would require $3Mm^3$ of native sand or $4Mm^3$ of borrow sand. The extraction and delivery of $12Mm^3$ of sand is likely to extend over a duration of 12 to 18 months.

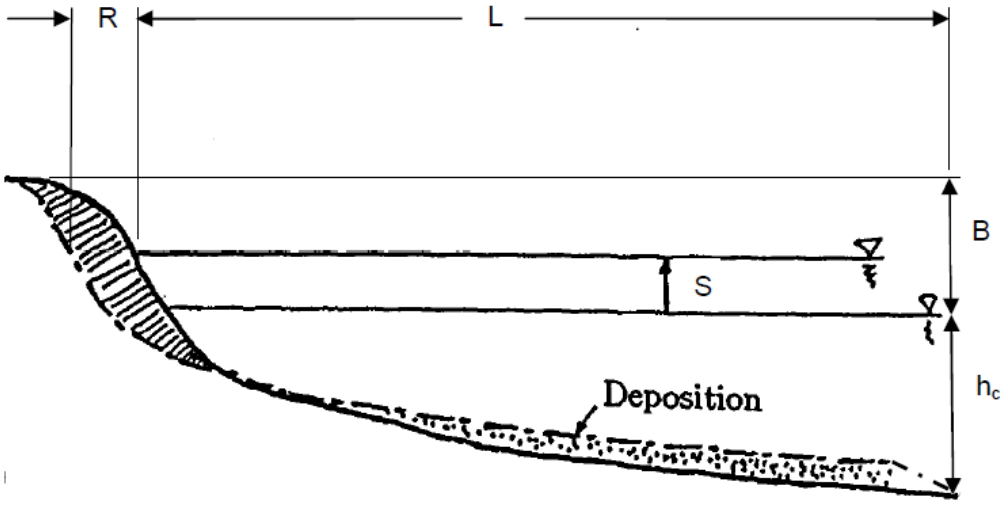

Figure 2 Bruun Rule concept

For a beach profile that is in equilibrium with the prevailing wave climate, the Bruun Rule equation is:

$$R = \frac{S}{(h_c + B)/L}$$

where:

R	= shoreline recession due to sea level rise (m)
S	= sea level rise (m)
h_c	= closure depth – the limit of offshore transport of littoral drift (m)
B	= beach berm height (m)
L	= length of the active zone – the distance to closure depth (m)

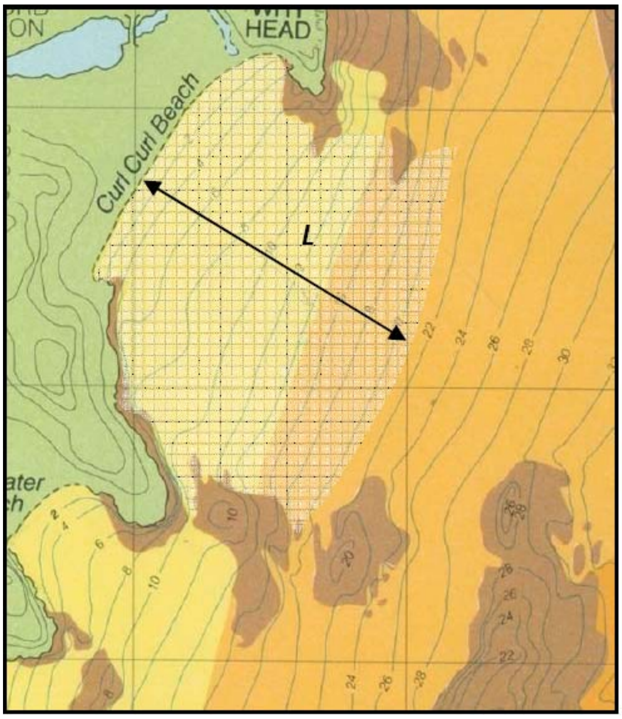

Figure 3 Typical extent of nourishment

Sand Extraction
Based on the high wave energy operating environment and the sand extraction water depth limitations of the dredging plant, the Trailing Suction Hopper Dredge (TSHD) is the most suitable dredging equipment for this project (Figure 4). Many sand extraction projects around the world utilise this equipment, particularly if the sand placement area is some distance away from the extraction area. The Trailing Suction Hopper Dredge skimming technique is considered more environmentally friendly than other techniques, such as a Cutter Suction Dredge, because plume generation is minimised.

Figure 4 Trailing Suction Hopper Dredge

A TSHD operates very much like a floating vacuum cleaner. It sails slowly (1-2 knots) over the area to be dredged filling its hopper as it proceeds. The accuracy of moving over a dredge area is enhanced by electronic displays in real time with information from an accurate Digital Global Positioning System (DGPS). On completion of loading the hopper, the TSHD sails to the disposal site with a sailing speed of 15-20 knots where the dredged material can be discharged either by opening the doors or valves in the hopper bottom, by using the dredging pump to deliver to a shore pipeline, or directly to shore by using a special bow jet.

Physical Constraints and Ecological Impacts
The physical and ecological impacts associated with extraction of sand offshore of Sydney have been investigated by Geomarine (1993) and The Ecology Lab (1993) for the Metromix Marine Aggregate Proposal (MMAP). Cardno Ecology Lab (2009) prepared a subsequent report for this study.

The coastal engineering criteria established for the design of the proposed extraction configurations, in conjunction with criteria from other specialised studies, led to the following generalised constraints to be addressed in any potential 'conditions of development consent":

- The near-shore depth limit for extraction off the rocky cliffed coast be the 25m isobath;
- The alongshore extent of extraction to the 25m isobath be beyond 1.5km of the end of a beach;
- The inshore limit of extraction directly off beaches be the 35m isobath;
- Extraction depth be limited to 5m below the natural surface;
- Allowance be made for initial batter slopes around the extraction configurations to develop to 1:20;

- Adequate buffers be left around shipwrecks and from reefs.

Within these constraints it was considered that it would be possible to undertake any extraction configuration within the proposed extraction areas without any measureable impact on the environment and amenity of shorelines.

For the MMAP the identified marine ecological impacts could be high for benthic biota, with rapid recovery of communities following extraction activities. While similar quantities of sand are estimated for extraction in this scoping study, a key difference from an operational and environmental perspective is that for the MMAP the extraction program was evenly spread over a 25 year period. For the sand nourishment campaign it is envisaged that activity would be high for a one to two year period interspersed by non-activity for the next 10 years. This may have environmental implications that were not addressed in the earlier marine ecological investigations and therefore further studies would be required.

Sand Placement

From an engineering, ecological and economic perspective, beach nourishment utilising offshore placement (profile nourishment) is the simplest, natural and most cost effective solution (Figure 5). Environmental impacts are likely to be kept to a minimum using this method with the volumes of nourishment sand placed offshore of the same order of magnitude as the storm demand (sand moved offshore) for a severe storm. An offshore nourishment program will not require closure of beach amenity and, therefore, social and business activities can continue without disruption.

Two options were considered feasible, both with similar cost structures. The preferred placement methods are:

Method 1

A Trailer Suction Hopper Dredge would be used to extract the sand from the designated offshore sand body and then sail under its own power to the nourishment site. The Trailer Suction Hopper Dredge has a large draft (>10m) and the sand would be transferred via pipeline to a spreader pontoon at the deposition site (-5m AHD to -10m AHD) and then placed on the seabed.

Method 2

The second method involves double handling of the extracted sand. A Trailer Suction Hopper Dredge would be used to extract the sand from the designated offshore sand body and then sail under its own power to offshore of the nourishment site. The sand would be discharged to the seabed in approximately 20m water depth (temporary storage site). A smaller Trailer Suction Hopper Dredge would load the sand from the temporary storage site and then sail close to the shoreline and place the sand within the nourishment zone (-5m AHD to -10m AHD).

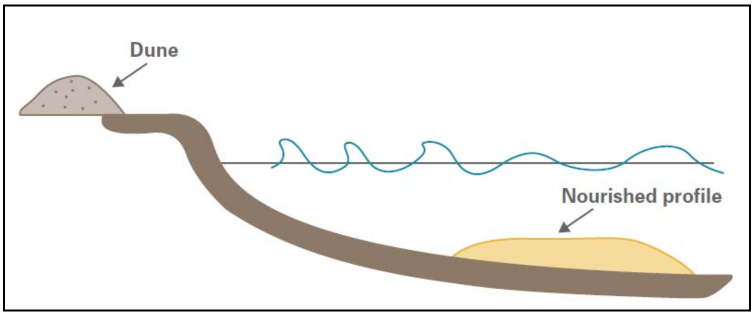

Figure 5 Offshore Sand Nourishment – Cronulla

Ecological Impacts
It is likely that the largest ecological effects of nourishment will occur in the near-shore environment where the spoil would be deposited. Given that intertidal species a) live within the sand, b) can probably survive some degree of burial and c) are adapted to sediment disturbance by waves, any nourishment effects on the intertidal biota are likely to be negligible if sand gradually accretes to the beach face via wave action.

Social
The social implications relating to beach amenity are immense. A social workshop held as a component of the study, identified loss of beach amenity as unacceptable. Loss of beach amenity will impact on numerous recreational and business activities. Some of the recreational activities include; surf lifesaving, surfing, fishing, beach volleyball, scuba diving, snorkelling, family gatherings and general relaxation. Environmental impacts associated with loss of inter-tidal zones and the flow on effects were also a major concern for community groups.

Social implications of a nourishment campaign are predominantly positive and beneficial for beach users. The social workshop identified concerns relating to beach closure or restricted access to beaches during a nourishment campaign and the potential short term changes to surfing breaks. Offshore profile nourishment will not require the closure of beaches. Extensive community consultation, education and workshops will help facilitate overall support of beach nourishment as a viable strategy to maintain and enhance beach amenity.

Nourishment Costs
Costs for the nourishment program have been estimated to facilitate the cost-benefit assessment of the project. Costs are based on an economy of scale approach. It is envisaged that all of Sydney's beaches will be nourished during the one period of time and then subsequently at trigger values of approximately every 10 years.

The first nourishment campaign is based on the extraction and placement of $12Mm^3$ of sand. Subsequent nourishment campaigns are based on the extraction and placement of $4Mm^3$ of sand.

The first nourishment campaign is estimated to cost \$300M at a unit rate of approximately $\$25/m^3$ of sand. In the first nourishment campaign, \$230M is directly related to engineering nourishment activities. The remaining \$70M is allocated to project management, environmental monitoring, community education and related investigations. The second and subsequent nourishment campaigns are estimated to cost \$120M at a unit rate of $\$30/m^3$ of sand.

Cost - Benefit
For each of the three case studies, a nourishment program is economically viable. The main economic benefits of the beach nourishment program to be valued are associated with the flow-on effects from loss of beach amenity to beach visitors, local residents and businesses and government revenues. In the case of Collaroy-Narrabeen this also includes the potential loss of property. A high-level benefit valuation has been undertaken using data from secondary sources on key parameters of expenditure on coastal goods and services and on indicators of other attributes of beach amenity where the market does not provide a satisfactory measure of economic value.

Case Study – Manly Beach
The cost-benefit analysis demonstrated that the proposed beach nourishment program is economically viable – it produced a net present value of $48 million, a benefit-cost ratio of 2.4 and an economic internal rate of return of 20%. The high economic rate of return for Manly Beach is because of its iconic status and importance to regional tourism. The value of the benefit-cost ratio indicates that, on the basis of the quantified benefits, the program is expected to provide high value for money.

The main quantified benefits are the avoided loss of:
- residential property values attributable to beach amenity (49% of total quantified benefits);
- expenditure by beach visitors (23%);
- rates revenue from businesses in the Manly Business District as a result of lower property values (13%); and
- non-traded value (consumer surplus) associated with beach visits (9%).

The sensitivity analysis confirmed the robustness of the economic results, with the program being economically viable in all sensitivity tests undertaken. Adopting the lower discount rate of 4% increases the benefit-cost ratio from 2.4 to 3.3.

Case Study – Collaroy-Narrabeen Beach
The cost-benefit analysis demonstrated that the proposed beach nourishment program is economically viable – it produced a net present value of $42 million, a benefit-cost ratio of 1.6 and an economic internal rate of return of 12%. The high economic rate of return for Collaroy-Narrabeen Beach is because of the intensely developed shoreline. The value of the benefit-cost ratio indicates that, on the basis of the quantified benefits, the program is expected to provide medium value for money.

The main quantified benefits are the avoided loss of:
- residential property values attributable to beach amenity (45% of total quantified benefits);
- value of residential properties located within hazard lines (38%);
- expenditure by beach visitors (8%); and
- rates revenue from residential property values within walking distance of the beach as a result of lower property values (4%).

The sensitivity analysis showed that the economic viability is reasonably robust. However, the program is not economically viable in the most extreme sensitivity test (where project benefits are reduced by 30% and project costs are increased by 30%).

Adopting a lower discount rate (4% instead of 7%), as is increasingly the overseas practice in economic appraisal of social and environmental projects with long-term benefits, increases the benefit-cost from 1.6 to 2.2.

The economic results are also sensitive to the shape of the relationship applying between beach width and the loss of economic value from the flow-on effects of reduced beach amenity – use of an exponential rather than linear relationship increases the benefit-cost ratio from 1.6 to 2.5.

Case Study – Bate Bay
The cost-benefit analysis demonstrated that the proposed beach nourishment program is economically viable – it produced a net present value of $13 million, a

benefit-cost ratio of 1.2 and an economic internal rate of return of 8%. However, the value of the benefit-cost ratio indicates that, on the basis of the quantified benefits, the program is expected to provide low value for money. The whole of Bate Bay may not require nourishment because a considerable extent of the shoreline contains a natural dune system. Therefore a smaller sand nourishment volume for Bate Bay will generate a higher economic return.

The main quantified benefits are the avoided loss of:

- residential property values attributable to beach amenity (73% of total quantified benefits);
- expenditure by beach visitors (13%);
- rates revenue from residential property values within walking distance of the beach as a result of lower property values (5%); and
- non-traded value (consumer surplus) associated with beach visits (5%).

The sensitivity analysis showed that the economic viability is not robust, with the program not being viable in most of the sensitivity tests. However, adopting the lower discount rate of 4% increases the benefit-cost from 1.2 to 1.6.

The economic results are also sensitive to the shape of the relationship applying between beach width and the loss of economic value from the flow-on effects of reduced beach amenity – use of an exponential rather than linear relationship increases the benefit-cost ratio from 1.2 to 1.8.

Financing Mechanisms

Funding mechanisms for a nourishment campaign will require commitment from local, state and federal government agencies, including support from communities, businesses and affected property owners. Extensive consultation will be required to develop a funding model. There are numerous funding models for sand nourishment campaigns in overseas countries.

The financing of beach nourishment programs is most advanced in the USA, where the primary source of funding is the Federal Government. Within the USA for a region to secure funding from a Federal body they must be able to provide capital generally equal to half the value of the studies and construction that needs to be undertaken. This is sometimes achieved by:

Transient Occupancy Tax/Hotel Tax

This is a tax that is levied on visitors to the area, where they are charged a tax on their accommodation when they are staying in the area which benefits from the beach nourishment program.

Real Estate Transfer Tax

This is a tax that is levied on properties when they are bought and sold – properties can be residential and/or commercial. This tax has in the past been very unpopular with the residents of regions that propose to, or do introduce real estate transfer taxes.

Taxation of Sports Goods

Revenue from taxation on the sale of sports goods has been used to pay for the cost of a beach nourishment programme in Texas.

User Fees

User fees are a way in which those who use the beach pay for the benefits of the nourishment project, this can include paid parking or beach use fees. In some cases these are only levied on visitors, not residents.

Approvals Process

On the basis of this study, the extraction of marine aggregate for purposes of beach nourishment from NSW statutory waters requires satisfaction of two principal NSW Acts:

- *Offshore Minerals Act 1999 (OM Act)*
- *Environmental Planning and Assessment Act 1979 (EP&A Act).*

There are other Commonwealth and NSW Acts and regulations that must be addressed in order to gain approval, such as *Protection of the Environment Operations Act 1997*, *Threatened Species Conservation Act 1995*, *Fisheries Management Act 1994*. These and other relevant Acts are discussed in AECOM (2009).

Business Case Outline

The NSW Gateway System is a process applied by NSW Treasury to examine a project at critical stages of its lifecycle. There are six defined gates at which reviews are undertaken. The first gate is the Strategic Gateway Review, which requires the presentation of a preliminary business case to:

- support the strategic assessment of the need for the proposed intervention and its priority and timing;
- identify any realistic options for the intervention;
- outline the high-level costs and benefits, risks and sustainability issues relevant to each option;
- identify any relevant technical standards or legislative requirements associated with the proposal and the options; and
- outline the governance arrangements (key elements, milestones and risks) planned to take the intervention proposal through to the next stage of the Gateway System, the final business case.

The Strategic Gateway Review will be prepared following finalisation of the scoping study report.

Conclusions

The environmental, economic and social evaluations of the nourishment campaign demonstrate substantial positive benefits. Some potential adverse ecological impacts may be caused by the nourishment program with the smothering of aqueous benthic communities. These are likely to be less severe than the ecological impacts associated with a “do nothing” approach and the subsequent loss of the inter-tidal beach, resulting in the total loss of the beach ecosystem. Environmental monitoring programs would need to be developed to measure and, if required, respond to ecological impacts.

The NSW Government have adopted a position prohibiting the commercial extraction of offshore marine sands. It is the intent of the SCCG that this study will provide a rational basis to inform both the member councils and NSW Government of the pros and cons of utilising offshore marine sand sources to facilitate immediate and longer term demands for nourishment purposes in the Greater Metropolitan Region.

As a result of the positive cost-benefit assessment and the favourable environmental and social outcomes, the preparation of the Strategic Gateway Review will be the first gate in the preparation of a business case to NSW Treasury to seek funding to progress the program.

References

AECOM (2009). Scoping Study – Maintaining Sydney's Beach Amenity against Climate Change Sea Level Rise by Sand Nourishment. Draft

Bruun, P. 1962. Sea-level rise as a cause of shore erosion. *Journal of the Waterways and Harbors Division,* 88, 117-130.

Bruun, P., 1983. Review of conditions for use of the Bruun Rule of erosion. Coastal Engineering 7, 77– 89.

Cardno Ecology Lab (2009) Extraction of offshore sand reserves – potential environmental impacts. Report prepared for AECOM.

Church, JA, White, NJ 2006, 'A 20th century acceleration in global sea-Level rise', Geophysical Research Letters, Vol 33.

The Ecology Lab (1993). Marine Aggregate Proposal: Marine Ecological Investigations Volume 1. Report prepared for Metromix Pty Ltd. 356 pp.

Geomarine (1993). *Marine Aggregate Proposal* – Coastal Processes. Report prepared for Metromix Pty Ltd.

Roy (2001). Sand Deposits of the NSW Inner Continental Shelf. Report prepared for Sydney Coastal Councils Group.