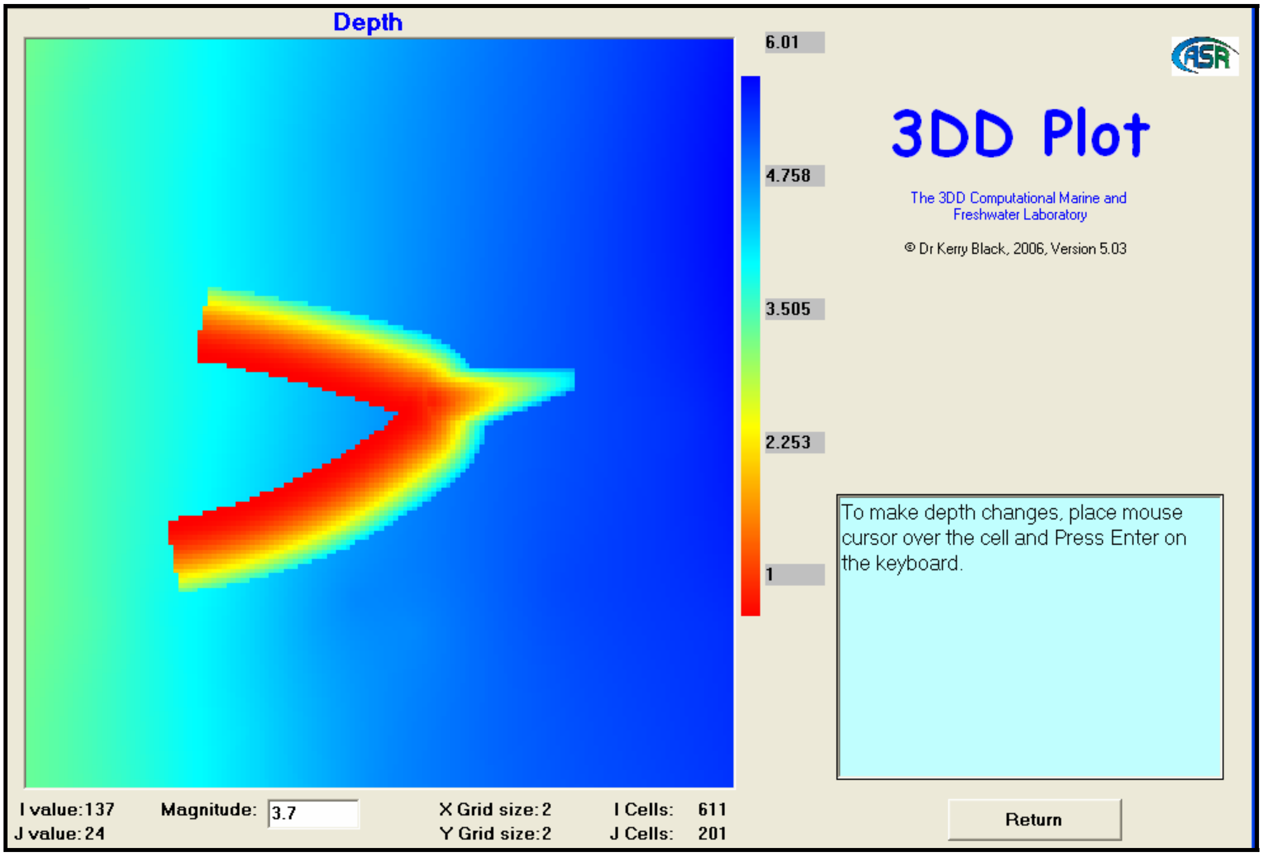
Conceptual Design Structure of a Multi-Purpose Artificial Surfing Reef for Brevard County using Geotextile Sand Filled Containers

A report prepared for the Feasibility Study of
Multi-Purpose Artificial Surf Reefs along Brevard
County, Florida



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1 Introduction

This report presents a conceptual design structure of a Multi-Purpose Artificial Surfing Reef (MPASR) for Brevard County, Florida. This reef will be constructed using geotextile sand filled containers. The design, materials, construction methodology, and a rough order estimate of construction costs are also presented.

2 Conceptual Design of Brevard County MPASR

The conceptual design calls for an asymmetric reef with a well defined focus and right and left breaking arms. The focus will concentrate the wave energy at the center of the reef and create a peak or "take-off zone". The reef crest height was set at 1.0 meters below mean sea level (MSL) to take full advantage of the energy dissipation caused by breaking the waves and to maximize the surfing opportunities during small wave conditions. The crest width (measured shore normal) of the MPASR is approximately 100 meters. The reef gradient is variable to maximize the wave breaking characteristics over the full range of expected wave heights (Mead, 2003). The total reef volume is 23,000 m^3.

The Brevard County MPASR has been oriented 10 degrees to the north and the southern (left-hand) arm is longer than the northern arm to account for the predominant wave climate. This orientation will improve the coastal protection properties of the reef via wave rotation (the re-direction of waves to reduce longshore currents - Black and Mead, 2001) and wave dissipation.

The effective longshore length of the reef is 96 meters and the cross-shore width is 166 meters. The reef has been positioned 300 meters offshore from MSL to enhance salient formation (B/S = 0.32), (Black and Andrews, 2001a-b), (Black, 2003), (Black and Mead, 2007). The basic reef configuration is shown in Figures 2.1 and 2.2.

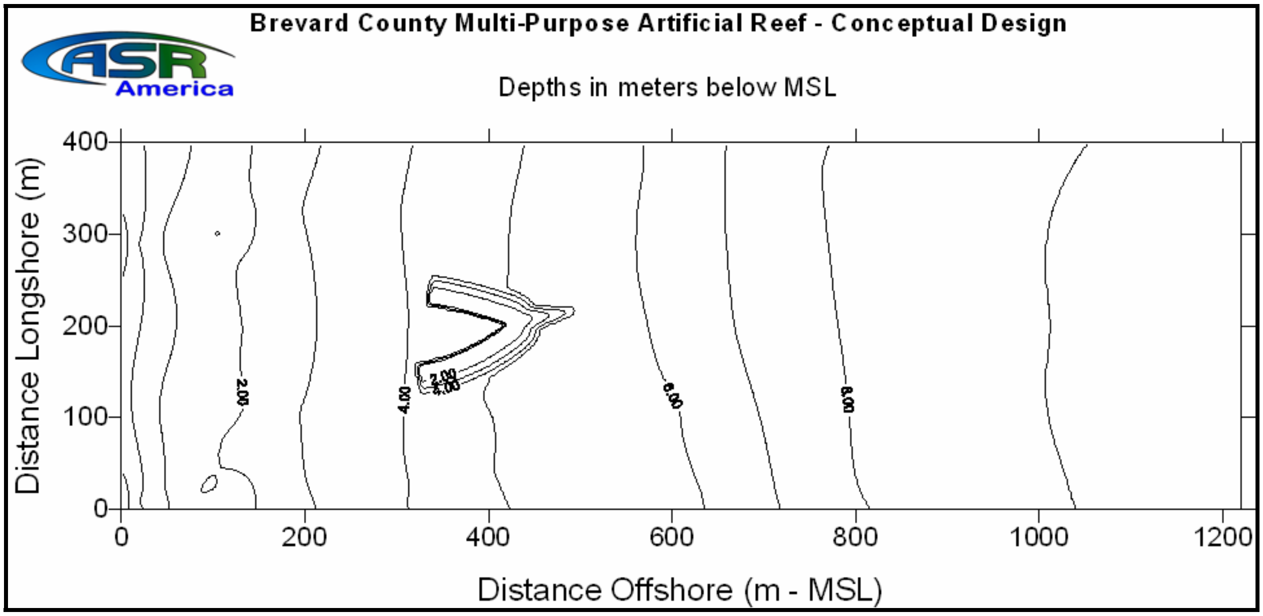


Figure 2.1 Brevard County Conceptual Reef Design with Typical Bathymetry

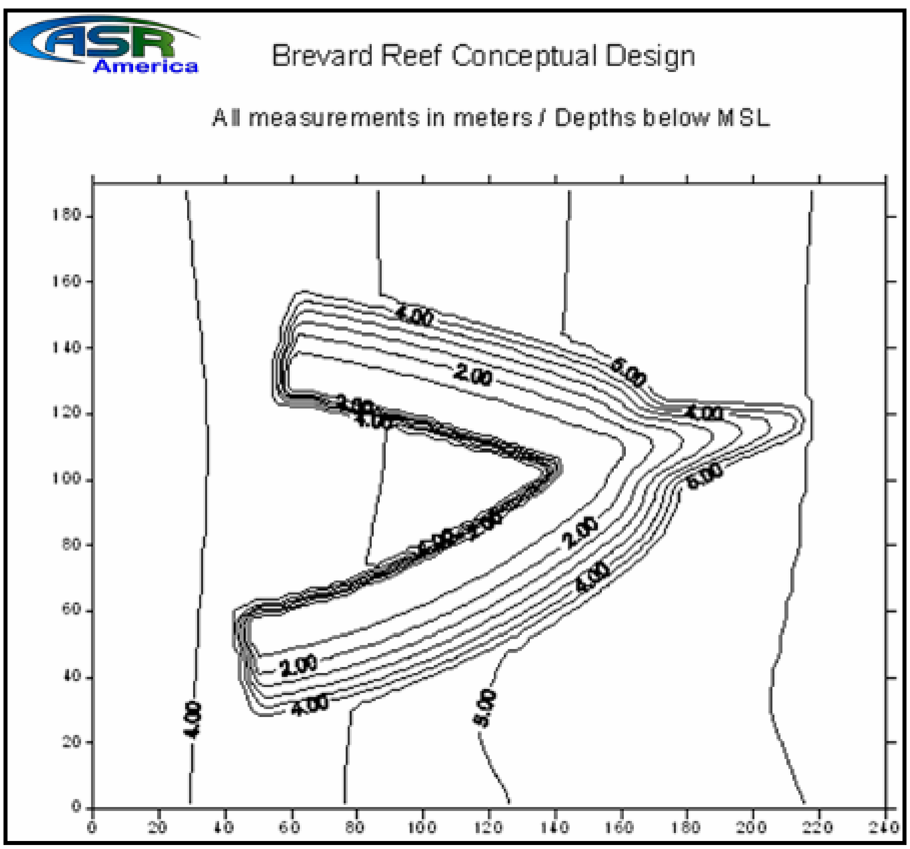


Figure 2.2 Brevard County Conceptual Reef Design

3 Reef Construction Materials and Methodology

3.1 Geotextile Sand Filled Containers

Multi-purpose reefs are a relatively new and innovative form of coastal structure with specifications over and above those of most marine construction. Such reefs must fulfill a large number of requirements that are standard to all coastal structures such as:

- DURABILITY
- ENVIRONMENTAL IMPACT
- STABILITY
- ECONOMIC FEASIBILITY
- WORKABILITY OF THE CONSTRUCTION METHOD
- MAINTENANCE

In addition, two further unique specifications are required to ensure the designed wave transformations occur for coastal protection (e.g. rotation of wave crests), and especially if surfing amenity is to be incorporated into the structure, as in the present case:

ACCURACY: - The reef profile must be constructed to achieve high tolerances and be free from large steps and irregularities to maximize the functional performance of the reef.

SAFETY: - The exposed surface of the reef must be soft to minimize the injury risk to surfers using the reef.

To achieve the requirements outlined above, geotextile sand filled containers (SFC) are considered the best material. Geotextiles are a family of synthetic materials including polyester and polypropylene that are formed into flexible, permeable, and durable sheet fabrics resistant to tension and tear. Large containers are pre-fabricated and then filled with sand to form the reef structure. Softrock™ 1200R and 1209RP have been successfully used for the construction of multi-purpose artificial reefs in Australia and New Zealand. The geotextile bags vary in size from 50m x 7.2m x 3.2m (filled) to 15m x 1.5m x 1.0m (filled). When filled with sand these bags weigh between 100 – 300 tons and are very stable in any wave climate.

Softrock™ 1200R is a non-woven geotextile fabric manufactured as sheets of directionally or randomly orientated fibers or filaments, thermally bonded or mechanically needle punched. The fabric has good resistance to the abrasion and mechanical damage likely to be imposed on it during deployment. An accelerated abrasion laboratory test was undertaken in 2003 using a variety of geotextile materials; both woven and non-woven materials were tested.

The test ran for 80,000 revolutions using sharp angular crushed basalt rock as the abrasion material. The results showed that there was a large variation in the performance of different geotextiles, with some types failing completely within the test period, while others showed minimal strength loss. Softrock™ 1200R and the related Softrock™ 1209RP were the best performing materials, with very little loss of strength and no reduction in mass

Furthermore, once in position on the seabed there is a tendency for a hard, dense layer of sand to build up around the fibers protruding from the surface of the material. As well as allowing the build up of the layer of sand, the protruding fibers also provide an excellent foothold for marine life. It is common for the material to become overgrown with marine life in a very short time after being installed in the coastal environment. Non-woven geotextiles have a very high capacity for elongation. This allows the material to distribute and dissipate induced local stresses without failure and is a very useful property in a highly mobile marine environment.

Based on over a decade of experience with respect to the application of geotextiles in the marine environment, it is recommended that the Brevard County MPASR be built using geotextile sand filled containers manufactured from Softrock™ non-woven material.

Figure 3.1 Softrock™ 1200R Non-Woven Geotextile

3.2 MPASR Construction Methodology

The unique requirements of MPASR necessitate an innovative approach to reef construction. In order to incorporate amenities such as surfing, the tolerances of the reef have to be small. Large humps and hollows in the reef will deform the wave face and greatly reduce the quality of the waves. Therefore a construction method is required that minimizes costs, while ensuring accurate reproduction of the structure. To address these construction issues, ASR Limited (New Zealand) developed and patented the R.A.D. (Rapid Accurate Deployment) method for submerged reef construction. This method was successfully employed in the construction of the Mount Maunganui MPASR and is presently being used for the Opunake and Boscombe reefs. ASR America recommends that the R.A.D. method be used to construct the Brevard County MPASR.

3.3 Rapid Accurate Deployment Method

The RAD method consists of the following primary components (Mead et al., 2007):

1. A geotextile bag layout is developed which replicates the design configuration of the reef.

2. Underlying webbing made from customized materials is assembled to form the framework for the reef bags. This webbing is staked out on shore at a site convenient to the reef construction location. A geomat is attached to the bottom of the webbing to prevent bag settlement into the seabed.

3. The empty geotextile bags are secured to the webbing. The webbing/bag assembly is folded up and placed onto a barge using a crane.

4. Prior to bag deployment, anchors are positioned on the seabed at precise locations using RTK GPS survey techniques.

5. The webbing/bag assembly is transported to the reef site via the barge during a calm weather window.

6. Leader lines from the webbing are fed through the seabed anchors and the entire assembly is winched to the seabed.

7. The geotextile bags are filled with sand in place using a barge mounted submersible pump which extracts sand from a seabed source close to the reef site.

Details of the Mount Maunganui Reef construction process using the R.A.D. method are shown in Figures 3.2 through 3.5 – these figures start with the computer design of the Mount Reef and demonstrate how physical modeling was then used to amalgamate the constraints of construction to develop the structural design using geo-container units.

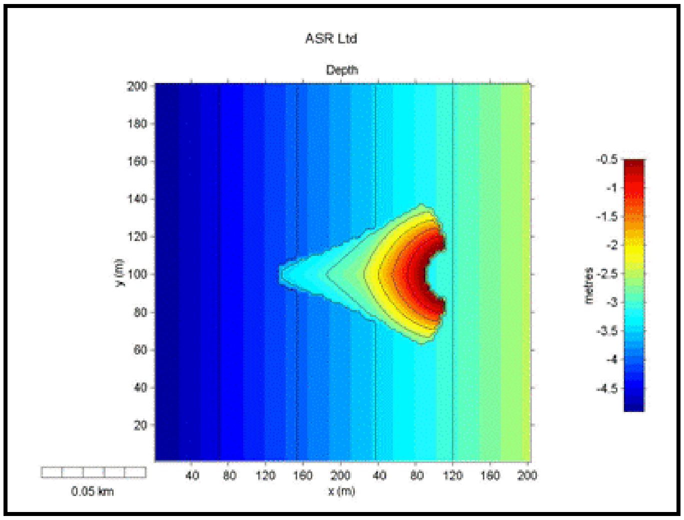
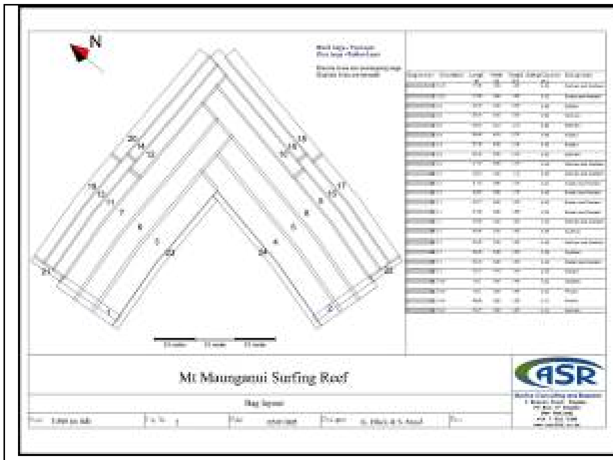


Figure 3.2 Mount Reef Computer Design
(Mead et al., 2007)

Figure 3.3 Mount Reef Geotextile Bag Layout - 3D View
(Mead et al., 2007)

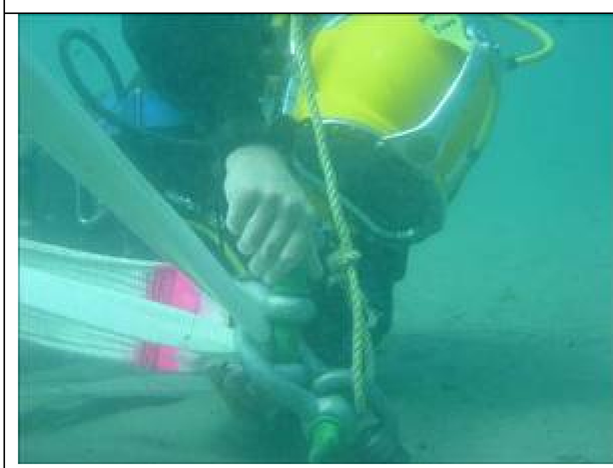


Mount Reef Bag Layout Design

Webbing and Bag Assembly

Reef Section Loading onto Barge

Reef Section Deployment



Reef Section Securing to Seabed

Reef Section Filling

Figure 3.4 Mount Reef Construction Photos (ASR Ltd)

Figure 3.5 Mount Reef Construction Complete (June 2008)

3.4 Foundation Structure and Scour Prevention

A foundation constructed of a layer of high-strength structural geotextile fabric should be placed on the seabed over the entire reef footprint. This layer of base reinforcement will act to span localized settlements and zones of weak foundation, by spreading the weight more evenly over the seafloor. Using a structural geotextile as basal reinforcement is a commonly used technique and has the added benefits that it will help to improve the overall stability of the structure by resisting lateral spreading of the reef units, will improve the bearing capacity of the foundation soil and decrease the risk of rotational slip failures. The geomat is fixed to the webbing below the SFC's prior to deployment using the R.A.D. method.

3.5 Geotextile Sand Filled Container Stability

Physical modeling tests of geotextile container stability under a range of wave conditions were undertaken at the University of Sydney in 1998. Tests were performed on SFC's equivalent to the Softrock™ 1200R containers described previously (120-300 Tons). These tests showed that sand-filled bags stacked upon each other would remain in position even after a prolonged period of extreme high sea conditions (Couriel *et al*., 1998). Part of the reason for the good stability of sand-filled geotextile containers can be attributed to the bags allowing water to move through them and the use of marine sands to fill them. Concrete and some types of rock, which have air trapped within their mass, experience a dramatic weight loss once they are placed underwater due to the effects of buoyancy (concrete weighs approximately half it's land weight underwater). Water will enter the permeable geotextile bags and fill any voids within the sand thereby preventing any buoyancy caused by entrapped air. The stability of the units under wave action is also ensured due to the large weight of each individual container and the friction between adjacent units. The stability of SFC's was confirmed on the Gold Coast in April 2001, when a 1 in 50 year wave event hit the coast (cyclone Sose). Comparison of bathymetric surveys of the Narrowneck Reef 1 week before and 1 week after the event failed to identify any structural changes. In March 2004, another extreme wave event, with waves peaking at 14 m high, occurred on the Gold Coast without damaging the Narrowneck Reef.

3.6 Estimated Design Life of a Geotextile Reef

The design life of the geotextile containers manufactured from Softrock™ is 25 years. However, in situations where the materials are protected from UV light (i.e. when underwater) the design life is estimated to be more than 40 years. The thick growth of marine life which covers the reef bags immediately after deployment may significantly extend the life of the reef. The extra layer of marine growth will help protect the reef from ultraviolet radiation and damage from debris impact. Small tears or punctures in the geotextile containers may be repaired by a dive team using patches and attaching hardware specifically designed for the purpose.

3.7 Sand Sources

There are a variety of sand sources available for the construction of the Brevard County MPASR. It is recommended that the sand be delivered and placed on the seabed adjacent to the reef site prior to reef construction. This sand placement could be coordinated with any future beach nourishment operations that Brevard County may undertake as part of their Federal Shore Protection project.

4 Construction Cost Estimate

Actual design and construction costs cannot be accurately determined until a detailed design study has been performed. The intent of this conceptual design and rough order cost estimate is to provide Brevard County with a broad overview of the project scope and order of magnitude costs which they may use as a basis for comparison.

4.1 Previous Multi-Purpose Artificial Reef Construction Costs

4.1.1 Mount Maunganui Reef

The 6500 cubic meter Mount Maunganui Reef (New Zealand) was constructed using the R.A.D. method for an approximate total cost of US$1.1 million in 2005 -2008. The reef cost per unit volume was US$170/$m^3$.

4.1.2 Opunake Reef

The 4800 cubic meter Opunake Reef (New Zealand) constructed using the R.A.D. method, is approximately 70% complete. The estimated total cost of the reef is US$1.0 million for a cost per unit volume of US$208/$m^3$.

4.1.3 Boscombe Reef

The 13,000 cubic meter Boscombe Reef (England) is presently under construction using the R.A.D. method. The estimated total cost of the reef is US$4.4 million, a cost per unit volume of US$338/$m^3$.

4.2 Rough Order Cost Estimate for Brevard County

Actual design and construction costs cannot be accurately determined until a detailed design study has been performed. The intent of this conceptual design and rough order cost estimate is to provide Brevard County with a broad overview of the project scope and order of magnitude costs which they may use as a basis for comparison.

The rough order cost estimate for the 23,000 cubic meter Brevard County conceptual design outlined in this report is $5.0 – $6.3 million. The cost per unit volume is estimated at US$217-274/$m^3$ which is comparable to the costs for recent MPASR projects at Mount Maunganui, Opunake, and Boscombe. A partial breakdown of the costs is outlined in Table 4.1.

Table 4.1 Rough Order Cost Estimate for Brevard County Conceptual Design

Item	Description	Estimated Cost ($US Million)
Site set-up, mobilization, demobilization, project management	Equipment shipping and storage, site office, site security, vehicles, travel, accommodation, insurance, project management, construction management	1.0 -1.4
Geotextile bags	23,000 cubic meters	1.8 – 2.2
Bag deployment and sand Pumping	RAD method deployment, pumping 23,000 cubic meters of sand, divers, boat and barge fees (note, the cost of sand has not been included)	2.2 – 2.7
Total		5.0 – 6.3

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