CALIFORNIA COASTAL COMMISSION
SOUTH CENTRAL COAST DISTRICT OFFICE
89 SOUTH CALIFORNIA STREET, SUITE 200
VENTURA, CALIFORNIA 93001-2801
(805) 585-1800 FAX (805) 641-1732
WWW.COASTAL.CA.GOV

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Prepared November 02, 2017 (for the November 09, 2017 Hearing)

To: Commissioners and Interested Parties
From: Steve Hudson, South Central Coast District Deputy Director
Subject: **South Central Coast District Deputy Director's Report for November 2017**

The following coastal development permit (CDP) waivers, immaterial CDP amendments, CDP extensions, and emergency CDPs for the South Central Coast District Office are being reported to the Commission on November 09, 2017. Pursuant to the Commission's procedures, each item has been appropriately noticed as required, and each item is also available for review at the Commission's South Central Coast District Office in Ventura. Staff is asking for the Commission's concurrence on the items in the South Central Coast District Deputy Director's report, and will report any objections received and any other relevant information on these items to the Commission when it considers the report on November 9th.

With respect to the November 9th hearing, interested persons may sign up to address the Commission on items contained in this report prior to the Commission's consideration of this report. The Commission can overturn staff's noticed determinations for some categories of items subject to certain criteria in each case (see individual notices for specific requirements).

Items being reported on November 09, 2017 (see attached)

Waivers

- 4-17-0348-W, City of Oxnard (Oxnard)

Immaterial Extensions

- 4-04-121-E11, Miran Enterprises (Calabasas)
- 4-08-080-E7, Horsted Extension (Topanga)
- 4-15-0390-E1, Broad Beach (Malibu)

- **Received an objection letter on extension 4-15-0390-E1**

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VENTURA, CA 93001
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NOTICE OF COASTAL DEVELOPMENT PERMIT WAIVER-DE-MINIMUS

DATE: October 27, 2017

TO: All Interested Parties

SUBJECT: Waiver of Coastal Development Permit Requirement
Waiver No.: 4-17-0348-W

Based on project plans and information submitted by the applicant regarding the development described below, the Executive Director of the Coastal Commission hereby waives the requirement for a Coastal Development Permit, pursuant to Title 14, Section 13238 of the California Code of Regulations.

Applicant: City of Oxnard

Location: Approximately 370 linear feet of seawall and pilasters along West Hemlock Street and 270 linear feet of pilasters throughout the Mandalay Bay Residential Community, Channel Islands Harbor, Oxnard (Ventura County)

Description: Repair of the pilasters along West Hemlock Street and throughout the Mandalay Bay Residential Community will consist of removing approximately 2" of the existing deteriorated concrete surface of each pilaster, applying a corrosion resistant epoxy over any exposed reinforcing bars and securing a new 6.5" concrete pilaster jacket over the roughened surface using a marine concrete mix. The West Hemlock Street seawall repairs will consist of removing approximately 1" of the existing deteriorated concrete surface over the entire length of the seawall repairs and securing a fiber reinforced polymer (FRP) panel over the exposed surface using a marine concrete mix. New weep holes will also be installed along the seawall to relieve hydrostatic pressure. In addition, the project includes the implementation of proposed Best Management Practices (BMPs) consisting of the use of a containment boom, silt curtain, and plastic tarps covering work platforms at each work station will catch debris. Any leaks or spills of epoxy or marine concrete mix will be immediately cleaned up.

Rationale: The proposed project is relatively minor in nature. The project involves the repair of an existing seawall and pilasters within the inland waterways in Mandalay Bay, a residential marina community constructed in the 1970s. The seawall and pilasters currently exhibit corrosion spalling and in some cases overstress cracking due to overloading and are at risk of premature failure if not repaired. The proposed repairs will provide additional strength, durability and corrosion protection. All repairs will be occurring on the face of existing seawall panels and pilasters above low tides and in dry conditions; however project activities may require removal and replacement of dock guide piles to access portions of the seawall or temporary shoring of pilasters during repair activities. Marine surveys concluded that project area does not include any eelgrass beds or *Caulerpa taxifolia* nor does it support any high value marine habitat for fish and invertebrates. In addition, the proposed work will implement best management practices including the use of a containment boom, silt curtain, and plastic tarps covering work platforms, at each work station to catch debris, and to protect water quality and coastal resources. As proposed, the project will not result in any significant adverse impacts to coastal resources, public access, or visual resources. Therefore, the proposed project is consistent with all applicable Chapter Three policies of the Coastal Act.

IMPORTANT: This waiver is not valid unless the project site has been posted and until the waiver has been reported to the Coastal Commission. This waiver is proposed to be reported to the Commission on November 9, 2017 in Bodega Bay. If three or more Commissioners object to this waiver, a coastal permit will be required. Persons having questions or wishing to object to the issuance of a coastal permit waiver for this project should contact the Commission office at the above address or phone number prior to the Commission meeting date.

Sincerely,

JOHN AINSWORTH
Executive Director

By: Wesley Horn
Coastal Program Analyst

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NOTICE OF EXTENSION REQUEST
FOR COASTAL DEVELOPMENT PERMIT

October 30, 2017

Notice is hereby given that Miran Enterprises, LLC has applied for a one year extension of 4-04-121 granted by the California Coastal Commission on October 13, 2005

for: Construction of a two story, 34 ft. high 4,452 sq. ft. single-family residence with attached 595 sq. ft. garage, septic system, retaining walls, paved driveway, access stairway, and 3,713 cu. yds. of grading (3,650 cu. yds. cut; 63 cu. yds. fill; 3,587 cu. yds. export). The application also includes after-the-fact approval of the subject parcel that was created pursuant to Certificate of Compliance #88-0083 and restoration of an unpermitted dirt road back to natural conditions.

at: 1510 Las Virgenes Road, Calabasas (Los Angeles County).

Pursuant to Section 13169 of the Commission Regulations, the Executive Director has determined that there are no changed circumstances affecting the proposed development's consistency with the Coastal Act. The Commission Regulations state that "if no objection is received at the Commission office within ten (10) working days of publishing notice, this determination of consistency shall be conclusive... and the Executive Director shall issue the extension." If an objection is received, the extension application shall be reported to the Commission for possible hearing.

Persons wishing to object or having questions concerning this extension application should contact the district office of the Commission at the above address or phone number.

Sincerely,

John Ainsworth
Executive Director

Julie Reveles
Staff Services Analyst

cc: Commissioners/File

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NOTICE OF EXTENSION REQUEST FOR COASTAL DEVELOPMENT PERMIT

October 30, 2017

Notice is hereby given that Eric Horsted has applied for a one year extension of 4-08-080 granted by the California Coastal Commission on September 9, 2009

for: Construction of a two-story, 35 ft. high, 5,788 sq. ft. single family residence with 680 sq. ft. attached garage, 123 sq. ft. balcony, swimming pool, septic system, driveway, retaining walls, 1,070 cu. yds. grading (680 cu. yds. cut, 390 cu. yds. fill), and request for after-the-fact approval for creation of the subject lot that is the proposed project site.

at: 2118 Rock View Terrace, Topanga (Los Angeles County) (APN(s): 4448021028)

Pursuant to Section 13169 of the Commission Regulations, the Executive Director has determined that there are no changed circumstances affecting the proposed development's consistency with the Coastal Act. The Commission Regulations state that "if no objection is received at the Commission office within ten (10) working days of publishing notice, this determination of consistency shall be conclusive... and the Executive Director shall issue the extension." If an objection is received, the extension application shall be reported to the Commission for possible hearing.

Persons wishing to object or having questions concerning this extension application should contact the district office of the Commission at the above address or phone number.

Sincerely,

John Ainsworth
Executive Director

Julie Reveles
Staff Services Analyst

cc: Commissioners/File

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NOTICE OF EXTENSION REQUEST FOR COASTAL DEVELOPMENT PERMIT

October 27, 2017

Notice is hereby given that Broad Beach Geologic Hazard Abatement District has applied for a one year extension of 4-15-0390 granted by the California Coastal Commission on October 9, 2015

for: Authorization of an approximately 4,150 ft. long rock revetment and re-location of the downcoast approximately 1,600 linear feet of the as-built rock revetment further landward; implementation of a beach nourishment program involving deposition of 300,000 cu. yds. of sand on the beach from inland sand quarries during the first year, with major renourishments of up to approximately 300,000 cu. yds. of sand and interim renourishments of up to 75,000 cu. yds. of sand allowed when certain triggers are reached; periodic sand backpassing operations to occur no more than once per year, and dune habitat restoration.

at: 30708 Broad Beach Road to 6526 Lechuza Point Road, Malibu (Los Angeles County)

Pursuant to Section 13169 of the Commission Regulations, the Executive Director has determined that there are no changed circumstances affecting the proposed development's consistency with the Coastal Act. The Commission Regulations state that "if no objection is received at the Commission office within ten (10) working days of publishing notice, this determination of consistency shall be conclusive... and the Executive Director shall issue the extension." If an objection is received, the extension application shall be reported to the Commission for possible hearing.

Persons wishing to object or having questions concerning this extension application should contact the district office of the Commission at the above address or phone number.

Sincerely,

John Ainsworth
Executive Director

Julie Reveles
Staff Services Analyst

cc: Commissioners/File

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(805) 585-1800

OBJECTION RECEIVED TO EXECUTIVE DIRECTOR'S DETERMINATION

Date: November 2, 2017

To: Commissioners and Interested Persons

From: John Ainsworth, Executive Director

Re: Objection to Executive Director's Determination Regarding Extension of Coastal Development Permit (CDP) No. 4-15-0390 (Broad Beach Geologic Hazard Abatement District)

On September 14, 2017, the applicant (Broad Beach Geologic Hazard Abatement District) submitted an application for a one-year time extension to CDP No. 4-15-0390. The permit was previously approved by the Commission on October 9, 2015 and authorized retention of an approximately 4,150 ft. long rock revetment and re-location of the downcoast approximately 1,600 linear feet of the as-built rock revetment further landward; implementation of a beach nourishment program; and dune habitat restoration at 30708 Broad Beach Road to 6526 Lechuza Point Road, Malibu, Los Angeles County.

The Executive Director determined that there were no changed circumstances affecting the proposed development's consistency with the Coastal Act, and notice of this determination was mailed on October 27, 2017, and also posted at the project site. This determination will be reported to the Commission at the November 9, 2017 Commission meeting. Pursuant to the Commission's Regulations, 14 Cal. Admin. Code Section 13169(c):

> *If the executive director received a written objection to his or her determination but concludes that the objection does not identify changed circumstances that may affect the consistency of the development with the Coastal Act or a certified local coastal program, if applicable, the executive director shall report this conclusion to the commission at the same time that the executive director reports the determination to the commission in accordance with subsection (b) above. The executive director shall provide a copy of the letter(s) of objection to the commission with the report. If three commissioners object to the extension on grounds that there are changed circumstances that affect consistency, the executive director shall schedule the extension for hearing(s) in accordance with subsection (d) below. If three commissioners do not object to the extension, the time for commencement of development shall be extended for one year from the expiration date of the permit.*

A letter of objection to the Executive Director's determination regarding the extension request was received on October 30, 2017 from Steven Kaufmann on behalf of four Broad Beach property owners (attached as Exhibit 1). The letter states that the extension should not be granted and should instead be scheduled for a full public hearing at a subsequent Commission meeting because there are changed circumstances that affect the project's consistency with the Coastal Act. The objectors assert that the applicant's inland quarry sand source for beach nourishment is no longer viable due to pending litigation associated with the sand transport truck route, and that the applicant is now pursuing an alternative sand source with a marine-based delivery. In response, Commission staff would note that while the applicant has indicated that they are exploring an alternative sand source with a marine-based delivery for beach nourishment and intend to submit a permit amendment application soon to allow for that alternative, the applicant has stated that the inland quarry sand source that was analyzed and approved by the Commission for beach nourishment remains a viable option. Therefore, the applicant's consideration of potential alternative sand sources does not constitute changed circumstances that would affect the development's consistency with the Coastal Act.

In addition, the objectors assert that the large number of truck trips and impacts to traffic associated with transporting sand to the site from inland areas constitute changed circumstances. However, the number of necessary truck trips and traffic impacts were fully evaluated as part of the Commission's approval of this project and do not constitute changed circumstances.

The objectors also assert that numerous owners of property subject to this CDP will not consent to the lateral public access license agreements that are required by Special Condition 13 of the CDP. These license agreements provide for lateral public access along the beach, generally between the mean high tide line and the seaward face of the approved revetment, as well as along a strip of land landward of the revetment when specific beach erosion conditions exist. The objectors raise a concern that the approved nourishment project will not work as intended and that an offshore artificial sand retention reef should be analyzed to mitigate expected erosion. The objectors state that they want the applicant and the Commission to consider an offshore sand retention reef as well as an alternative sand source with a marine-based delivery in the context of a new permit or permit amendment, and that the subject extension request should be conditioned to require consideration of those alternatives. However, the assertion that some property owners will not consent to the required lateral public access license agreements is a condition compliance matter and does not constitute changed circumstances that affects the development's consistency with the Coastal Act. It has not been demonstrated that consent by all property owners is unattainable. Further, the Commission contemplated the challenge of the applicant's ability to obtain lateral public access license agreements signed by all revetment property owners in its action on the CDP. The Commission's approved findings identified a potential alternative mechanism of eminent domain that could be used to comply with the requirement in the absence of individual property owner agreement. Although the Broad Beach GHAD Plan of Control waives the power of eminent domain, GHAD law authorizes the GHAD Board of Directors to pass resolutions which modify or restrict the powers of the GHAD itself, most importantly with respect to eminent domain powers. So, even if individual property owners are unwilling to agree to the CDP conditions and an eminent domain action would be necessary, the GHAD resolutions waiving eminent domain could always be reversed by another majority action of the Board.

Lastly, the objectors state that the approved project did not address an offshore sand retention reef alternative in order to mitigate the underlying erosion rates on Broad Beach and that a group of Broad Beach property owners recently received an independent Feasibility Study (attached as part of Exhibit 1) for this alternative. The objectors assert that this new information constitutes a changed circumstance that affects the development's consistency with the Coastal Act. However, the identification of additional project alternatives that could be considered, such as an offshore reef, is not a changed circumstance that affects the approved development's consistency with the Coastal Act. The approved revetment and nourishment project was considered along with several project alternatives and found by the Commission to be consistent with the Coastal Act in its action on the subject CDP. While the applicant is free to submit a new permit, or permit amendment, for an offshore reef, the fact that some property owners believe that such a reef may be feasible does not affect the consistency of the approved project with Chapter 3. However, an offshore reef is likely not a feasible alternative to the project given that it would need to be located within a designated Marine Protected Area (MPA) that does not allow for such development.

Therefore, for the reasons discussed above, the Executive Director, determines that there are no changed circumstances affecting the proposed development's consistency with the Coastal Act so that the one year extension may be issued.

NOSSAMAN LLP

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Refer To File #: - 502620-0001

VIA OVERNIGHT DELIVERY AND E-MAIL

October 30, 2017

John Ainsworth
Executive Director
California Coastal Commission
45 Fremont Street, Suite 2000
San Francisco, CA 94105

Re: CDP 4-15-039 (Broad Beach Restoration Project)
Opposition to BBGHAD Extension Request

Dear Jack:

This firm, working with Don Schmitz of Schmitz & Associates, is counsel to several Broad Beach property owners: Mark Magidson, Trustee of the Magidson Revocable Trust of 1987 (2006 Restatement), and Malibu-Broad Beach S-1, LLC, a California limited liability company through its Manager Mark Magidson; Alexander Haagen III, as managing member of 30956 BB, LLC and BB Malibu Place, LLC; Mike and Cheryl Schwab; and Andrew and Barbara Leigh.

On October 9, 2015, the Commission approved the Broad Beach restoration project (CDP 4-15-039), with Special Conditions to be cleared before permit issuance. Since then, fundamental issues have emerged concerning the project approved, and these changed circumstances now affect the project's consistency with the Chapter 3 policies of the Coastal Act. The Broad Beach GHAD (BBGHAD) has requested an extension of its permit. We oppose the extension request and ask, for the reasons discussed below and further in the "Conclusion," that the extension not be granted and that the matter be set for a full public hearing, consistent with Section 13169 of the Commission's Regulations.

In summary, the changed circumstances are the following:

1) The original land-based sand sources for the project are no longer viable. Cities which would be impacted by heavy truck traffic involved for sand transport, Fillmore and Moorpark, have both objected to the truck route and litigation between them is likely to eliminate the availability of sand from inland quarries. A new, alternative sand source, however, with marine-based delivery, has become available for the project. This alternative has been endorsed by the BBGHAD and the Malibu City Council.

EXHIBIT 1

2) The public access requirement in Special Condition 13B of Springing Licenses and 100% Property Owners consent cannot be met, and alternatives need to be assessed.

3) Although alternatives to the current approved project were addressed in the original Commission decision, an offshore sand retention reef alternative was not analyzed. An independent Feasibility Analysis on the use of such an alternative for Broad Beach has now been completed. Importantly, that analysis concludes that the underlying erosion rates (an issue that the original project does not mitigate) can be cut by 50% or more. This more than merits a full engineering study based on the Feasibility Analysis on the alternative of a sand retention reef. A sand retention reef offers the prospect of longer sand retention on the beach, fewer impactful beach nourishments, and lower annual assessment costs to the homeowners, which are essential to successful funding of sand nourishment at Broad Beach.

The current project has proven infeasible. The estimated costs of beach nourishment have spiraled out of control – three times the initial estimate projected by the BBGHAD less than five years ago. For some Broad Beach homeowners, the current assessment contemplated by the BBGHAD would result in as much as $173,250 annually, and might actually force some affected owners to sell their properties.

Given what we now know, what is required to create an effective program is a way to dissipate wave energy. This can be accomplished only by a constructed offshore reef, as already demonstrated by the success of a number of such projects in different parts of the world. Otherwise, even assuming the current project were viable (and it is not), all the Broad Beach homeowners would be doing for the foreseeable future is hauling in hundreds of thousands of cubic yards of sand for regular replenishment, at enormous costs, only to see all of the sand washed away in (at best) a few years or, in the event of a serious storm, perhaps washed away in as little as 24 to 48 hours.

An extension of the permit, therefore, is not the answer. Because there clearly are changed circumstances which may affect the consistency of the project previously approved with the Chapter 3 policies of the Coastal Act, a full public hearing is needed and requested.

Changed Circumstance: Sand Source

The proposed land-based sand sources considered for the project in the CDP are likely infeasible, but a less impactful sand source utilizing marine delivery now exists for the nourishment at Broad Beach.

Current Permit Requirements and Issues:

- The sand sources assessed as part of the permit were inland quarries based in the Moorpark/Fillmore area.
- Utilizing these sources would require approximately 22,000 truck trips (by the BBGHAD's own estimate) for the initial 300,000 cubic yard nourishment. The sand would need to be transported 40-45 miles to Broad Beach and construction worker vehicles and haul trucks are forecast to generate 1350 vehicle trips per day (675 inbound and 675 outbound) for approximately 3-5 months (5 days a week; from 7:00 am to 9:00 pm).
- A large parking lot at Zuma Beach would be required for storage of trucked-in sand, thus diminishing public access through re-purposing a Zuma Beach parking lot.
- The impacts and disruption from this project alone on public access and recreation and on coastal access routes to and along the beaches in Malibu would be substantial and for a sustained period of time.
- The current CDP allows interim nourishments of 75,000 cubic yards of sand once certain triggers are reached; each interim nourishment would require close to 5,400 additional truck trips, with consequent impacts on public access and recreation to and along the Malibu beaches.
- The project engineers estimate that, given current erosion rates and barring any storms, one 10-year period would require 3 major nourishments and 2 minor ones totaling over **76,500 truck trips** from the Moorpark/Fillmore area to Malibu.
- A portion of the Zuma Beach parking lot and the whole of Broad Beach would be closed to the public during each nourishment event as the parking lot would be utilized for sand storage while construction equipment and conveyors move sand from Zuma to Broad Beach across Trancas Creek.
- Unanticipated storms could result in the need for emergency re-nourishments and even more truck trips as a result.
- There is significant local opposition to this component of the project from both the inland cities of Fillmore and Moorpark, including litigation between them, after Moorpark conditioned that the trucks for the project bypass Moorpark. Fillmore, in turn, has conditioned CEMEX's (the primary sand source for the project) CUP extension to not supply the Broad Beach project through Fillmore.
- At its September 25, 2017 meeting, the Malibu City Council approved a motion to authorize the Mayor to send a letter to the CCC supporting marine delivery of sand versus land delivery because of the reduced environmental impacts.
- Nourishment would need to be done perpetually and impacts would be ongoing.

Figure 1. Traffic impacts on coastal routes to and along Malibu's beaches will be significant and ongoing into perpetuity with the land based sand sources

Alternative:

- Marine delivery of sand for the project is available from the Orca Sand & Gravel quarry, located on Vancouver Island in British Columbia.
- Orca ships approximately 3 million tons of sand annually to California on self-unloading barges operated by Canada Steamship Lines (CSL) and Lind Marine.
- Orca has been in operation for 10 years and is 12% owned by the Namgis First Nation, an indigenous nation of British Columbia. Orca has certifications for clean products (ANSI/NSF) and Environmental Product Declarations (EPD5).
- Orca Sand & Gravel, Canada Steamship Lines, and Lind Marine have proposed a marine-supplied sand solution to deliver sand from a self-unloading ship, pumped to shore as a slurry (a mixture of sand and water).
- The fine sand from Orca meets all project specifications for size, shape and cleanness. The last remaining issues have been the color of the sand and heat retention of the sand. Orca has supplied large new sand samples that the BBGHAD and Malibu City Council agree are acceptable. Orca met recently with CCC staff and presented data showing no heat retention difference with the native Board Beach sand. Staff requested further data that Orca plans to complete by November 9, 2017.
- CSL ships are state of the art and the method of pumping sand slurry for beach replenishment has been successfully carried out multiple times by Lind Marine under the same high levels of environmental standards in Northern California.
- The marine-supplied sand solution will place the sand faster, provide access to the beach during construction, avoid clogging coastal access routes to and along Malibu's beaches, be completed sooner, with fewer environmental impacts (emissions, fine particulates) and virtually no social impacts (traffic, noise, dust).

Figure 2. Marine based delivery will be faster and less impactful

Inconsistencies with the Chapter 3 policies of the Coastal Act:

- The utilization of a land-based sand source, while a marine-based sand delivery option with less environmental impacts is available, would be inconsistent with Section 30253 of the Coastal Act, specifically 30253(d) which requires that new development minimize energy consumption and vehicle miles traveled, and the public access and recreation policies in Section 30210, et seq., of the Coastal Act.
- The approval of a more impactful method of sand delivery is inconsistent with the basic goals set forth in Section 30001.5, specifically (a) protect, maintain, and where feasible, enhance and restore the overall quality of the coastal zone environment and its natural and artificial resources.

<u>Changed Circumstance: Springing Licenses</u>

Numerous Broad Beach homeowners will not sign the Springing Licenses required to fulfill Special Condition 13(B) of the CDP. The Springing License, as a concept, was imposed to ensure that public access along Broad Beach would still be possible when the beach has eroded significantly, a likely scenario given the high underlying erosion rate on Broad Beach but which the project, as approved, does not appropriately mitigate through a means of sand retention.

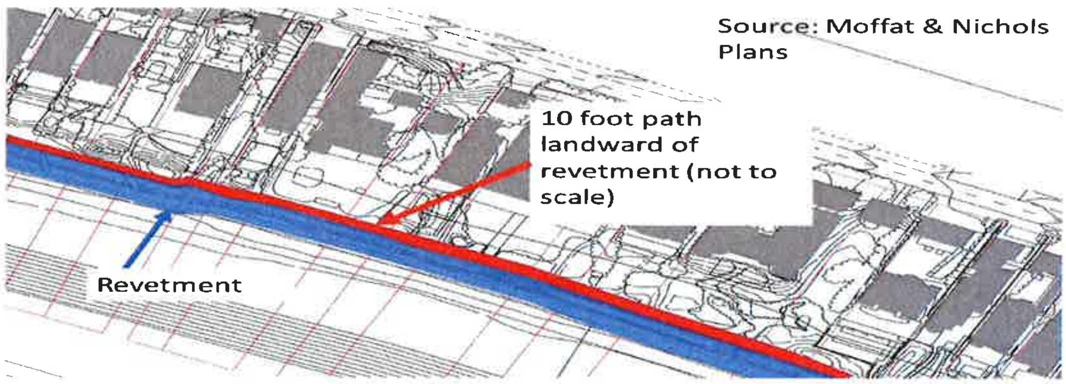

Figure 3. Example of the access requirements resulting from the Springing License

Current Permit Requirements and Issues:

- The current CDP requires that all the homeowners on Broad Beach behind the rock revetment enter into an agreement with the Commission and BBGHAD in the form of an irrevocable license that provides for public access landward of the 2010 MHTL if the beach erodes past certain widths.
- Of the 78 homeowners that are required to sign springing licenses, approximately 30 or less have done so, and many have indicated they will not sign them.
- The BBGHAD has no legal right to commit the homeowners to the springing license requirement, and several homeowners have stated that they will not provide such a license.

Alternative

- The project needs to address the underlying erosion rate on the beach to ensure that sand remains on the beach for as long as possible and that public access across Broad Beach is maintained.

- The independent Feasibility Analysis of the offshore reef option for Broad Beach concludes that erosion rates can be cut by approximately 50% or more. This would ensure sand remains on the beach for longer periods and that the required nourishments will be spaced out and not cost prohibitive for the BBGHAD. The bottom line: a revised project would be more likely to ensure that public beach access is maintained.

Inconsistencies with the Chapter 3 policies of the Coastal Act:

- The changed circumstances, combined with the underlying erosion rate on Broad Beach and the fact that sand will likely not stay on the beach for a significant period of time, means that the project is not consistent with the public access and recreation policies of the Coastal Act Section 30210, et seq.

Changed Circumstance: Feasibility of an Artificial Sand Retention Reef

The original project approved did not address mitigating the underlying erosion rates on Broad Beach that necessitated the emergency revetment. Various alternatives were addressed, but the project proposed neither considered nor analyzed the alternative of an offshore sand retention reef. The "Reef Group" of homeowners, of which our clients are a part, has now received an independent Feasibility Analysis done on an artificial sand retention reef for Broad Beach. That study concludes that erosion rates could be cut by 50% or more.

Current Permit Requirements and Issues:

- The current CDP requires that a minimum width of 30 feet of dry beach be maintained over the 10-year period.
- The project scope did not address the underlying erosion rates on Broad Beach (estimated to range from 35,000 up to 70,000 cubic yards/year post nourishment). As such, maintaining this beach width would require frequent re-nourishments (currently estimated as every other year) and yearly backpassing. Given the fact that the sand required for beach nourishment, let alone repeated sand replenishment, is not available, and the extraordinary annual assessments projected for the approved project are not feasible or lawful (they violate, among other things, Proposition 218), the ability of the BBGHAD to sustain the required re-nourishments into perpetuity is questionable.
- The continuous and frequent nourishments and subsequent erosion would result in marine resources being affected by sediment dispersal.

Table 2. GENESIS predicted beach width for Project Alternative 4C with 75,000 cy re-nourishment at Year 2

Time after Beach Fill (Years)	Beach Width Added-Section 408	Beach Width Added-Section 409	Beach Width Added-Section 410	Beach Width Added-Section 411	Beach Width Added-Section 412
0	66	103	108	91	60
0.5	64	88	88	70	44
1	61	72	68	48	28
1.5	55	61	54	35	17
75,000 cy Re-nourishment					
2	51	55	85	81	52
2.5	53	57	68	57	35
3	56	59	52	33	17
3.5	49	50	40	22	9
4	43	40	28	11	0
4.5	31	26	12	-	-
300,000 cy Re-nourishment at year 5					

Even with the interim nourishment the beach significantly eroded by the end of the 10 year period

Figure 4. Erosion on Broad Beach will be significant even with a 75,000 cy re-nourishment at Year 2 (Source: Moffat & Nichols)

Alternative

- The initial Feasibility Analysis of an artificial sand retention reef concludes that erosion at Broad Beach can be cut by 50% or more. This figure may increase with more in-depth engineering and is an alternative that needs to be considered.

- This would result in less sedimentation of marine habitats, and reduce the financial burden of the BBGHAD, making it more likely that this project and beach width at Broad Beach will be sustainable in the long term.

- An artificial reef additionally will, if designed correctly (and especially if Reef Balls are used), enhance the marine environment.

Inconsistencies with the Chapter 3 policies of the Coastal Act:

- The high erosion rates, frequent re-nourishment, and the resulting sedimentation makes the project inconsistent with Section 30230 of the Coastal Act, which requires that marine resources shall be maintained, enhanced and where feasible, restored. The project alternative of using an Artificial Sand Retention Reef with the potential for habitat enhancement would be consistent with this policy by protecting and enhancing the marine environment.

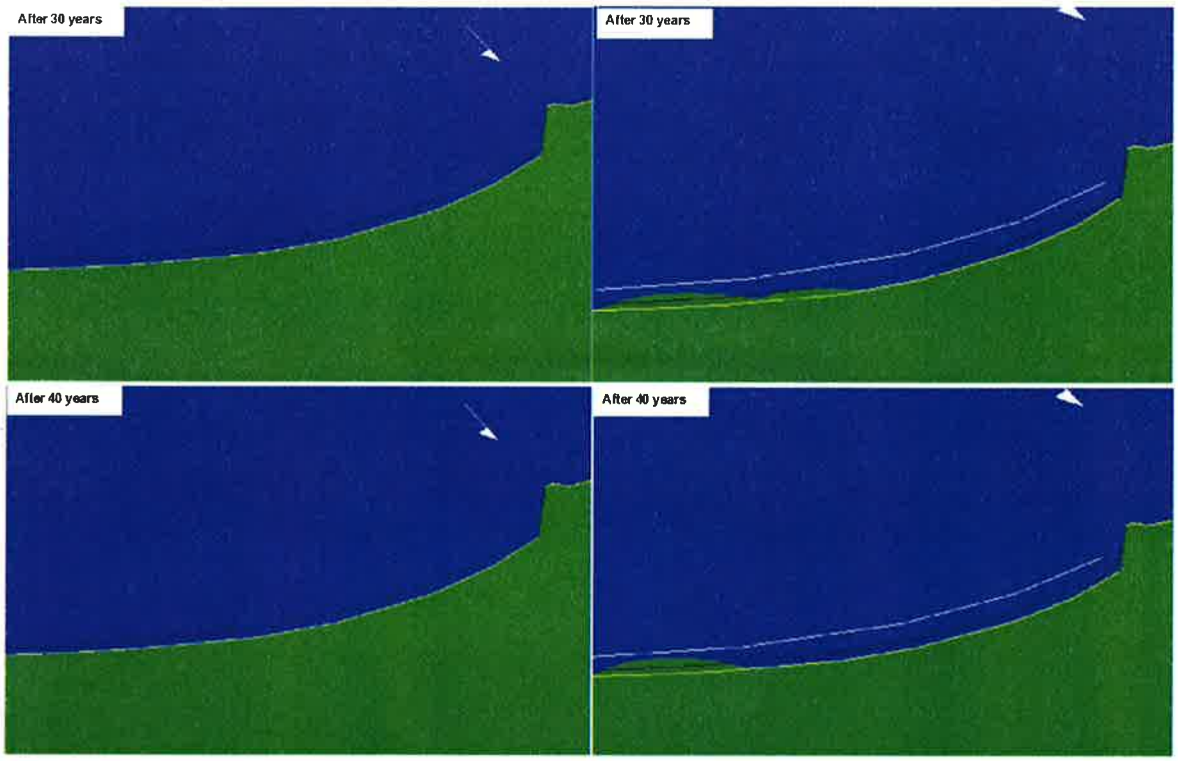

***Figure 46** Effect of the reef placement on the long term shoreline change (30 and 40 years).*

Figure 5. An artificial reef may cut erosion approximately 50% or more, reduce the need for future nourishments and impacts to the marine environment from sedimentation, and enhance marine habitat

We have enclosed additional background information prepared by Schmitz & Associates relating to the Artificial Sand Retention Reef alternative, as well as the 68-page "Feasibility Study for an Artificial Reef at Broad Beach, CA, USA" (October 2, 2017), prepared by Dr. Mariano Buccino. The Feasibility Study is a preliminary study of two potential offshore sand retention devices, and demonstrates that the permanent offshore sand retention reef is a cost-effective measure to perpetuate the sand nourishment at Broad Beach, and warrants further analysis.

Conclusion

In requesting an extension of the CDP, the BBGHAD is asking the Commission to perpetuate a revetment plan that will not work and that has exponentially increased in cost to the point where even if BBGHAD could solve already insurmountable problems, the project, as approved, would not be doable. So far, the project has not resulted in a single grain of sand being deposited on Broad Beach, and the only beneficiaries of the project have been lawyers and engineers. Fundamental changed circumstances have arisen since the Commission's approval, requiring a fresh and careful look by the Commission at the issue of beach nourishment at Broad Beach.

For the foregoing reasons, our clients respectfully request that the extension requested not be granted, but rather that, pursuant to Section 13169 of your regulations, the matter be set at a subsequent Commission meeting for a full public hearing to determine whether there are changed circumstances and whether a different and potentially superior project ought to be considered.

It is important to understand that the BBGHAD itself has written and verbally expressed its position that the current CDP cannot go forward for the several reasons set forth in its September 13, 2017 letter. As a result, those grounds constitute changed circumstances which ordinarily require the Commission to deny an extension request and a new application for permit. It is worth pointing out, however, that BBGHAD is requesting the extension so that it can amend its existing CDP to request marine transport of sand, as opposed to land-based trucking. In effect, BBGHAD is requesting a conditional extension. Nothing in the Commission's regulations forecloses an extension granted, under exceptional circumstances, subject to conditions. Thus, one alternative to denial of the extension following the full public hearing on changed circumstances is to approve the extension, subject to conditions which require BBGHAD to file an application to amend its existing CDP to pursue and fully consider the offshore sand retention reef alternative (in cooperation with the Reef Group), marine transport, and issues related thereto. Either approach can lead to the same result.

Thank you very much for your consideration.

Sincerely,

Steven H. Kaufmann
for Nossaman LLP

SHK:jr

Ccs (w/attachments):
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Coastal Commissioners
Steve Hudson, Deputy Director, CCC
Barbara Carey, District Manager, CCC
Deanna Christensen, Supervising Coastal Program Analyst, CCC
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Artificial Reefs to Protect California's Beaches

An alternative to revetments, sea walls and endless beach nourishment

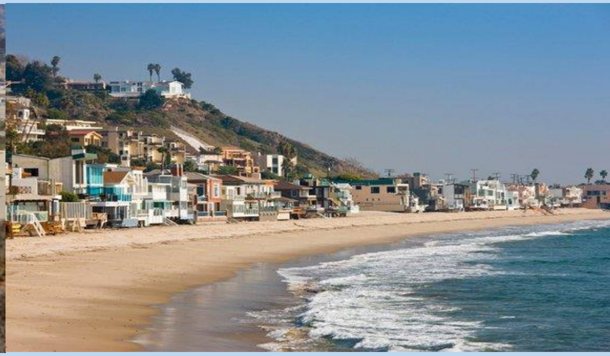
Schmitz & Associates, Inc

Providers of Land Use Planning for a Better Community

California’s beaches are under attack

- By 2100 many beaches in California will erode to the order of around 165 feet
- Due to rising sea levels and climate change, 31 to 67% of beaches will be completely eroded
    - Dr. Patrick Barnard, Research Geologist, USGS Pacific Coastal and Marine Science Center



“The prospect of losing so many our beaches in Southern California to sea level rise is frankly unacceptable. The beaches are our public parks and economic heart and soul of our coastal communities. We must do everything we can to ensure that as much of the iconic California coast is preserved for future generations.”

Jack Ainsworth, California Coastal Commission Executive Director (March 27, 2017)

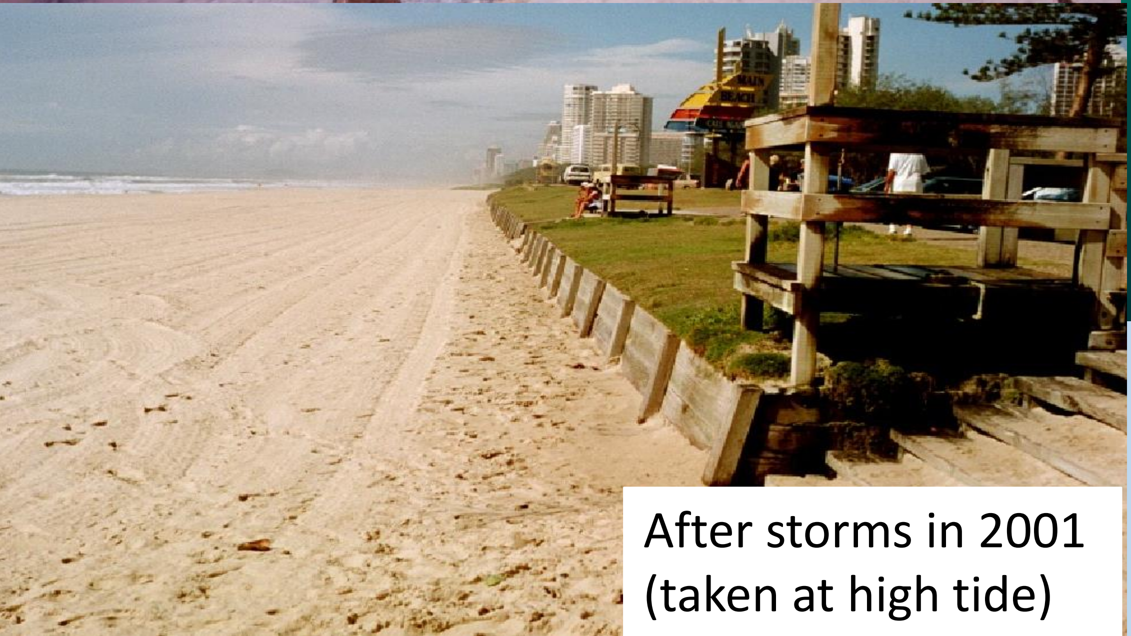
The Traditional Solutions

- Revetments to protect private property
  - Does not restore the beach
  - Visually intrusive
  - Can often affect public access on beach

- Beach Nourishment
  - Temporary solution that only works in low erosion environments
  - Stabilizing beach nourishments often require visually intrusive groins or breakwaters
  - Expensive to implement because multiple nourishments are often required
  - Loss of recreational opportunities when the beach is being constructed and maintained
  - Effects on biodiversity; repeated nourishments in San Diego have been shown to cause long lasting declines in invertebrates and knock on effects on pre availability for shorebirds and fish (*Wooldridge T. et al. "Effects of beach replenishment on intertidal invertebrates: a 15-month, eight beach study." Estuarine, Coastal and Shelf Science*

Narrowneck Artificial Reef on the Gold Coast

Storm erosion in 1996
(taken at high tide)



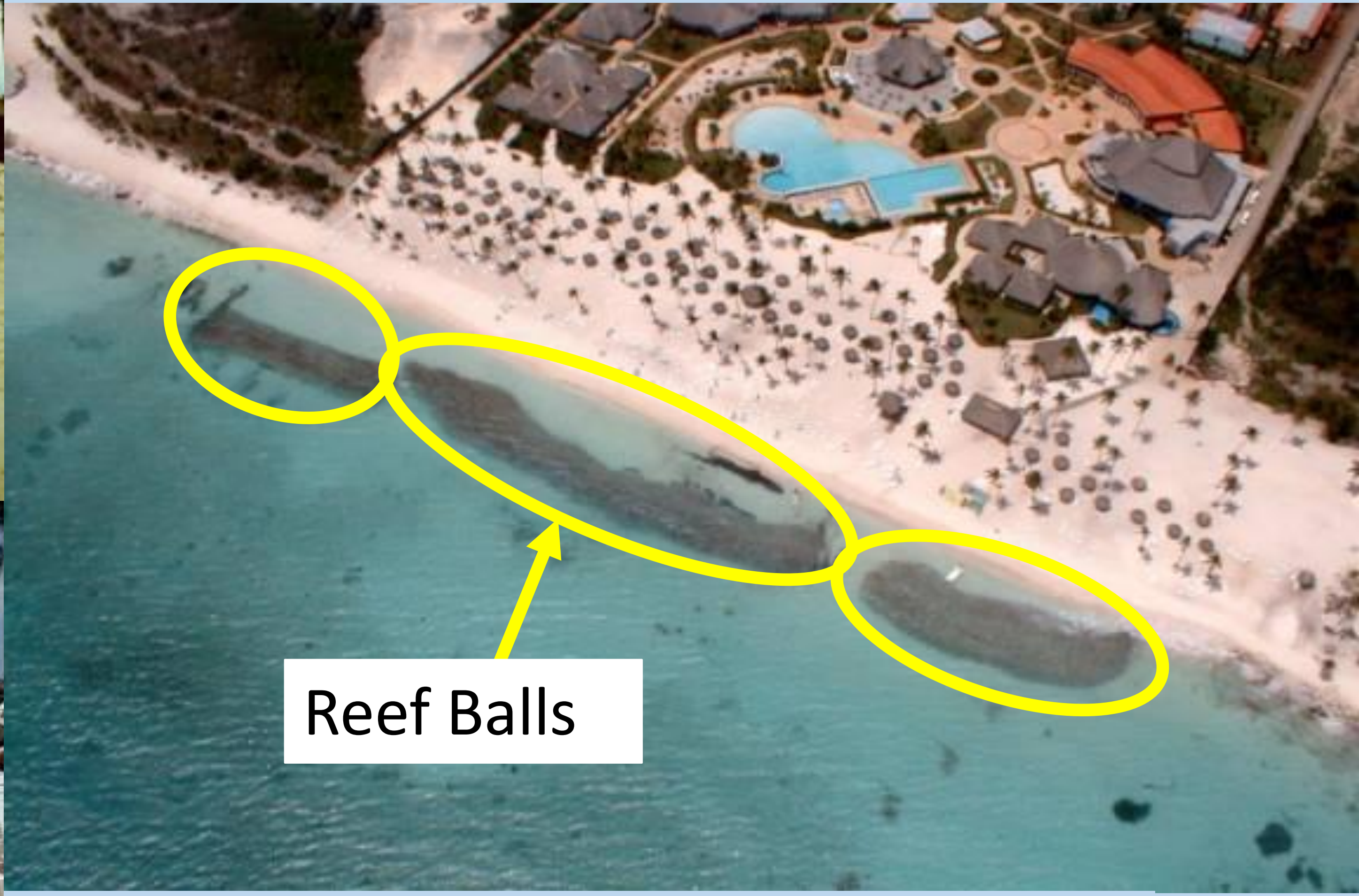
After storms in 2001
(taken at high tide)

Nourished sand was not eroded by storms due to the reef

Gran Dominicus Sand Retention Reef

Prior to reef installation - 1999

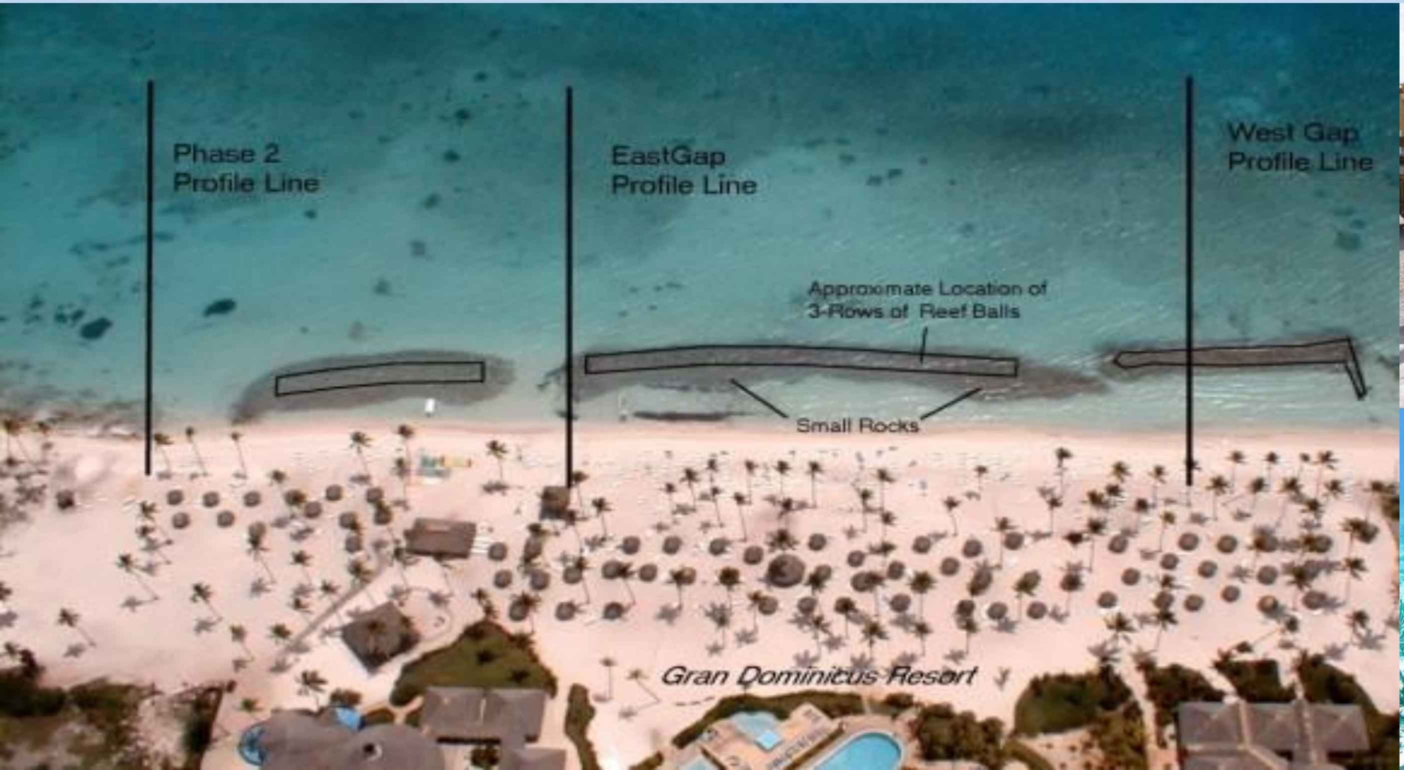
After reef installation - 2001



Natural accretion of sand occurred after reef installation

Sand Retention Reef Alternative

- Using sand retention reefs can reduce erosion on beaches without visual impacts while also providing recreational opportunities for surfing and diving
- Submerged Artificial Reef Training Structures (SMART), developed by the Reef Ball Foundation and the Army Corps of Engineers for Florida is a modular system that allows reefs to be moved if required
- Reef Balls provide habitat enhancement by creating the equivalent of a rocky reef habitat






Potential of a Sand Retention Reef for Broad Beach

- The currently proposed sand nourishment project for Broad Beach (CDP) is fatally flawed as it does not address the underlying erosion rate that necessitated the emergency revetment
- Maintaining the nourished beach would require frequent re-nourishments (currently estimated as every other year) and yearly backpassing at huge financial cost and impacts to the marine environment by the continued sediment dispersal and construction disturbance

Table 2. GENESIS predicted beach width for Project Alternative 4C with 75,000 cy re-nourishment at Year 2

Time after Beach Fill (Years)	Beach Width Added- Section 408	Beach Width Added- Section 409	Beach Width Added- Section 410	Beach Width Added- Section 411	Beach Width Added- Section 412
0	66	103	108	91	60
0.5	64	88	88	70	44
1	61	72	68	48	28
1.5	55	61	54	35	17
75,000 cy Re-nourishment					
2	51	55	85	81	52
2.5	53	57	68	57	35
3	56	59	52	33	17
3.5	49	50	40	22	9
4	43	40	28	11	0
4.5	31	26	12	-	-
300,000 cy Re-nourishment at year 5					

Even with the interim nourishment the beach significantly eroded by the end of the 10 year period

Erosion on Broad Beach will be significant even with a 75,000 cy re-nourishment at Year 2 (Source: Moffat & Nichols)

Potential of a Sand Retention Reef for Broad Beach

- The initial Feasibility Analysis of an Artificial Sand Retention Reef indicates that erosion can be cut by at least 50%. This figure may increase with more in-depth engineering and is an alternative that needs to be considered.
- This would result in less sedimentation of marine habitats and reduce the financial burden of the BBGHAD, making it more likely that this project will be sustainable in the long term.
- An artificial reef will, if designed correctly (and especially if Reef Balls are used), enhance the marine environment.

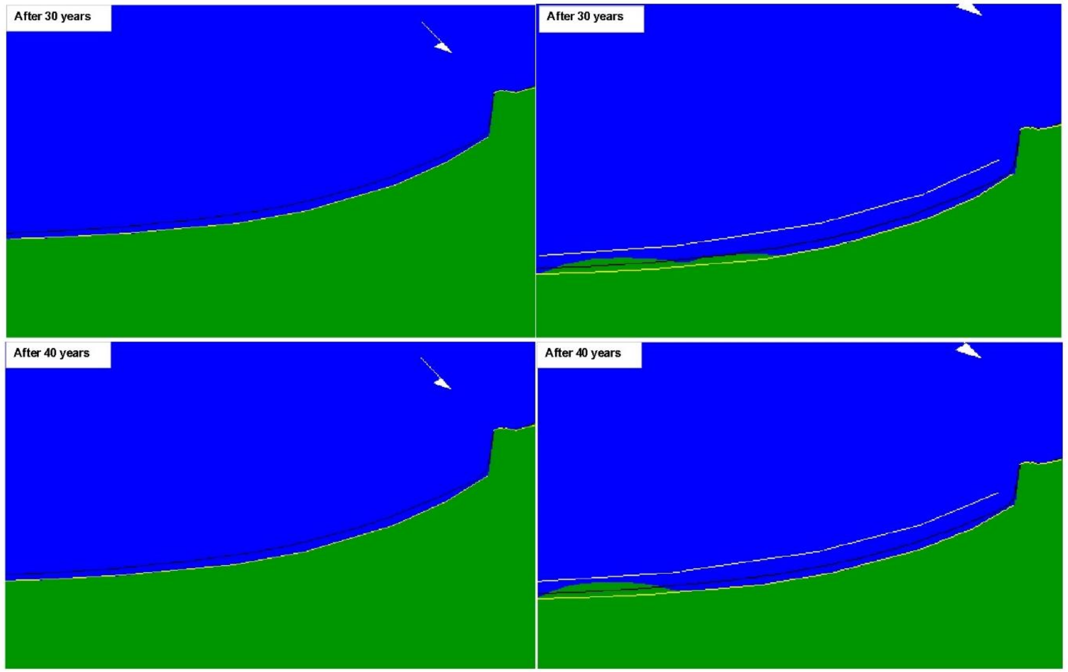


Figure 46 *Effect of the reef placement on the long term shoreline change (30 and 40 years).*

An artificial reef may cut erosion by 50% or more (Source: Feasibility Study for an Artificial Reef at Broad Beach – Dr. Mariano Buccino, 10/12/2017)

FEASIBILITY STUDY FOR AN ARTIFICIAL REEF AT BROAD BEACH, CA, USA.

Dr. Mariano Buccino.

Professor of Coastal Engineering,

University of Naples Federico II

FINAL REPORT, 2017/10/2

TABLE OF CONTENTS

BACKGROUND 7
1. WAVES IN DEEP WATER 8
1.1 Site Exposure 8
1.2 Offshore Wave Climate Analysis 8
1.2.1. The wave buoy 46025 9
1.2.2. The wave buoy 46053 13
1.2.3. General characteristics of wave climate 16
1.3 Extreme (long term) wave statistics. 16
2. WATER LEVELS 18
2.1. Tides 18
2.2. Extreme Sea Levels 18
2.3. Long Term Sea Level Rise 20
3. BEACH MORPHOLOGY 21
3.1. Cross shore beach profile 21
3.2. Depth of closure 25
3.3. Equilibrium Beach Profile 26
3.4. Alongshore orientation of the shoreline 27
4. SEDIMENT TRANSPORT ANALYSIS 29
4.1. The Littoral Drift Rose (LDR) 29
4.2. Application of the LDR concept to Broad Beach 30
4.3. The Equivalent wave climate 32
5. WAVES IN THE NEARSHORE AND RELATED CURRENTS. 33
5.1 Propagation Study 33
5.2. Nearshore Circulation study 38
6. SEDIMENT TRANSPORT STUDY 42
6.1. Littoral Drift study 42
6.1.1 The GENESIS model. 42
6.1.2. Model Calibration 43
6.1.3. Effect of Revetment 43
6.2. Storm effects 48
6.2.1. Simulations 48
7. REEF DESIGN 50
7.1 Height of the reef (submergence) 50

7.1.1 Wave transmission 50
7.1.2 Number of RB rows and distance of the reef from the shoreline 52
8. BEACH RESPONSE TO THE REEF PLACEMENT 55
8.1. Interaction with littoral drift 55
8.2. Effects on storms 61
9. CONCLUSIONS..62
10. REFERENCES...63
APPENDIX AI: The Conventional (Japanese) Artificial Reef.. ...64

LIST OF FIGURES

Figure 1 View of the site exposure. 8
Figure 2 Location of the Wave Buoy 46025.......... 9
Figure 3 Location of the Wave Buoy 46053.......... 9
Figure 4 Wave Rose for WB 46025..........11
Figure 5 Histogram of wave directions for WB 46025. 12
Figure 6 Scatter plot Hs Tp for WB 46025..........12
Figure 7 Wave Rose for WB 46053..........14
Figure 8 Histogram of wave directions for WB 46053. 15
Figure 9 Scatter plot Hs-Tp for WB 46053..........15
Figure 10 AMS of Hs on a Weibull chart (WB 46025). 16
Figure 11 The station ICAC1..........18
Figure 12 CdF of tide levels. 19
Figure 13 Transects of the Broad Beach Fall 2011 Profile Survey..........21
Figure 14 Example of beach profile from the Broad Beach Fall 2011 Profile Survey. 22
Figure 15 Bathymetric study for Broad Beach conducted by Chambers Group..........22
Figure 16 Transects sampled for subtidal community study. 23
Figure 17 Comparison between BB Fall 2011 and Army Corps beach profiles. 24
Figure 18 Slope of the underwater beach..........24
Figure 19 Depth of closure for Transect 409. 25
Figure 20 The MMLC. Source: Coastal Engineering Appendix to the GHAD Engineer's Report 2015. 27
Figure 21 Aerial photograph of the shoreline from Point Lechuza (to the west) to Point Dume (to the east). Courtesy of Ben Suber (Schmitz & Associates, Inc.)..........28
Figure 22 Azimuth of normal to the shoreline..........28
Figure 23 Definition sketch for LDR..........30
Figure 24 LDR for buoy 46053. Littoral drift in cubic meters/s..........31
Figure 25 LDR for buoy 46025. Littoral drift in cubic meters/s..........31
Figure 26 Comparison between real and equivalent LDRs. Littoral drift in cubic meters. 32
Figure 27 View of bathymetry and reference point for nearshore waves..........34
Figure 28 Propagation plot LDR equivalent wave..........35
Figure 29 Propagation plot 25 years return period wave (angle 260°N). 36
Figure 30 Propagation plot 25 years return period wave (angle 200°N). 37
Figure 31 Nearshore Circulation for the LDR equivalent wave..........39
Figure 32 Nearshore Circulation for the 25y return period (offshore angle 260°N)..........40
Figure 33 Nearshore Circulation for the 25y return period (offshore angle 200°N)..........41
Figure 34 Reach of shoreline simulated with GENESIS..........43
Figure 35 Volume variation of Broad Beach. GENESIS simulation with K =0.005. 44
Figure 36 Variation of the shoreline position at Broad Beach. GENESIS lasting 40 yearssimulation with K =0.005..........44
Figure 37 Volume variation for a reach of coast extending 1 km downdrift of Broad Beach. GENESIS simulation with K =0.005. 45
Figure 38 Inclusion of the unerodable line in the GENESIS model. 45
Figure 39 Effect of the unerodable line (revetment) on the long term shoreline change. 46
Figure 40 Volume variation of Broad Beach in presence of revetment. 47

Figure 41 Volume variation for a reach of coast extending 1 km downdrift of Broad Beach. Simulation with revetment. 47
Figure 42 Example of SBEACH simulation (Hs = 5.78m; Tp = 13.44s; Dir = 195°N; duration 6hrs. 49
Figure 43 View of the designed reef (QUALITATIVE DRAWING). 54
Figure 44 GENESIS simulation with the inclusion of the reef. 55
Figure 45 Effect of the reef placement on the long term shoreline change (10 and 20 years). 57
Figure 46 Effect of the reef placement on the long term shoreline change (30 and 40 years). 58
Figure 47 Volume variation of Broad Beach in with and without the reef. 59
Figure 48 Volume variation of a reach of coast extending 1 Km downdrift Broad beach. With and without the reef. 60

LIST OF TABLES

Table 1 Directional distribution of Hs for WB 46025. 10
Table 2 Joint distribution Hs-Tp for WB 46025. 11
Table 3 Directional distribution of Hs for WB 46053. 13
Table 4 Joint distribution Hs-Tp for WB 46053. 14
Table 5 Extreme wave climate for WB 46025 17
Table 6 CdF for delected tide levels. 19
Table 7 Extreme sea levels (source: Moffat & Nichol 2015). 19
Table 8 Depth of closure for transects of the Broad Beach Fall 2011 Profile Survey. 25
Table 9 Scale parameter for the available data. 26
Table 10 Deep water design conditions. 33
Table 11 Nearshore parameters. 38
Table 12 48
Table 13 Transmission Coefficients for littoral drift analysis. 52
Table 14 Transmission Coefficients for extreme waves. 53
Table 15 Reef Characteristics. 53
Table 16 Effects of reef on storm events. 61

BACKGROUND

Broad Beach is located at the base of Santa Monica mountains and extends by nearly 1.8 Km between Lechuza Point (to the north) and Zuma Beach (to the south). This reach of coast has been experiencing a structural erosion since late sixties, at a rate of approximately 15,000 cubic meters per year (cu.m./y). Despite a beach fill project is already planned, the client requested a feasibility study for an artificial reef consisting of Reef Ball modules.

Based on the available information on wave climate and beach morphology, this report analyzes the hydrodynamic and sediment transport processes that characterize *Broad Beach* and provides a first stage design of the reef. A number of numerical model simulations have been carried the out to assess the performance of the new structure.

1. WAVES IN DEEP WATER

1.1 Site Exposure

Waves can approach *Broad Beach* through different windows, created by the *Channel Islands* and the coast of California. As shown in Figure 1, two main windows can be individuated; the first is included between the directions 165°N and 265°N, with a small shadow zone (210 to 220°) corresponding to *San Nicolas Island*. This window essentially exposes *Broad Beach* to southern swells and seas generated locally. The second window, included between *Anacapa Island* and *Arguello Terrace* (275-290°N), allows North Pacific swells to reach the coast through the *Santa Barbara Channel*.
The most eastern directions (less than 165°N) are protected by the islands of *San Clemente and Santa Catalina* as well as the Californian coast.

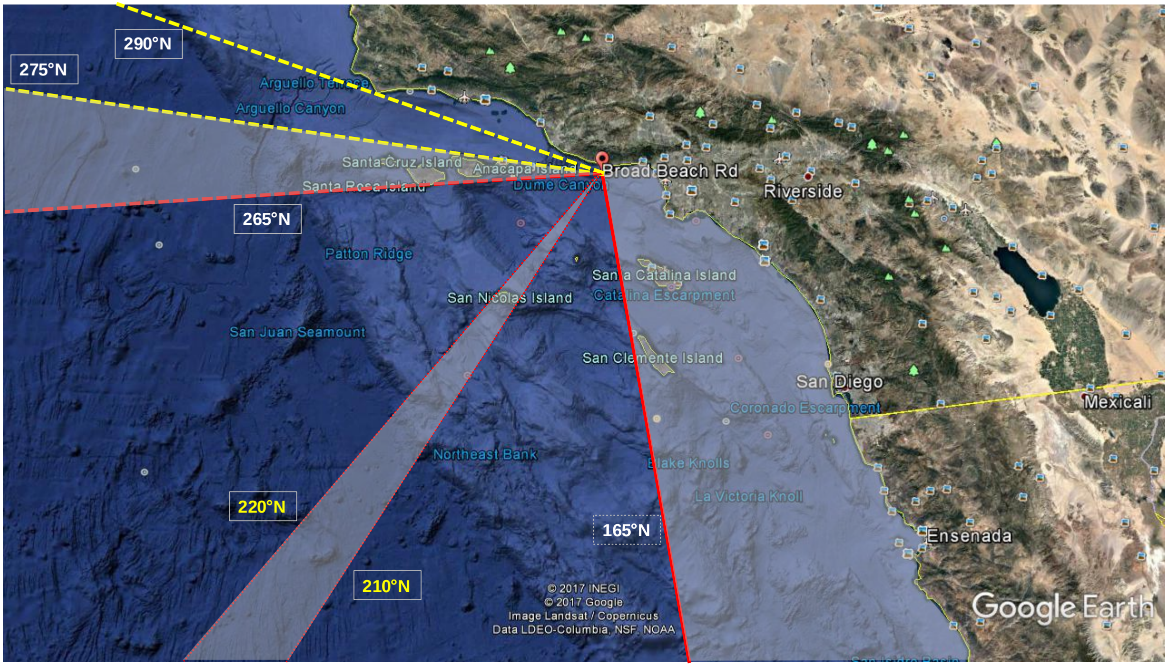


Figure 1 *View of the site exposure.*

1.2 Offshore Wave Climate Analysis

The wave climate offshore *Broad Beach* has been studied using two buoys. One is the NOAA Wave Buoy **46025**, approximately 33 miles northwest *Catalina Island* (Figure 2); the other is the NOAA wave buoy **46053** (Figure 3), 12 miles Southwest *Santa Barbara*. The former gathers waves from the “main window” 165°N – 265°N; the latter gives information on the North-Western quadrants.

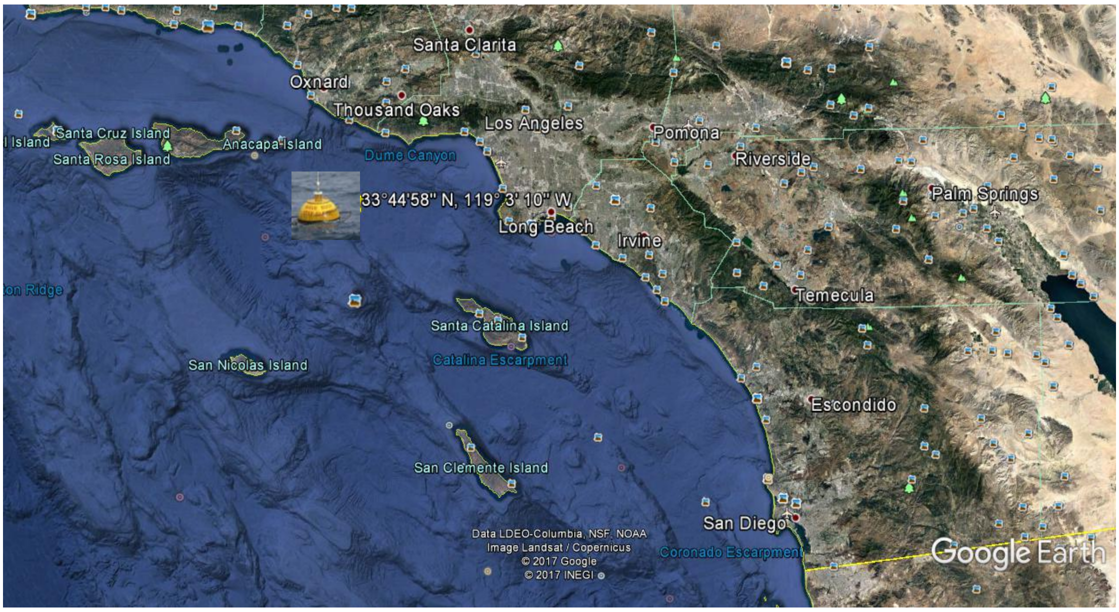


__Figure 2__ Location of the Wave Buoy 46025.

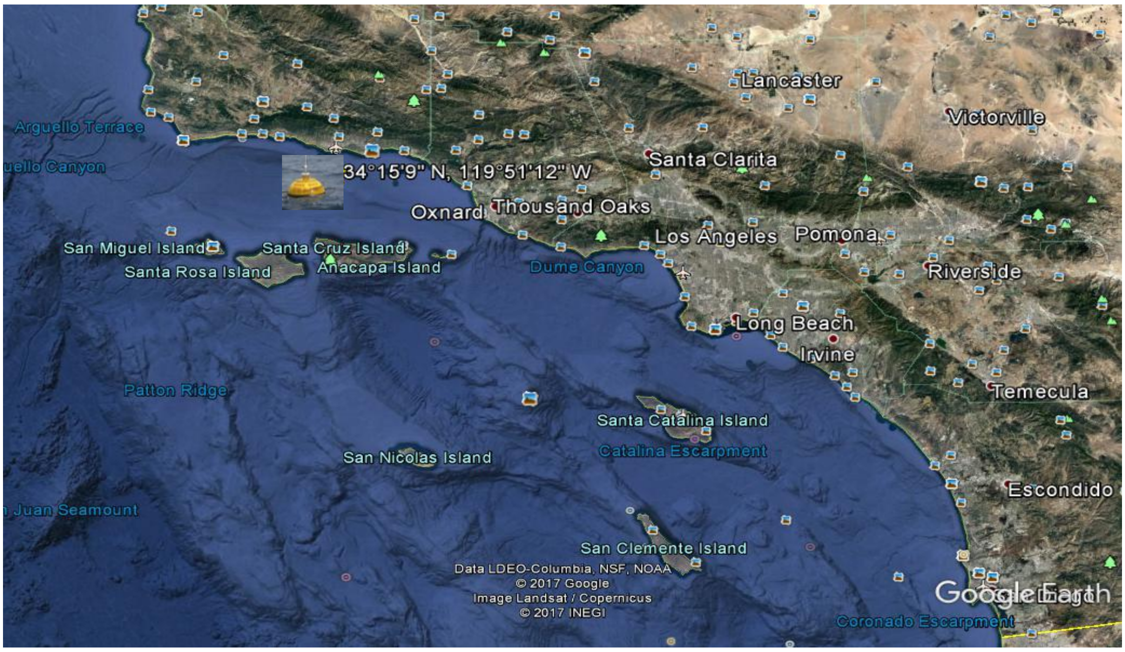


__Figure 3__ Location of the Wave Buoy 46053.

1.2.1. The wave buoy 46025

The Buoy is moored on 905.03 m water depth and provides:

- Significant wave height, Hs, in meters;
- Dominant wave period, Tp, (period with maximum wave energy) in seconds;
- Average wave period, Tm, in seconds;
- Average wave direction, Dir (wave direction at the dominant period), in degrees from the true North.

All data are supplied at a 1-hr time step. Wave directions are available from July 1991 to May 2017 (119268 data on total).Tables 1 and 2 show the directional distribution of Hs and the joint distribution Hs-Tp respectively. Figures 4, 5 and 6 give the wave rose, the histogram of wave directions and the scatter plot Hs, Tp.

Hs(m) / Dir(°N)	≤ 0.50	0.50 ÷ 1.00	1.00 ÷ 1.50	1.50 ÷ 2.00	2.00 ÷ 2.50	2.50 ÷ 3.00	3.00 ÷ 3.50	3.50 ÷ 4.00	4.00 ÷ 4.50	4.50 ÷ 5.00	> 5.00	Total
0° ÷ 10°	0.0034%	0.0537%	0.0243%	0.0034%	-	-	-	-	-	-	-	**0.085%**
10° ÷ 20°	0.0017%	0.0436%	0.0252%	0.0034%	0.0008%	-	-	-	-	-	-	**0.075%**
20° ÷ 30°	0.0008%	0.0537%	0.0386%	0.0327%	0.0059%	-	-	-	-	-	-	**0.132%**
30° ÷ 40°	0.0017%	0.0713%	0.0562%	0.0419%	0.0075%	-	-	-	-	-	-	**0.179%**
40° ÷ 50°	0.0008%	0.0503%	0.0671%	0.0226%	0.0059%	-	-	-	-	-	-	**0.147%**
50° ÷ 60°	0.0008%	0.0319%	0.0268%	0.0143%	-	-	-	-	-	-	-	**0.074%**
60° ÷ 70°	-	0.0243%	0.0117%	0.0025%	-	-	-	-	-	-	-	**0.039%**
70° ÷ 80°	0.0034%	0.0394%	0.0084%	0.0067%	0.0075%	0.0008%	-	-	-	-	-	**0.066%**
80° ÷ 90°	0.0042%	0.0520%	0.0134%	0.0017%	0.0008%	0.0017%	-	-	-	-	-	**0.074%**
90° ÷ 100°	0.0025%	0.0579%	0.0126%	0.0034%	-	0.0008%	-	-	-	-	-	**0.077%**
100° ÷ 110°	0.0042%	0.0688%	0.0218%	0.0075%	-	0.0017%	-	-	-	-	-	**0.104%**
110° ÷ 120°	0.0042%	0.0880%	0.0168%	0.0067%	0.0034%	-	-	-	-	-	-	**0.119%**
120° ÷ 130°	0.0034%	0.1207%	0.0361%	0.0084%	0.0025%	-	-	-	-	-	-	**0.171%**
130° ÷ 140°	0.0059%	0.1710%	0.0880%	0.0075%	0.0034%	-	-	-	-	-	-	**0.276%**
140° ÷ 150°	0.0059%	0.3639%	0.1442%	0.0184%	0.0084%	0.0059%	-	-	-	-	-	**0.547%**
150° ÷ 160°	0.0159%	0.7647%	0.3547%	0.0335%	0.0126%	0.0109%	0.0017%	-	-	-	-	**1.194%**
160° ÷ 170°	0.0176%	1.5411%	0.6674%	0.0587%	0.0168%	0.0109%	0.0059%	-	-	-	-	**2.318%**
170° ÷ 180°	0.0495%	3.0813%	1.0531%	0.0671%	0.0285%	0.0159%	0.0042%	0.0008%	-	-	-	**4.300%**
180° ÷ 190°	0.0989%	4.4882%	1.4555%	0.0989%	0.0285%	0.0134%	0.0067%	0.0017%	-	-	-	**6.192%**
190° ÷ 200°	0.1241%	4.7984%	1.6417%	0.1048%	0.0243%	0.0109%	0.0042%	0.0017%	-	-	-	**6.710%**
200° ÷ 210°	0.1417%	4.1931%	1.3658%	0.0964%	0.0243%	0.0042%	0.0008%	0.0008%	-	-	-	**5.827%**
210° ÷ 220°	0.1006%	3.3446%	1.1470%	0.0763%	0.0117%	0.0025%	0.0008%	0.0008%	-	-	0.0008%	**4.685%**
220° ÷ 230°	0.1065%	2.8004%	1.1227%	0.0964%	0.0268%	0.0084%	-	0.0025%	0.0008%	-	-	**4.165%**
230° ÷ 240°	0.0805%	2.7686%	1.3994%	0.2096%	0.0478%	0.0117%	0.0025%	0.0042%	-	-	-	**4.524%**
240° ÷ 250°	0.0981%	3.3186%	2.5648%	0.5727%	0.1333%	0.0486%	0.0159%	0.0059%	-	0.0008%	-	**6.759%**
250° ÷ 260°	0.0813%	4.8915%	5.8314%	1.6526%	0.3983%	0.1518%	0.0470%	0.0143%	0.0017%	0.0008%	-	**13.071%**
260° ÷ 270°	0.0671%	5.9739%	9.0812%	3.5248%	0.9776%	0.3002%	0.1199%	0.0293%	0.0126%	0.0008%	-	**20.088%**
270° ÷ 280°	0.0436%	2.8767%	4.7070%	2.3435%	0.9910%	0.3287%	0.1090%	0.0201%	0.0075%	0.0025%	0.0008%	**11.431%**
280° ÷ 290°	0.0243%	1.0799%	1.4581%	0.8091%	0.3823%	0.1710%	0.0595%	0.0151%	0.0042%	0.0017%	-	**4.005%**
290° ÷ 300°	0.0193%	0.4519%	0.4243%	0.2398%	0.1350%	0.0579%	0.0252%	0.0067%	-	-	-	**1.360%**
300° ÷ 310°	0.0134%	0.2289%	0.1442%	0.0612%	0.0293%	0.0151%	0.0034%	-	-	-	-	**0.496%**
310° ÷ 320°	0.0059%	0.1585%	0.0595%	0.0109%	0.0050%	0.0025%	-	-	-	-	-	**0.242%**
320° ÷ 330°	0.0025%	0.1274%	0.0411%	0.0042%	0.0008%	-	0.0008%	-	-	-	-	**0.177%**
330° ÷ 340°	0.0050%	0.0989%	0.0218%	0.0050%	-	-	-	-	-	-	-	**0.131%**
340° ÷ 350°	0.0050%	0.0604%	0.0268%	-	-	-	-	-	-	-	-	**0.092%**
350° ÷ 360°	0.0034%	0.0444%	0.0184%	0.0034%	0.0017%	-	-	-	-	-	-	**0.071%**
Total	**1.147%**	**48.382%**	**35.177%**	**10.250%**	**3.322%**	**1.176%**	**0.407%**	**0.104%**	**0.027%**	**0.007%**	**0.002%**	**100.000%**

Table 1 *Directional distribution of Hs for WB 46025.*

Hs(m) / Tp(s)	≤ 0.50	0.50 ÷ 1.00	1.00 ÷ 1.50	1.50 ÷ 2.00	2.00 ÷ 2.50	2.50 ÷ 3.00	3.00 ÷ 3.50	3.50 ÷ 4.00	4.00 ÷ 4.50	4.50 ÷ 5.00	> 5.00	Total
≤ 4	0.0008%	0.2784%	0.0646%	0.0008%	-	-	-	-	-	-	-	**0.345%**
4 ÷ 6	0.0025%	2.8432%	3.7780%	1.0933%	0.2415%	0.0310%	0.0008%	-	-	-	-	**7.990%**
6 ÷ 8	0.0050%	2.6386%	5.2328%	2.6285%	1.3189%	0.5140%	0.1291%	0.0184%	0.0017%	-	0.0008%	**12.488%**
8 ÷ 10	0.0394%	3.5123%	3.5500%	1.0707%	0.3312%	0.0964%	0.0386%	0.0210%	0.0017%	0.0008%	-	**8.662%**
10 ÷ 12	0.1736%	3.8049%	2.9924%	0.8686%	0.2105%	0.0545%	0.0193%	0.0008%	-	-	-	**8.125%**
12 ÷ 14	0.6045%	15.4048%	7.8252%	2.2244%	0.5802%	0.2197%	0.0981%	0.0252%	0.0092%	0.0008%	-	**26.992%**
14 ÷ 16	0.2733%	15.5004%	8.3208%	1.7062%	0.5333%	0.2071%	0.0922%	0.0277%	0.0109%	0.0034%	-	**26.675%**
16 ÷ 18	0.0419%	3.6716%	2.8633%	0.5123%	0.0855%	0.0470%	0.0260%	0.0092%	0.0017%	0.0008%	0.0008%	**7.260%**
18 ÷ 20	0.0059%	0.6154%	0.4352%	0.1132%	0.0143%	0.0050%	0.0034%	0.0017%	0.0017%	0.0008%	-	**1.196%**
> 20	-	0.1124%	0.1149%	0.0319%	0.0067%	0.0008%	-	-	-	-	-	**0.267%**
Total	**1.147%**	**48.382%**	**35.177%**	**10.250%**	**3.322%**	**1.176%**	**0.407%**	**0.104%**	**0.027%**	**0.007%**	**0.002%**	**100%**

Table 2 *Joint distribution Hs-Tp for WB 46025.*

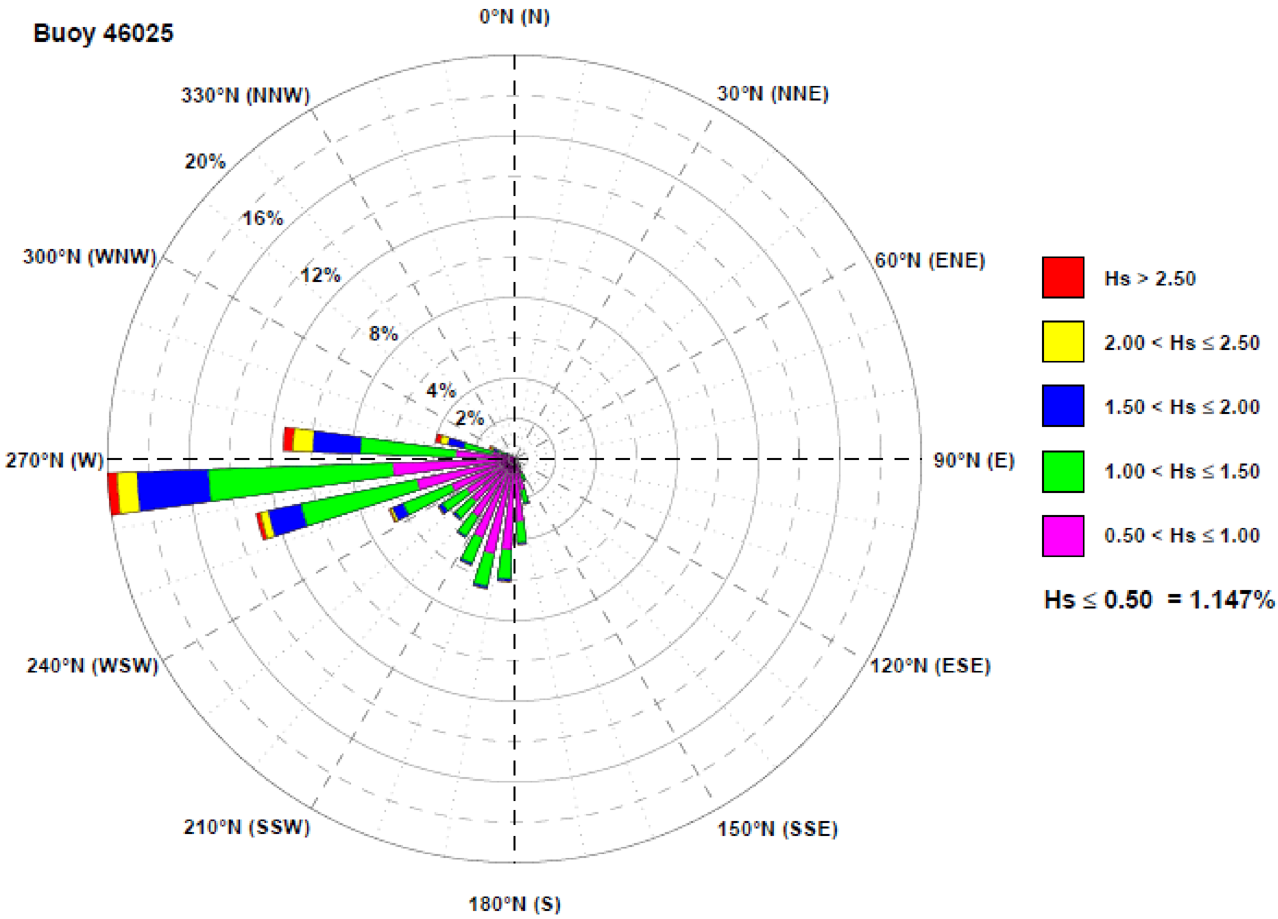


Figure 4 *Wave Rose for WB 46025.*

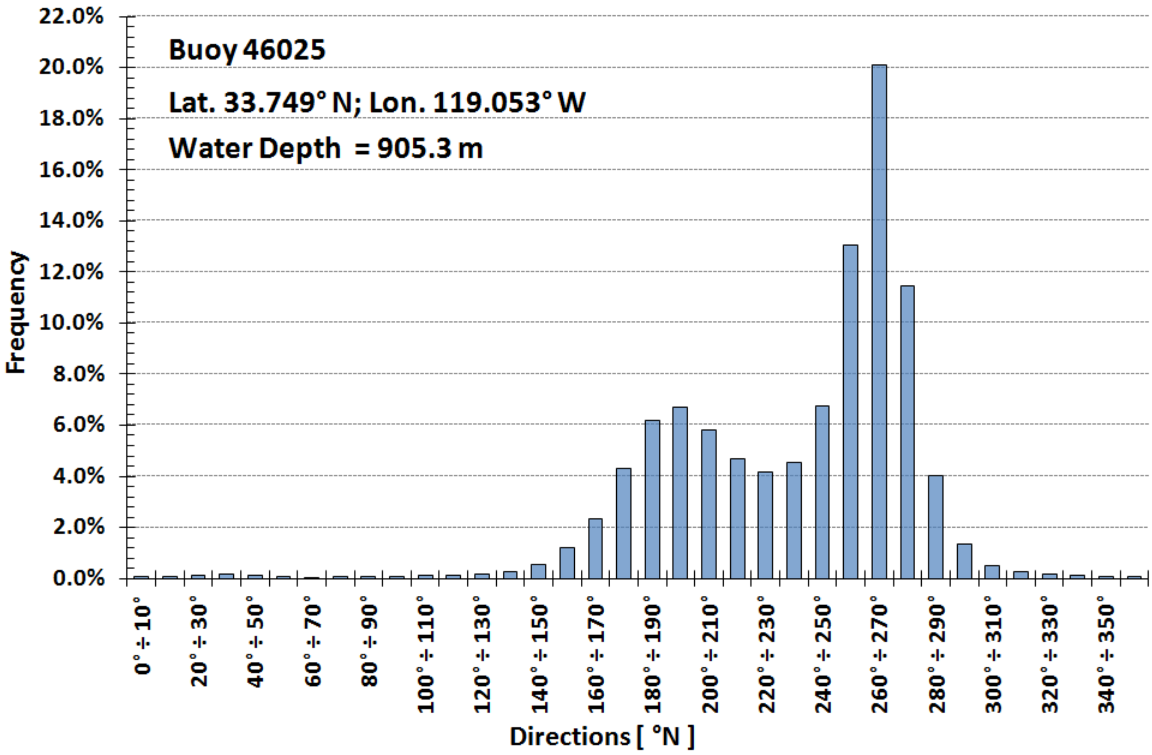


Figure 5 *Histogram of wave directions for WB 46025.*

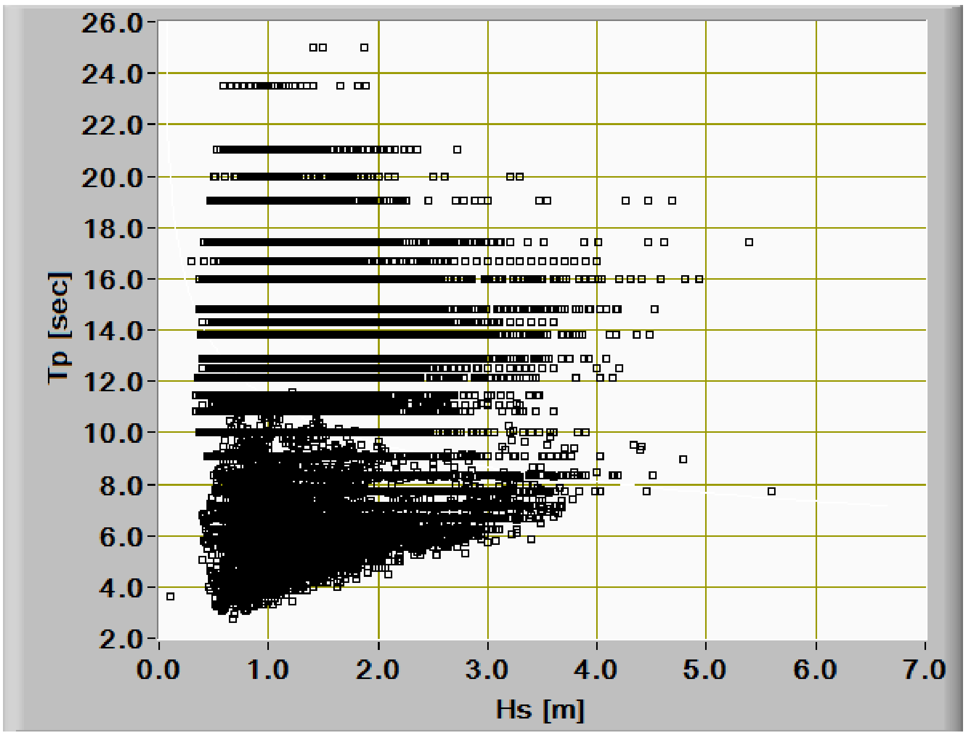


Figure 6 *Scatter plot Hs Tp for WB 46025.*

1.2.2. The wave buoy 46053

Buoy 46053 gives 1-hourly sampled data from January 1994 to January 2008 and half-hourly sampled data from February 2008 to May 2017 (85574 valid data on total). The wave climate characteristics are summarized in Tables 3 and 4, as well as in Figures 7-9.

Hs(m) / Dir(°N)	≤ 0.50	0.50 ÷ 1.00	1.00 ÷ 1.50	1.50 ÷ 2.00	2.00 ÷ 2.50	2.50 ÷ 3.00	3.00 ÷ 3.50	3.50 ÷ 4.00	4.00 ÷ 4.50	4.50 ÷ 5.00	> 5.00	Total
0° ÷ 10°	0.0058%	0.0140%	0.0082%	0.0012%	-	-	-	-	-	-	-	0.029%
10° ÷ 20°	0.0058%	0.0152%	0.0035%	0.0012%	-	-	-	-	-	-	-	0.026%
20° ÷ 30°	0.0023%	0.0105%	0.0012%	0.0012%	-	-	-	-	-	-	-	0.015%
30° ÷ 40°	0.0012%	0.0117%	0.0012%	-	-	-	-	-	-	-	-	0.014%
40° ÷ 50°	0.0035%	0.0082%	0.0047%	-	-	-	-	-	-	-	-	0.016%
50° ÷ 60°	0.0035%	0.0105%	0.0023%	-	-	-	-	-	-	-	-	0.016%
60° ÷ 70°	0.0012%	0.0093%	-	0.0012%	-	-	-	-	-	-	-	0.012%
70° ÷ 80°	0.0012%	0.0117%	0.0117%	0.0012%	-	-	-	-	-	-	-	0.026%
80° ÷ 90°	0.0070%	0.0210%	0.0187%	0.0012%	0.0012%	-	-	-	-	-	-	0.049%
90° ÷ 100°	0.0129%	0.0304%	0.0538%	0.0222%	0.0082%	-	-	-	-	-	-	0.127%
100° ÷ 110°	0.0140%	0.0479%	0.0491%	0.0386%	0.0164%	0.0035%	-	-	-	-	-	0.169%
110° ÷ 120°	0.0105%	0.0678%	0.0351%	0.0199%	0.0070%	0.0012%	-	-	-	-	-	0.141%
120° ÷ 130°	0.0129%	0.0444%	0.0245%	0.0070%	0.0023%	-	-	-	-	-	-	0.091%
130° ÷ 140°	0.0105%	0.0327%	0.0082%	-	0.0012%	0.0012%	-	-	-	-	-	0.054%
140° ÷ 150°	0.0164%	0.0222%	0.0058%	-	-	-	-	-	-	-	-	0.044%
150° ÷ 160°	0.0140%	0.0210%	0.0023%	-	-	-	-	-	-	-	-	0.037%
160° ÷ 170°	0.0082%	0.0234%	0.0047%	-	-	-	-	-	-	-	-	0.036%
170° ÷ 180°	0.0082%	0.0351%	0.0047%	0.0012%	-	-	-	-	-	-	-	0.049%
180° ÷ 190°	0.0164%	0.0397%	0.0070%	-	-	-	-	-	-	-	-	0.063%
190° ÷ 200°	0.0222%	0.0573%	0.0152%	0.0012%	-	-	-	-	-	-	-	0.096%
200° ÷ 210°	0.0257%	0.0678%	0.0199%	0.0012%	0.0012%	-	-	-	-	-	-	0.116%
210° ÷ 220°	0.0479%	0.1204%	0.0374%	0.0070%	-	-	-	0.0012%	-	-	-	0.214%
220° ÷ 230°	0.0689%	0.3085%	0.1180%	0.0164%	0.0187%	0.0012%	-	0.0012%	-	-	-	0.533%
230° ÷ 240°	0.1683%	0.9921%	0.4803%	0.1192%	0.0479%	0.0082%	0.0023%	0.0035%	0.0012%	-	-	1.823%
240° ÷ 250°	0.2512%	3.5688%	2.6620%	0.8250%	0.2805%	0.0818%	0.0339%	0.0222%	0.0012%	-	-	7.727%
250° ÷ 260°	0.4569%	7.1762%	6.8303%	2.5510%	0.9430%	0.3436%	0.1028%	0.0339%	0.0152%	0.0058%	0.0012%	18.460%
260° ÷ 270°	0.7771%	9.8266%	10.5605%	3.9299%	1.2971%	0.4219%	0.1180%	0.0456%	0.0152%	0.0058%	0.0023%	27.000%
270° ÷ 280°	0.5971%	8.3577%	9.6314%	4.6334%	1.7470%	0.4861%	0.1239%	0.0421%	0.0152%	0.0035%	0.0035%	25.641%
280° ÷ 290°	0.2033%	3.7815%	4.4044%	2.9285%	1.3754%	0.3903%	0.0947%	0.0444%	0.0093%	0.0093%	-	13.241%
290° ÷ 300°	0.0689%	0.8110%	0.8519%	0.8168%	0.4616%	0.1297%	0.0421%	0.0082%	-	-	-	3.190%
300° ÷ 310°	0.0245%	0.1858%	0.1496%	0.1169%	0.0596%	0.0187%	0.0070%	0.0023%	0.0012%	-	-	0.566%
310° ÷ 320°	0.0105%	0.0771%	0.0467%	0.0140%	0.0047%	-	-	-	-	-	-	0.153%
320° ÷ 330°	0.0164%	0.0526%	0.0210%	0.0035%	0.0023%	-	-	-	-	-	-	0.096%
330° ÷ 340°	0.0058%	0.0316%	0.0140%	0.0035%	-	-	-	-	-	-	-	0.055%
340° ÷ 350°	0.0093%	0.0245%	0.0058%	0.0012%	-	-	-	-	-	-	-	0.041%
350° ÷ 360°	0.0070%	0.0152%	0.0082%	0.0023%	-	-	-	-	-	-	-	0.033%
Total	2.917%	35.931%	36.103%	16.067%	6.275%	1.887%	0.525%	0.205%	0.058%	0.025%	0.007%	100%

Table 3 *Directional distribution of Hs for WB 46053.*

Hs(m) / Tp(s)	≤ 0.50	0.50 ÷ 1.00	1.00 ÷ 1.50	1.50 ÷ 2.00	2.00 ÷ 2.50	2.50 ÷ 3.00	3.00 ÷ 3.50	3.50 ÷ 4.00	4.00 ÷ 4.50	4.50 ÷ 5.00	> 5.00	Total
≤ 4	0.0888%	0.7607%	0.0538%	-	-	-	-	-	-	-	-	**0.903%**
4 ÷ 6	0.1461%	5.8090%	5.7015%	1.5343%	0.2419%	0.0058%	-	-	-	-	-	**13.439%**
6 ÷ 8	0.5002%	6.4073%	6.4541%	1.9831%	0.7362%	0.1461%	0.0117%	0.0023%	-	-	-	**16.241%**
8 ÷ 10	0.8764%	9.2832%	7.3901%	2.8104%	0.7678%	0.2068%	0.0316%	0.0058%	-	-	-	**21.372%**
10 ÷ 12	0.3237%	4.4710%	4.5072%	2.0357%	0.7713%	0.2185%	0.0491%	0.0058%	-	-	-	**12.382%**
12 ÷ 14	0.4896%	5.7179%	8.1205%	5.1347%	2.2472%	0.6123%	0.1881%	0.0631%	0.0070%	0.0035%	-	**22.584%**
14 ÷ 16	0.3775%	2.4447%	2.6188%	1.8393%	1.1102%	0.5118%	0.1741%	0.0888%	0.0316%	0.0070%	-	**9.204%**
16 ÷ 18	0.0865%	0.7339%	0.8355%	0.4779%	0.3085%	0.1578%	0.0538%	0.0327%	0.0164%	0.0082%	0.0058%	**2.717%**
18 ÷ 20	0.0199%	0.2594%	0.3377%	0.2010%	0.0736%	0.0222%	0.0129%	0.0058%	0.0035%	0.0058%	0.0012%	**0.943%**
> 20	0.0082%	0.0444%	0.0841%	0.0502%	0.0187%	0.0058%	0.0035%	-	-	-	-	**0.215%**
Total	**2.917%**	**35.931%**	**36.103%**	**16.067%**	**6.275%**	**1.887%**	**0.525%**	**0.205%**	**0.058%**	**0.025%**	**0.007%**	**100%**

Table 4 *Joint distribution Hs-Tp for WB 46053.*

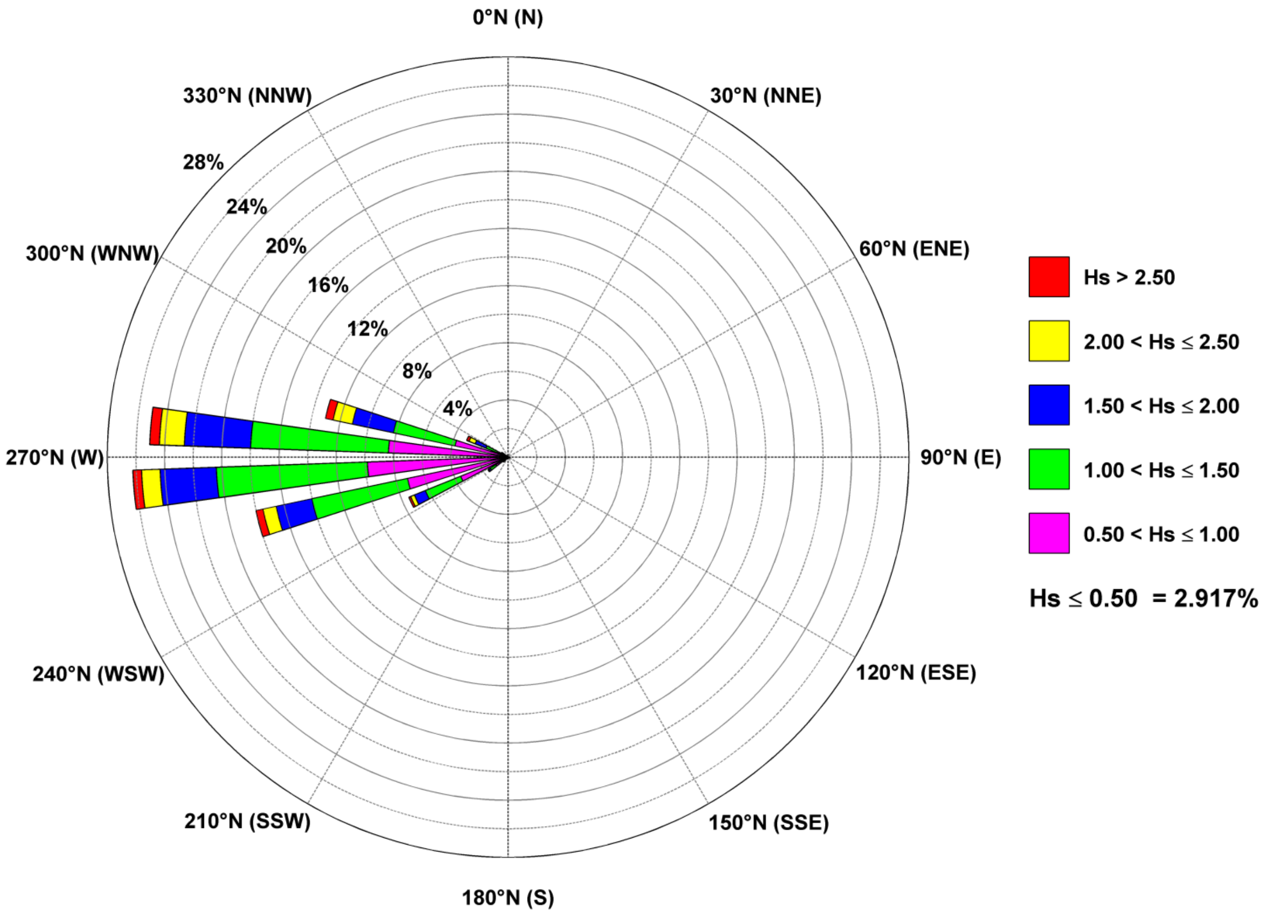


Figure 7 *Wave Rose for WB 46053.*

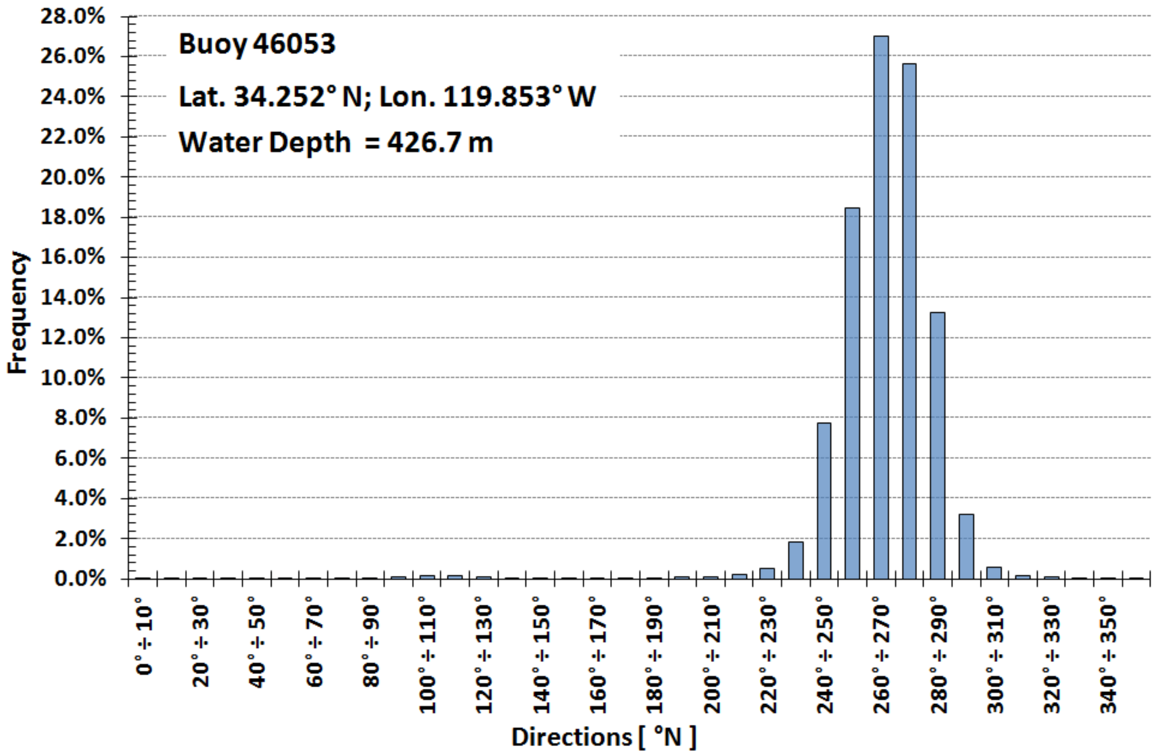


Figure 8 *Histogram of wave directions for WB 46053.*

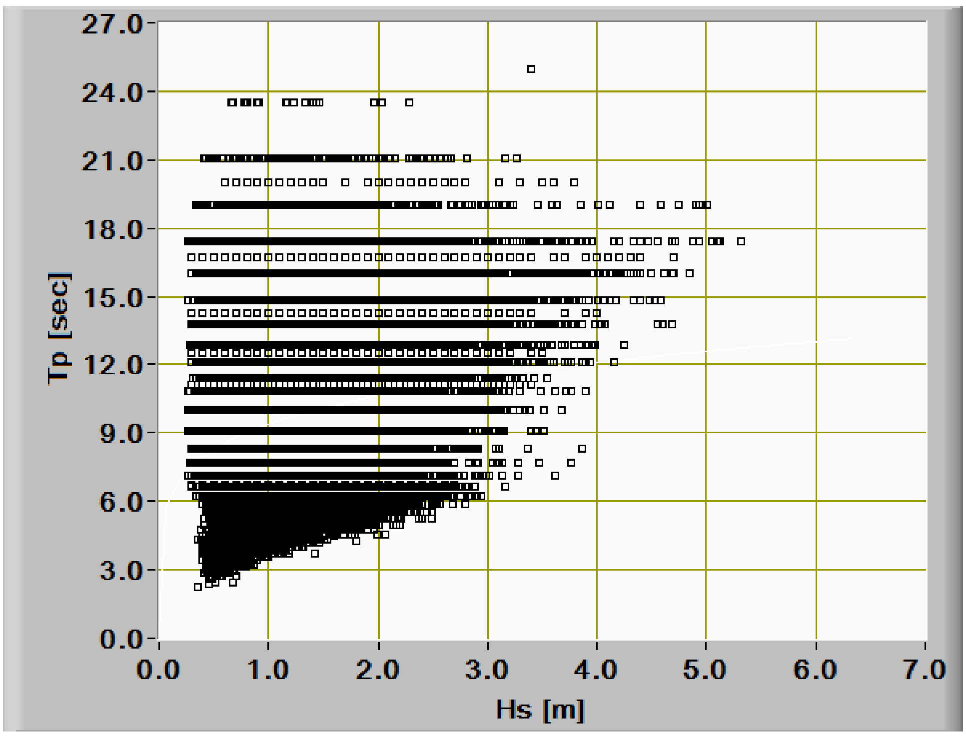


Figure 9 *Scatter plot Hs-Tp for WB 46053.*

1.2.3. General characteristics of wave climate

From the inspection of tables and graphs reported above, it can be readily concluded that:

I. The most frequent and the most energetic wave attacks come from the West direction (around 270°N, Figures 4 and 7), according to the studies previously carried out on the site of *Broad Beach*;

II. There is no significant relationship between significant wave height, Hs, and peak period, Tp (Figures 6 and 9). The average Tp equals **11.85s** on WB 46025 and **10.22s** on WB 46053.

1.3 Extreme (long term) wave statistics.

To assess the response of the reef under extreme seas, the Annual Maxima Series (AMS) of Hs for WB 46025 has been analyzed. WB 46053 has been preliminarily not considered at this stage, since it includes waves propagating at great angles, which will be likely reduced by wave refraction. A 3-parametric Weibull distribution in the form:

$$F(H^*) = Prob(Hs \leq H^*) = 1 - \exp\left[-\left(\frac{H^* - A}{B}\right)\right] \tag{1.1}$$

proved to be the most suited to fit the data, as shown in Figure 10.

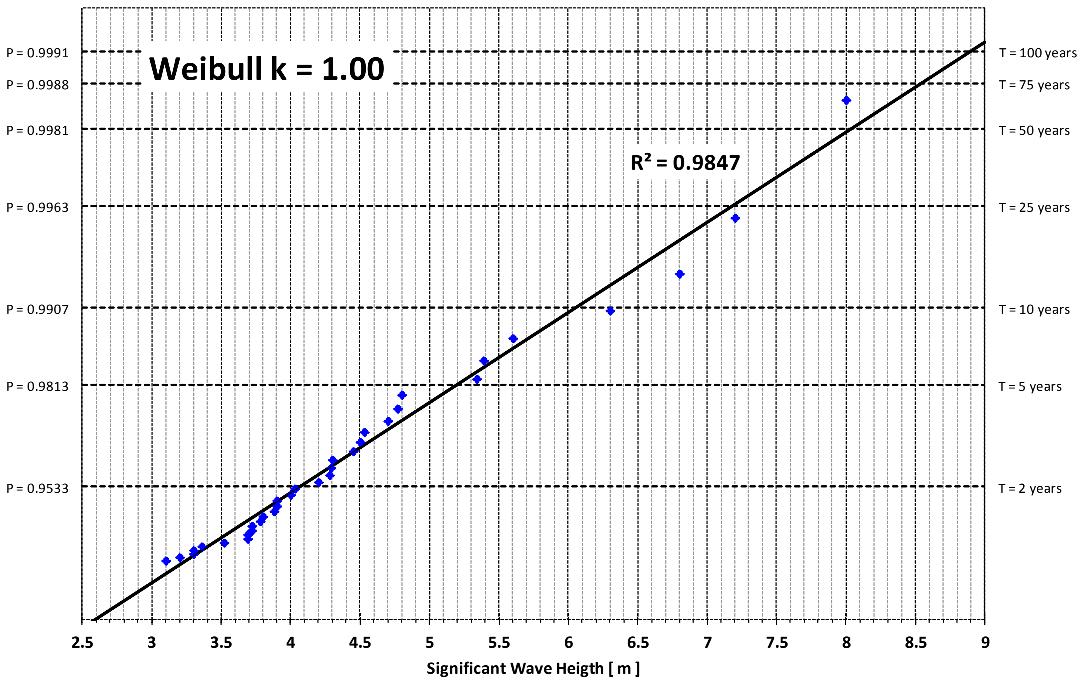


Figure 10 *AMS of Hs on a Weibull chart (WB 46025).*

Thus, the following extreme wave statistics have been inferred:

Return period (years)	Hs (m)	Tp (s)
2	4.08	10.12
5	5.20	11.43
10	6.06	12.34
15	6.56	12.83
20	6.91	13.18
25	7.18	13.44
50	8.04	14.21

Table 5 *Extreme wave climate for WB 46025*

Note that values of Tp have been obtained through the formula:

$$Tp = \frac{2\pi}{0.4}\sqrt{\frac{Hs}{g}} \tag{1.2}$$

where g is gravity. Eq. (1.2) assumes a *Pierson and Moskovitz* wave spectrum, valid for *fully developed seas*.

In this feasibility study, the waves of Table 5 are assumed to conservatively propagate normal to the shore.

2. WATER LEVELS

Water levels are crucial to the design of the reef, since they rule either the efficiency in attenuating waves or the degree of visual intrusion in the landscape. In this section, the effects of tides, storm surge and rise of the mean sea level are discussed.

2.1. Tides

Tide data have been gathered at the station **ICAC1** (Figure 11), close to the Santa Monica coast. Values of the sea level have been acquired from 1994/1/1 through 2017/7/6 at a rate of 6 min. Figure 12 pictures the *Cumulative distribution Function (CdF)* from the MLLW. For each value of the abscissa, *x*, *CdF* gives the percentage of time in which the tide level does not exceed *x*. Table 6 reports the *CdF* of selected sea levels.

2.2. Extreme Sea Levels

Extreme values of the sea level for design purposes have been taken from the "*Broad Beach Restoration Project Coastal Engineering Appendix To The Broad Beach Geologic Hazard Abatement District Engineers Report 2015 Update*" prepared by Moffat & Nichols in June 2015.

A statistical analysis of extreme water elevations (<u>including tide and storm surge</u>) was developed based on recorded annual extreme high water elevations obtained from the National Ocean Service for the outer Los Angeles Harbor reference tide station. Water elevation records were taken from 1923 to 2002. Results are reported in Table 7.

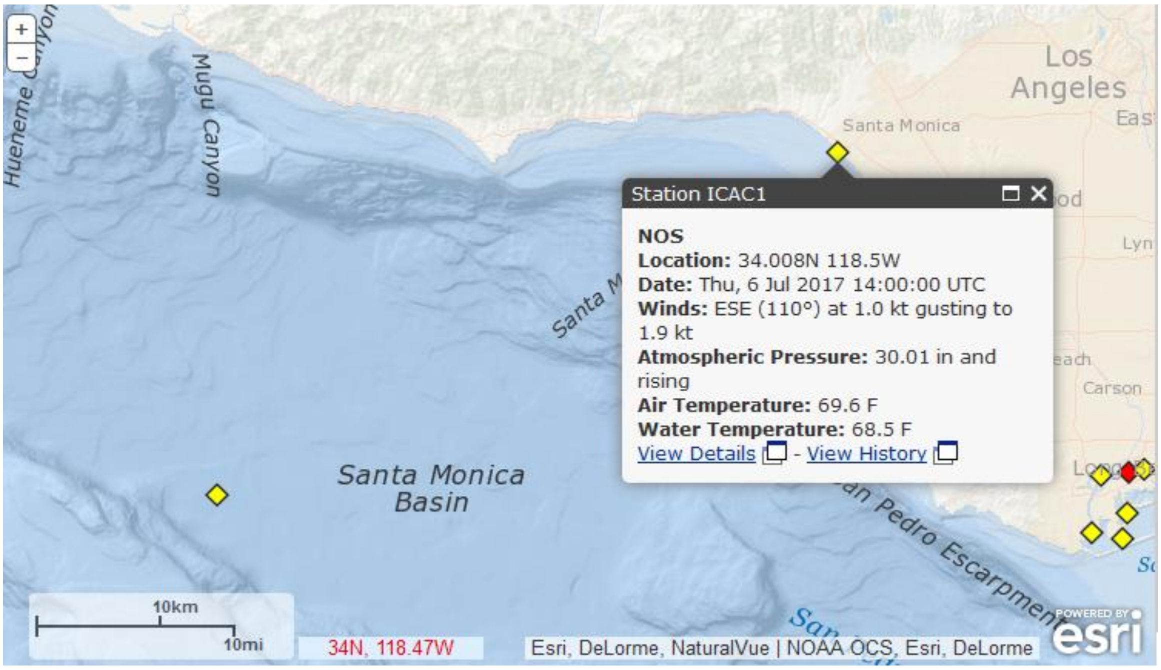


Figure 11 *The station ICAC1.*

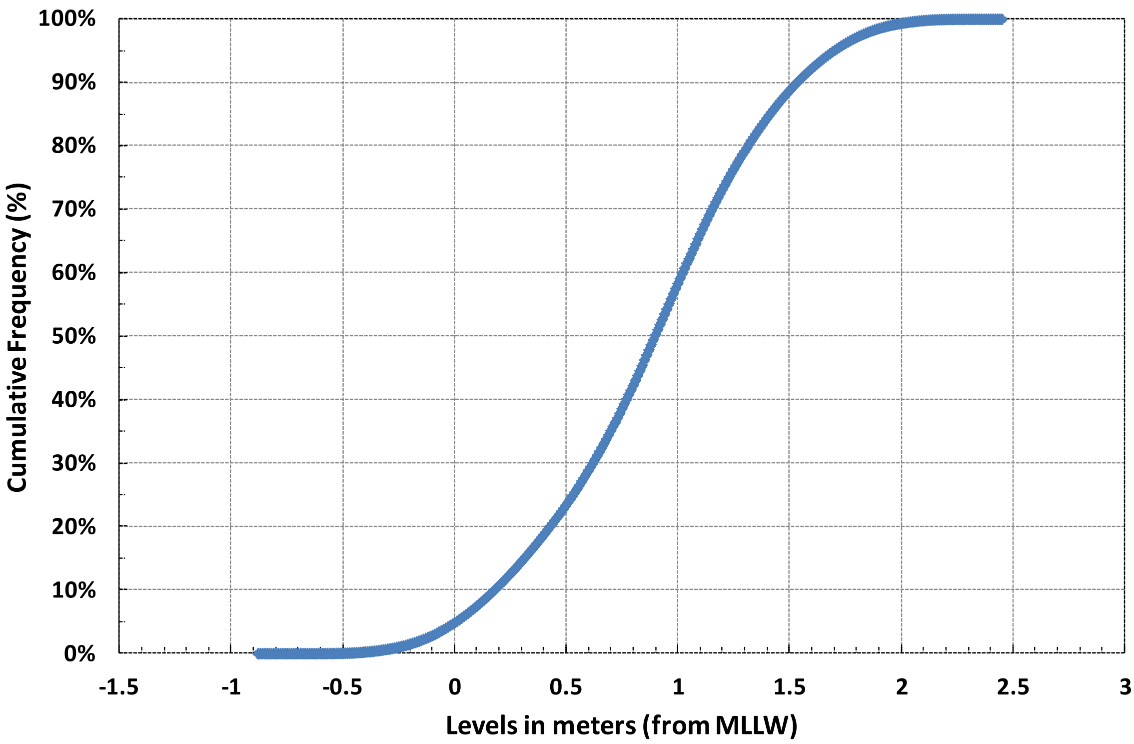


Figure 12 *CdF of tide levels.*

Level	value (m)	CdF (%)	hours/day on average
MLLW	0	5.00	1.2
MLW	0.283	13.75	3.3
MSL	0.849	46.29	11.10
MHL	1.429	85.86	20.40
MHHL	1.659	94.32	22.63

Table 6 *CdF for delected tide levels.*

Return period (years)	Extreme water level from MLLW (m)
5	2.26
10	2.32
25	2.35
50	2.41
100	2.44

Table 7 *Extreme sea levels (source: Moffat & Nichol 2015).*

2.3. Long Term Sea Level Rise

Estimates of long term sea level rise are affected by a large uncertainty. The projections of the *National Research Council (NRC)* by 2050 range from 0.12 and 0.60m, with an expected value of 0.27m (Moffat & Nichol, 2015). On the other hand, information collected directly on site suggest an expected rise rate of 0.0015 m/year, corresponding to approximately 0.05m in 33 years (R.K. Browne, personal communication).

Despite the long term set-up of the sea level rise is, in principle, an important design variable, it is readily seen that it affects the results of this feasibility study only slightly. This because a long term variation of the water level as large as 0.60m can be easily compensated by an adjustment of the top of the reef. For this reason, according to the conclusions of the Reef Specialist Debrief held in Malibu on 2017/6/28, it has been decided to leave SLR out of consideration at this stage.

3. BEACH MORPHOLOGY

3.1. Cross shore beach profile

The cross-shore profile of the beach has been reconstructed using:

a) The *Broad Beach Fall 2011 Profile Survey* conducted by Coastal Frontiers Corporation for Moffat & Nichol;

b) The bathymetric study carried out by *Chambers Group*, upon request of the Army Corps of Engineers on May 2014.

The *Broad Beach Fall 2011 Profile Survey* supplies for five transects (Figures 13 and 14)

- 3 fall profiles (Oct 2009, Nov 2010 a15nd Oct 2011);
- 1 spring profile (May 2011).

The survey extends about 500m offshore the MLLW shoreline.

Figure 13 *Transects of the Broad Beach Fall 2011 Profile Survey.*

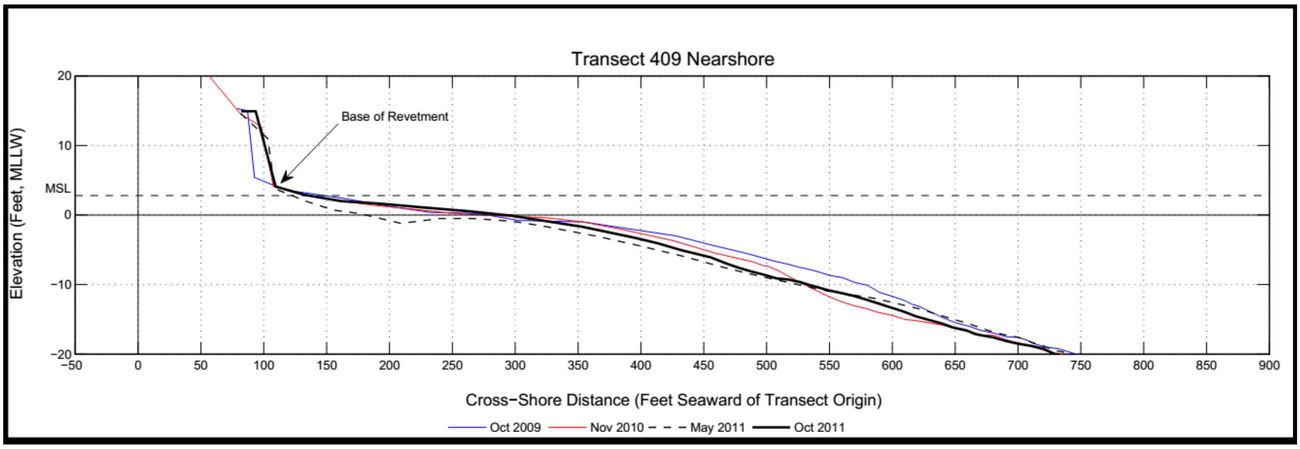


Figure 14 *Example of beach profile from the Broad Beach Fall 2011 Profile Survey.*

Chambers Group performed its bathymetric analysis on May 2014. Figure 15 provides a plan view of the obtained results.

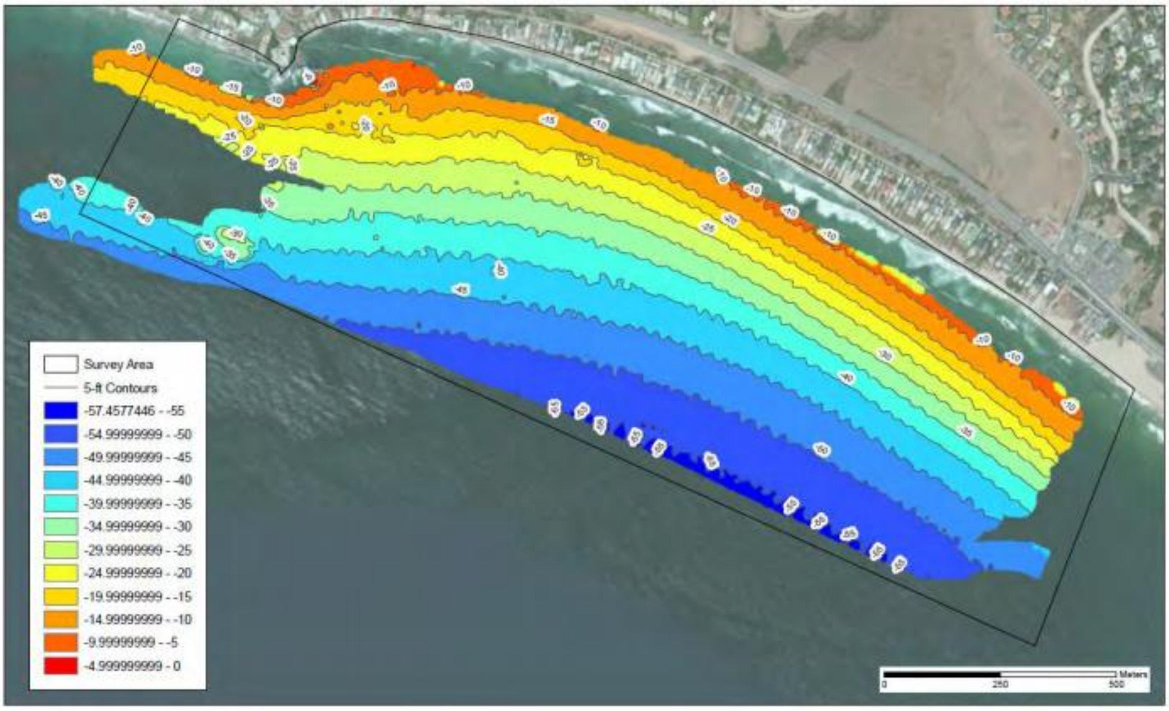


Figure 15 *Bathymetric study for Broad Beach conducted by Chambers Group.*

Moreover, in June 2014, a dive survey was also conducted to characterize the dominant fauna and flora within identified habitats (Figure 16).

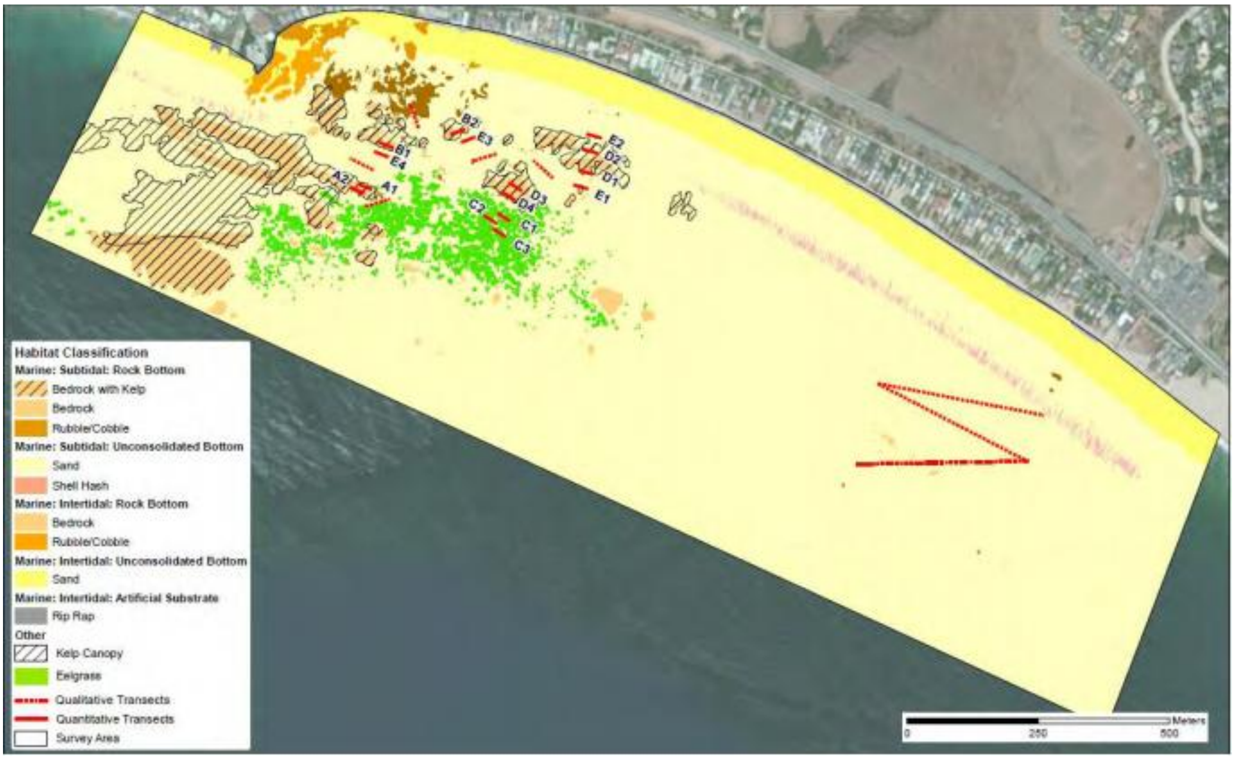


Figure 16 *Transects sampled for subtidal community study.*

In this study, which is of a purely conceptual nature, available data have been handled as follows:

a) <u>*Broad Beach Fall 2011 Profile Survey*</u>

- Only the transects 409-410-411 have been considered, corresponding to the (hypothetic) zone of placement of the Reef (Figure 13);
- For each transect, the 3 fall profiles have been first averaged; then an average is taken with the spring profile. This gives an “annually averaged profile” for each transect
- The “annually averaged profiles” of transects 409-410-411 have been finally averaged, to get an ideal mean beach profile.

b) <u>*Army Corps of Engineers*</u>

- From the plan view of Figure 15, three profiles have been reconstructed that correspond to the transects 409-410-411. Then the three profiles have been averaged.

Figure 17 compares the obtained results. The profiles appear similar only in the range 0 - 2m. As for the rest, *Army Corps* data draws a gentler beach, with slopes not exceeding 4% up to 5m below the MLLW (Figure 18).

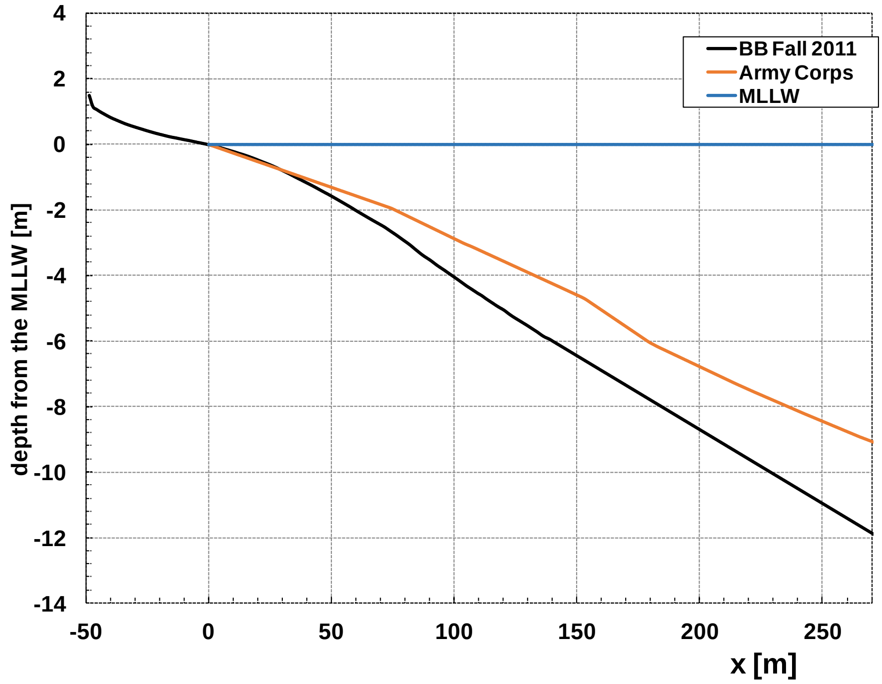


Figure 17 *Comparison between BB Fall 2011 and Army Corps beach profiles.*

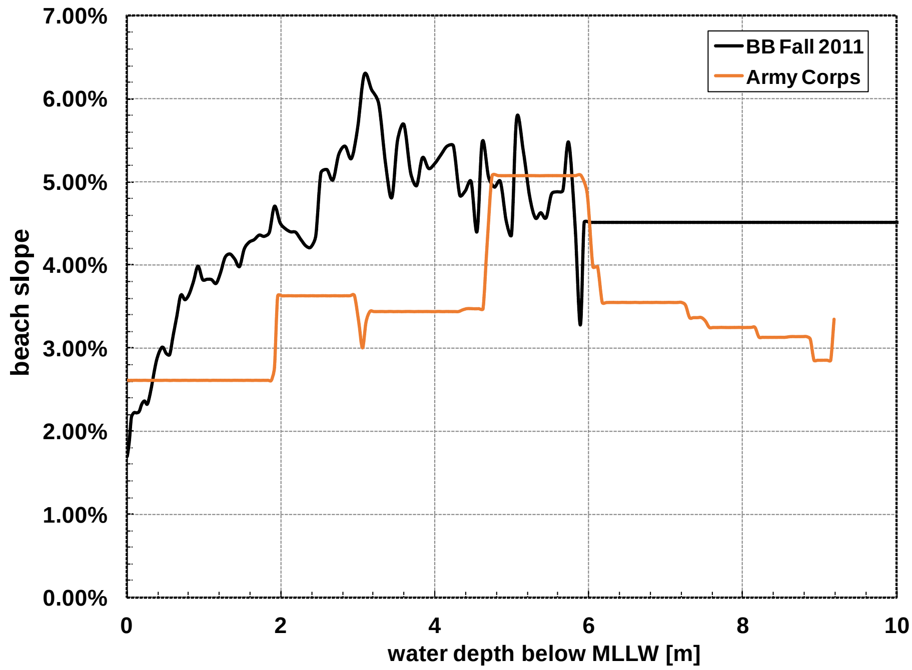


Figure 18 *Slope of the underwater beach.*

3.2. Depth of closure

<u>The depth of closure</u>, *dc*, is essentially the water depth offshore which waves have no significant interaction with sea bottom. It can be most reliably estimated from the *Broad Beach Fall 2011 Profile Survey*, as the point where all the four available profiles converge in one (e.g. Figure 19).

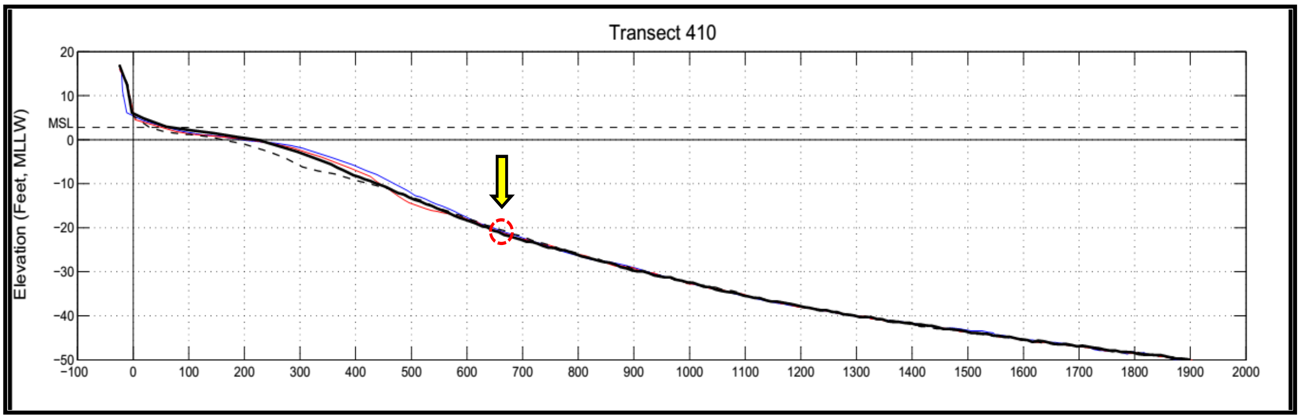


Figure 19 *Depth of closure for Transect 409.*

From the values obtained at each transect (Table 8), an average of **7.38**m has been calculated.

Transect #	**Depth of Closure (m)**
408	7.62
409	7.01
410	7.92
411	7.32
412	7.02

Table 8 *Depth of closure for transects of the Broad Beach Fall 2011 Profile Survey.*

Hallermeier (1981) suggested estimating the depth of closure based on the wave climate, according to the formula:

$$dc = 2\,H_{s,\mu} + 11H_{s,\sigma} \tag{3.1}$$

where $H_{s,\mu}$ and $H_{s,\sigma}$ are the mean and the standard deviation of the significant wave height respectively. From data of the buoy **46025,** one obtains:

$$H_{s,\mu} = 1.13m$$

$$H_{s,\sigma} = 0.45m$$

and hence:

$$dc = 2 \cdot 1.13m + 11 \cdot 0.45m = 7.25m$$

which is consistent with the direct estimation.

3.3. Equilibrium Beach Profile

It is commonly assumed that the cross-shore profile of a beach tends to oscillate around an ideal "*Equilibrium Profile"*, whose mathematical form is (Dean 1977):

$$d = A \cdot x^{\frac{2}{3}} \tag{3.2}$$

In the equation above, *d* represents the water depth at a distance *x* from the shoreline; *A* is a **scale parameter**, which can be estimated from the knowledge of the *depth of closure dc* and of its distance from the shoreline *x*c. It is clear that:

$$A = \frac{dc}{(xc)^{2/3}} \tag{3.3}$$

The results based on the data here available are summarized in Table 9.

Profile (Fig.17)	**dc (m)**	**xc (m)**	**A ($m^{1/3}$)**
Fall 2011 Survey	7.38	170.70	0.24
Army Corps	7.38	216.41	0.20

Table 9 *Scale parameter for the available data.*

Both the depth of closure, *dc,* and the scale parameter, *A*, are crucial to the modeling of the long term evolution of the beach.

3.4. Alongshore orientation of the shoreline

As pointed out in the *Coastal Engineering Appendix to GHAD Engineer's Report 2015, Broad Beach* lies within the *Modern Malibu Littoral Cell* (MMLC), which extends from *Port Hueneme*, to the North, to *Marina del Rey*, to the South (Figure 20).

Figure 20 *The MMLC. Source: Coastal Engineering Appendix to the GHAD Engineer's Report 2015.*

However, to study the capability of a reef in retaining sand on Broad Beach, it is of convenient to model the response of the shoreline bounded by *Point Lechuza* to the North and *Point Dume* to the South (Figure 21). This because both *Point Lechuza* and *Point Dume* are rocky sites, where the position of the shoreline can be considered constant in time (*pinned points*). This provides good boundary conditions for the long term modeling.

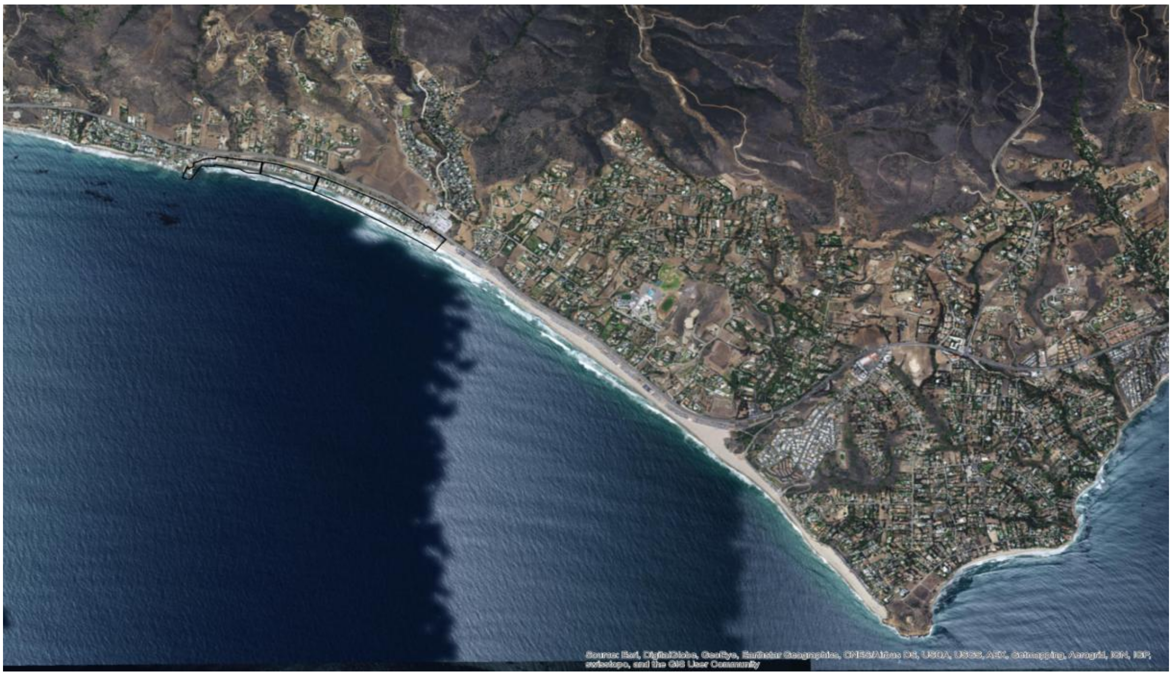


Figure 21 *Aerial photograph of the shoreline from Point Lechuza (to the west) to Point Dume (to the east). Courtesy of Ben Suber (Schmitz & Associates, Inc.)*

It is worth mentioning that, due to the wide tidal range, reconstructing the actual position of the shoreline (relative to MLLW) from aerial photographs and nautical charts has resulted rather difficult. This represents one of the most important source of uncertainty of present study, and an ad hoc survey is recommended for future investigations.

The Figure 22 pictures the orientation of the shoreline; the azimuth of the normal to the coast decreases from 230°N at *Point Dume*, to 190°N at *Point Lechuza.* At *Broad Beach*, the normal orientation ranges from 190° to approximately 210°.

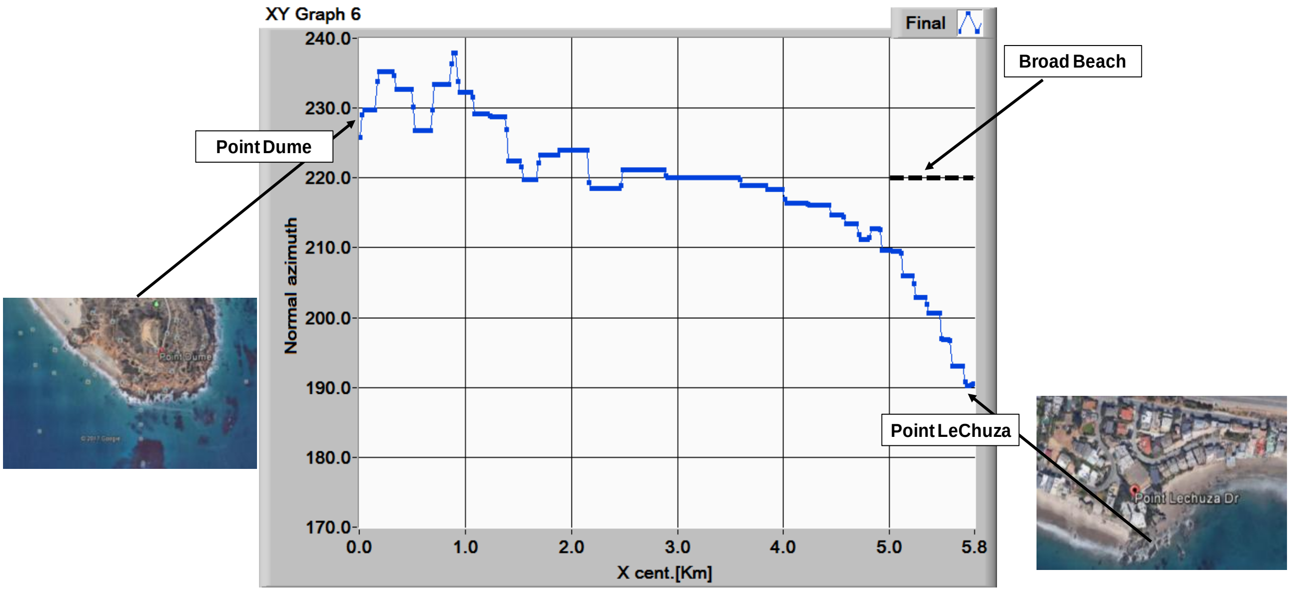


Figure 22 *Azimuth of normal to the shoreline.*

4. SEDIMENT TRANSPORT ANALYSIS

According to the *Coastal Engineering Appendix to GHAD Engineer's Report 2015*, *Broad Beach* lost approximately 458,733 cubic meters (600,000 cy) of sand between 1974 and 2009, with an average deficit of approximately 15,291 cubic meters (20,000cy) per year in the period 1968-2009 . An acceleration of the erosional rate was also noticed between 2004-2009, with a loss of 26,759 cubic meters per year (35,000 cy). It was concluded the sand imbalance to have been due to a west to east littoral drift gradient, created either by a reduction in sand supplying entering around Lechuza Point or an increase of longshore sediment transport towards Trancas Creek.

Previous conclusion has been checked through the *Littoral Drift Rose* concept described below.

4.1. The Littoral Drift Rose (LDR)

The Littoral Rose Drift (Walton, 1973; Waltan and Dean 2010) is a compact polar graph representation of the potential littoral drift for various shoreline orientations (β). For a given deep water wave climate, characterized by a series of events (Hs, Tp, Dir), it can be shown that the potential littoral drift rate can be expressed as follows:

$$Q\ (\beta) = \sum P \cdot \frac{K \cdot (Hs)^{2.4} \cdot (Tp)^{0.2} \cdot g^{0.6}}{16 \cdot (S-1)(1-n)\pi^{0.2}\gamma^{0.4}} \cdot sin\ 2(\beta - Dir) \tag{4.1}$$

where:

- Q is the in-place volumetric transport of sediment past a hypothetical plane perpendicular to the beach;
- K is a *sediment transport coefficient*;
- g is gravity;
- $S \approx 2.6$ is the specific gravity of sediment;
- $n \approx 0.4$ is the porosity;
- $\gamma \approx 0.6$ is the breaker index (wave height to depth ratio);
- β is the azimuth of the outward normal to the shoreline;
- Dir is the azimuth from which waves originate;
- P is the probability of occurrence of the event (Hs, Tp, Dir) and the summation includes all the events with $\beta - 90° \leq Dir \leq \beta + 90°$.

LDR is based on the well-known CERC formula for littoral drift and is consistent with the standard US convention that alongshore sediment transport is positive if it moves to the right (when looking offshore, Figure 23)

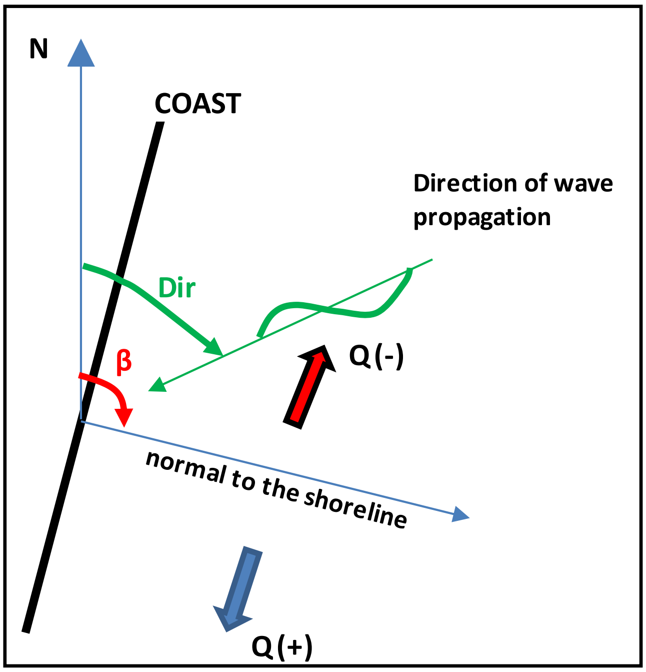


Figure 23 *Definition sketch for LDR.*

4.2. Application of the LDR concept to Broad Beach

The Figures 24 and 25 show the LDRs for the buoy **46025** and **46053** respectively. In the calculations, a value of the sediment transport coefficient K = 0.39 has been employed, according to SPM 1984. The graph suggest that:

- The waves reaching *Broad Beach* (shoreline orientation 190-210°N) through the *Santa Barbara Channel* (buoy **46053,** Figure 24), do not produce significant littoral drift, due to their large inclination relative to the beach.
- Waves recorded by buoy **46025** (Figure 25) induce a *negative drift*, that is the sediment transport is directed from West to East;
- Since moving from West to East the shoreline orientation at *Broad Beach* increases from 190°N to 210°N, the littoral drift is expected to grow in magnitude along Broad Beach; this causes a sand deficit, which produces in turn a structural erosion of the shoreline;
- The potential imbalance (setting K = 0.39) is of 0.02 cubic meters/s, corresponding to 630,720 cubic meters/year. This means that to pass from the potential to the real sand loss rate (15,291cubic meters/year), a value of $K \approx$ 0.001should be adopted.

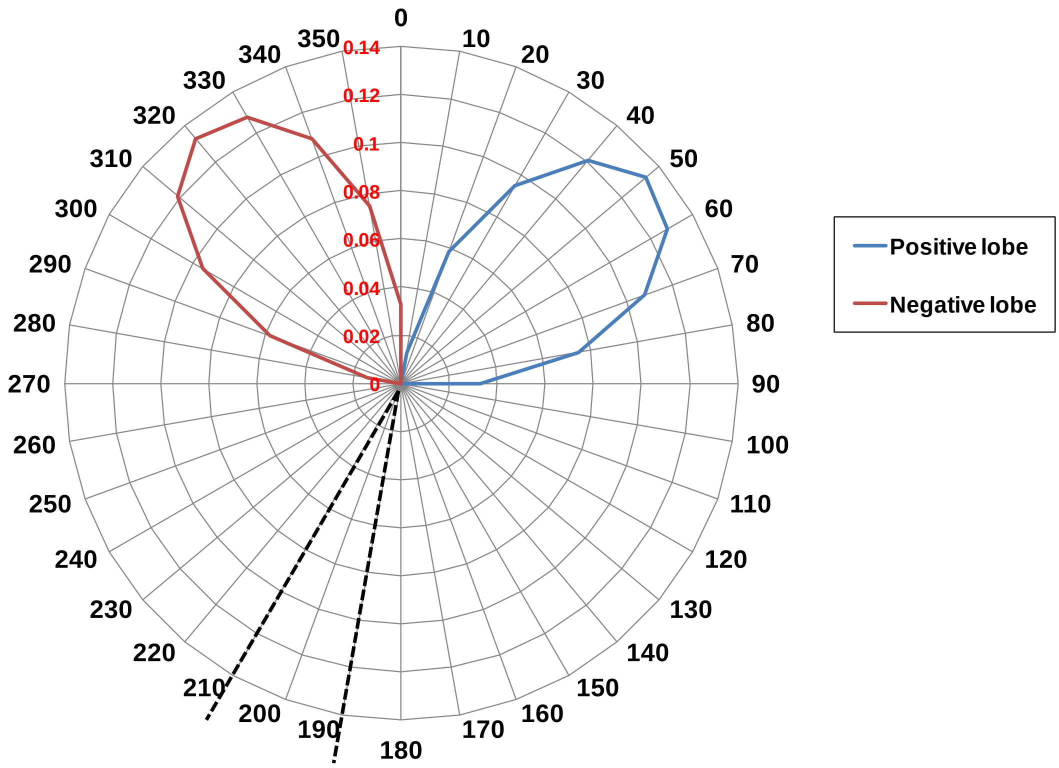


Figure 24 *LDR for buoy 46053. Littoral drift in cubic meters/s.*

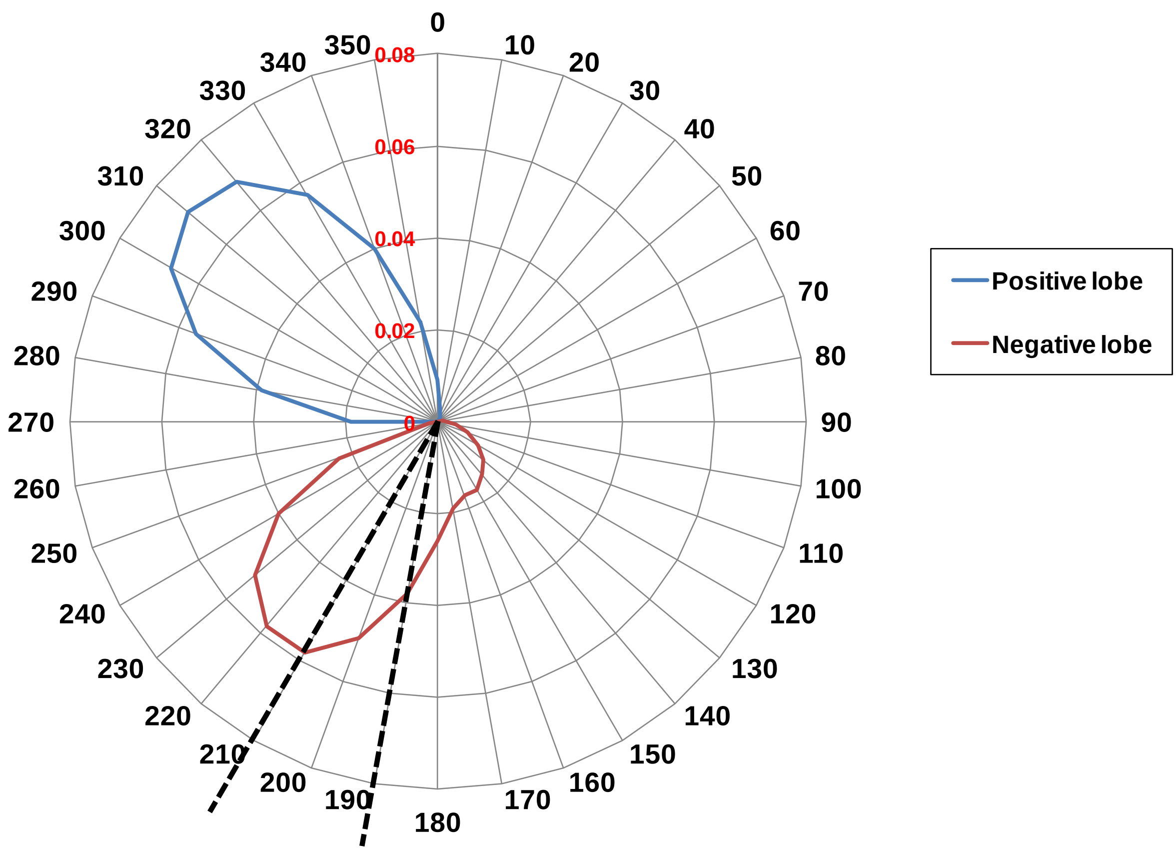


Figure 25 *LDR for buoy 46025. Littoral drift in cubic meters/s.*

4.3. The Equivalent wave climate

The Littoral Rose Drift as shown in Figures 24 and 25 result from a wave climate made upon on a number of deep water wave components, propagating over arbitrary directions. However, the same LDRs can be obtained using a single (equivalent) wave attack, of computable $Hs_{,eq}$, $Tp_{,eq}$ and $Dir_{,eq.}$ This wave can be then used instead of the entire climate in long term shoreline erosion problems. For the case of the buoy 46025 we found:

$$\mathbf{Hs_{,eq} = 1.0\ m;\ Tp_{,eq} = 11.85\ s;\ Dir_{,eq.} = 260°N.}$$

Figure 26 compare the real LDR for buoy 46025 and that obtained using the equivalent wave attack. It is seen that the real and the "equivalent" *LDRs* are very similar to each other for a wide range of shoreline orientations included between 180°N and 290°N).

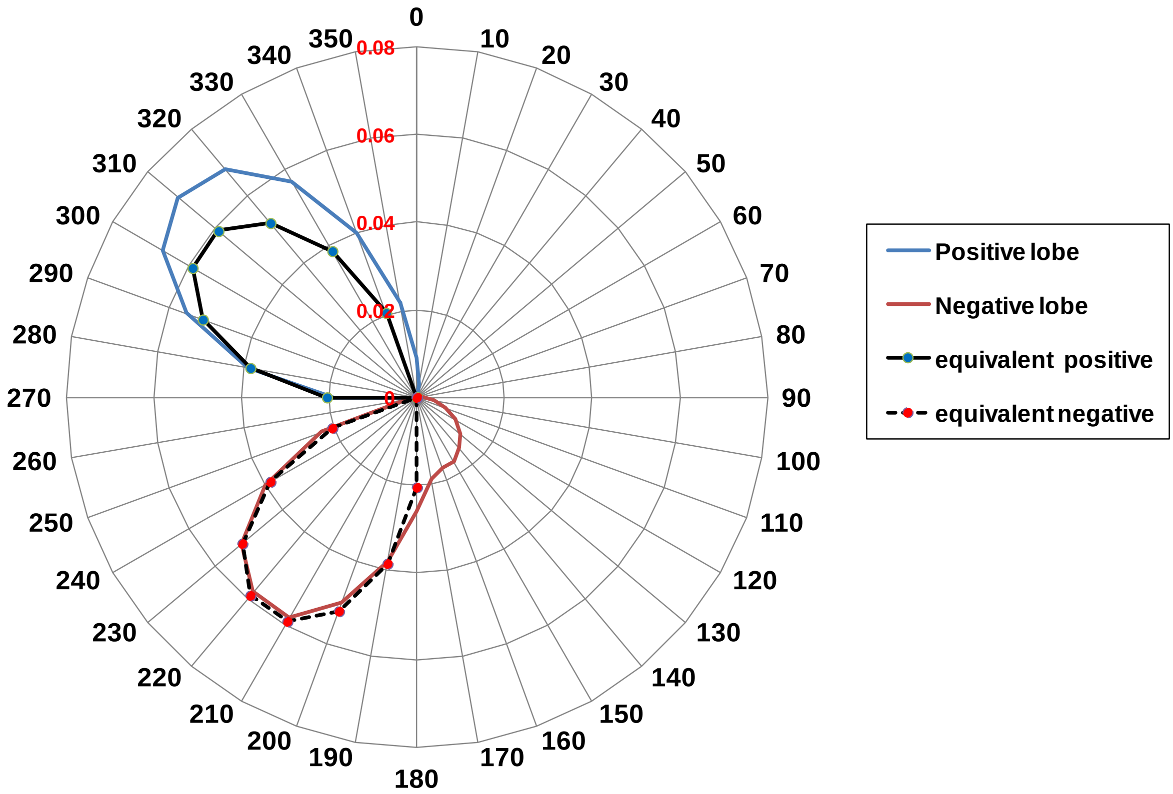


Figure 26 *Comparison between real and equivalent LDRs. Littoral drift in cubic meters.*

It should be finally pointed out that the parameters of the equivalent wave do not depend on the value of the sediment transport coefficient *K.*

5. WAVES IN THE NEARSHORE AND RELATED CURRENTS.

Based on the results obtained in the previous sections, two deep water wave conditions have been considered for the aims of this study:

- The “equivalent wave” for longshore transport analysis (see Section 4), which is representative of the yearly mean climate at *Broad Beach*;
- The annual maximum wave with a 25 years return period, representative of the climate under extreme conditions (storms).

To the “equivalent wave” , which is used for a long term analysis of the shoreline response, the MSW has been associated. On the other hand, for extreme conditions the water level with a 25 years return period has been employed. Hydraulic parameters are summarized in Table 10.

Name	Hs (m)	Tp (s)	Dir (deg. N)	Water level from MLLW (m)
LDR equivalent	1.00	11.85	260	+0.849
25 y. Return Per.	7.18	13.44	200	+2.350
25 y. Return Per.	7.18	13.44	260	+2.350

***Table 10** Deep water design conditions.*

It is seen that the 25 years Return period wave have been associated with 2 directions and namely **200°N**, i.e. nearly normal to the Broad Beach shoreline, and **260°N**, corresponding to the most frequent and “most energetic” wave direction recorded by the buoys.

5.1 Propagation Study

Design wave attacks reported in Table 10 have been propagated up to a depth of 18m below the MLLW, via the numerical suite MIKE 21, powered by Dansh Hydraulic Institute. In particular, the *Spectral Wave* propagation module (*SW*), which is based on the Spectral Action Balance Equation. The latter reads:

$$\frac{\partial S}{\partial t}+\frac{\partial\left(S\cdot c_{gx}\right)}{\partial x}+\frac{\partial\left(S\cdot c_{gy}\right)}{\partial y}+\frac{\partial\left(S\cdot c_{g\sigma}\right)}{\partial \sigma}+\frac{\partial\left(S\cdot c_{g\theta}\right)}{\partial \theta}=0 \tag{5.1}$$

in which:

- x and y are coordinates in the horizontal plane;
- σ is the angular frequency of the generic spectral component;

- θ is the angle of the generic spectral component;
- $S(\theta, \sigma)$ is generic spectral component;
- $c_{gx,y}$ is the group celerity;
- $c_{g\sigma}$ is propagation speed of frequency;
- $c_{g\theta}$ is the propagation speed of wave angle.

Figure 27 gives a view of the bathymetry and the point where nearshore wave characteristics have been extracted. Figures 28-30 show the wave direction plots; nearshore wave characteristics are finally summarized in Table 11.

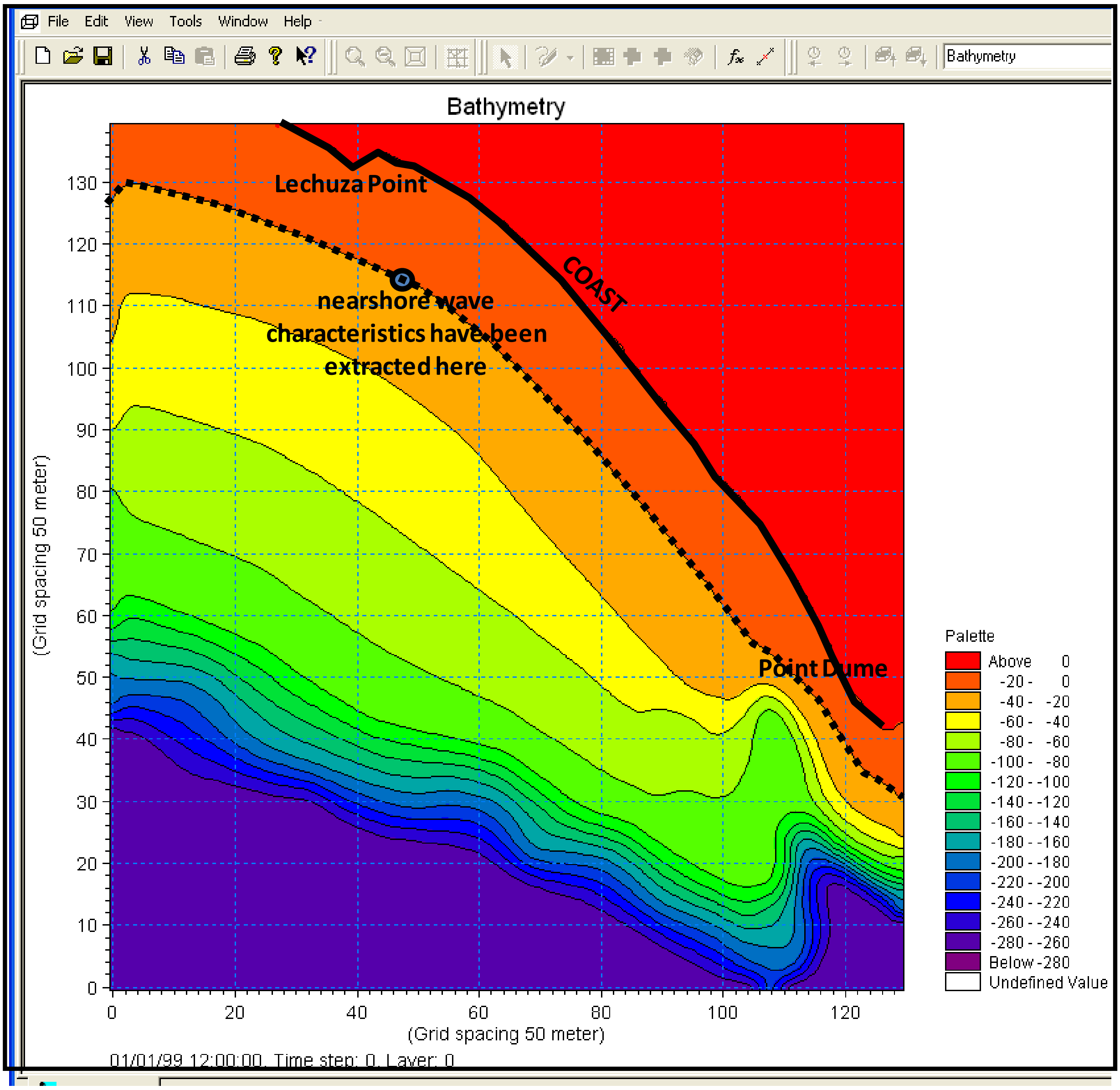


Figure 27 *View of bathymetry and reference point for nearshore waves.*

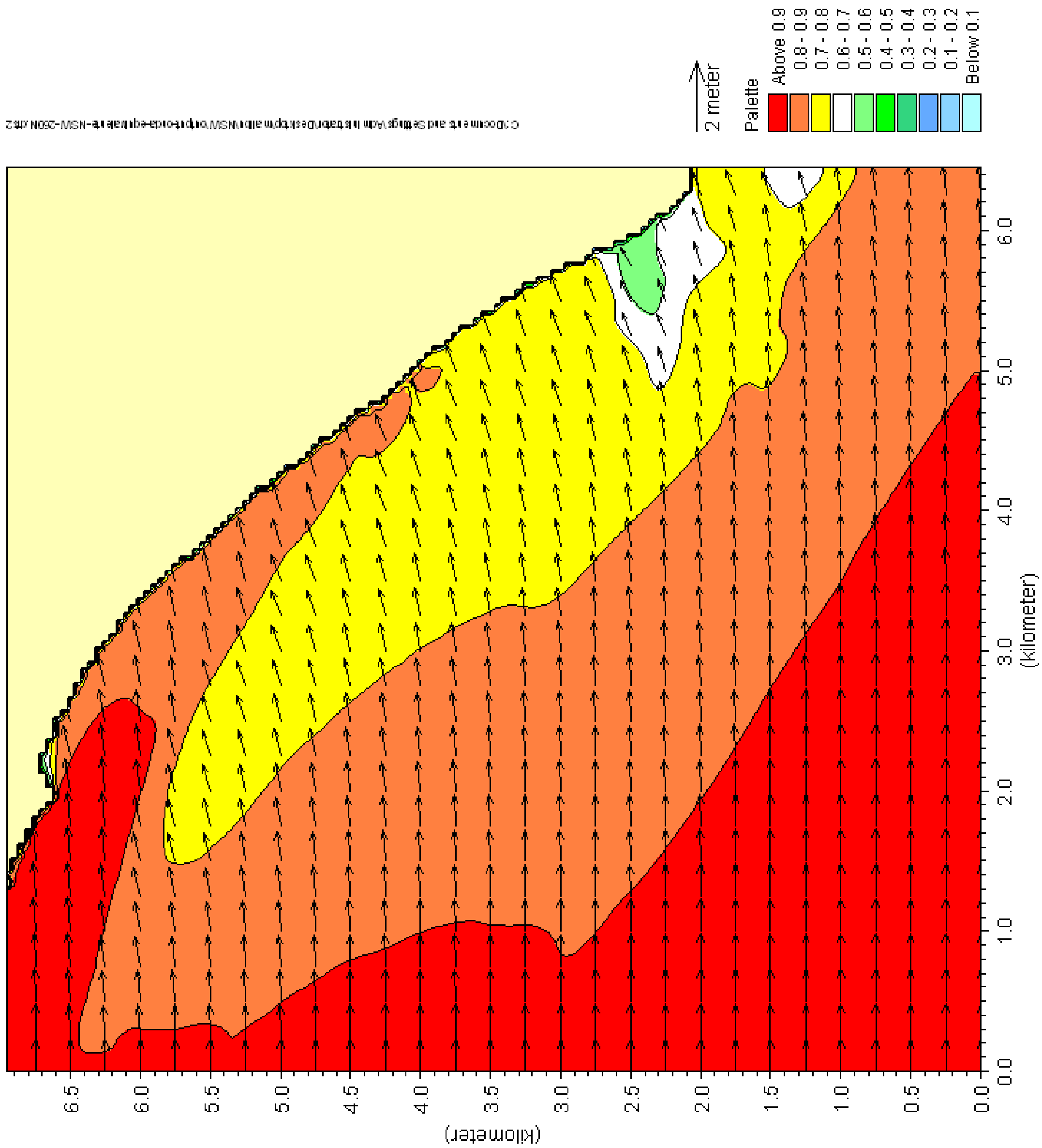


Figure 28 *Propagation plot LDR equivalent wave.*

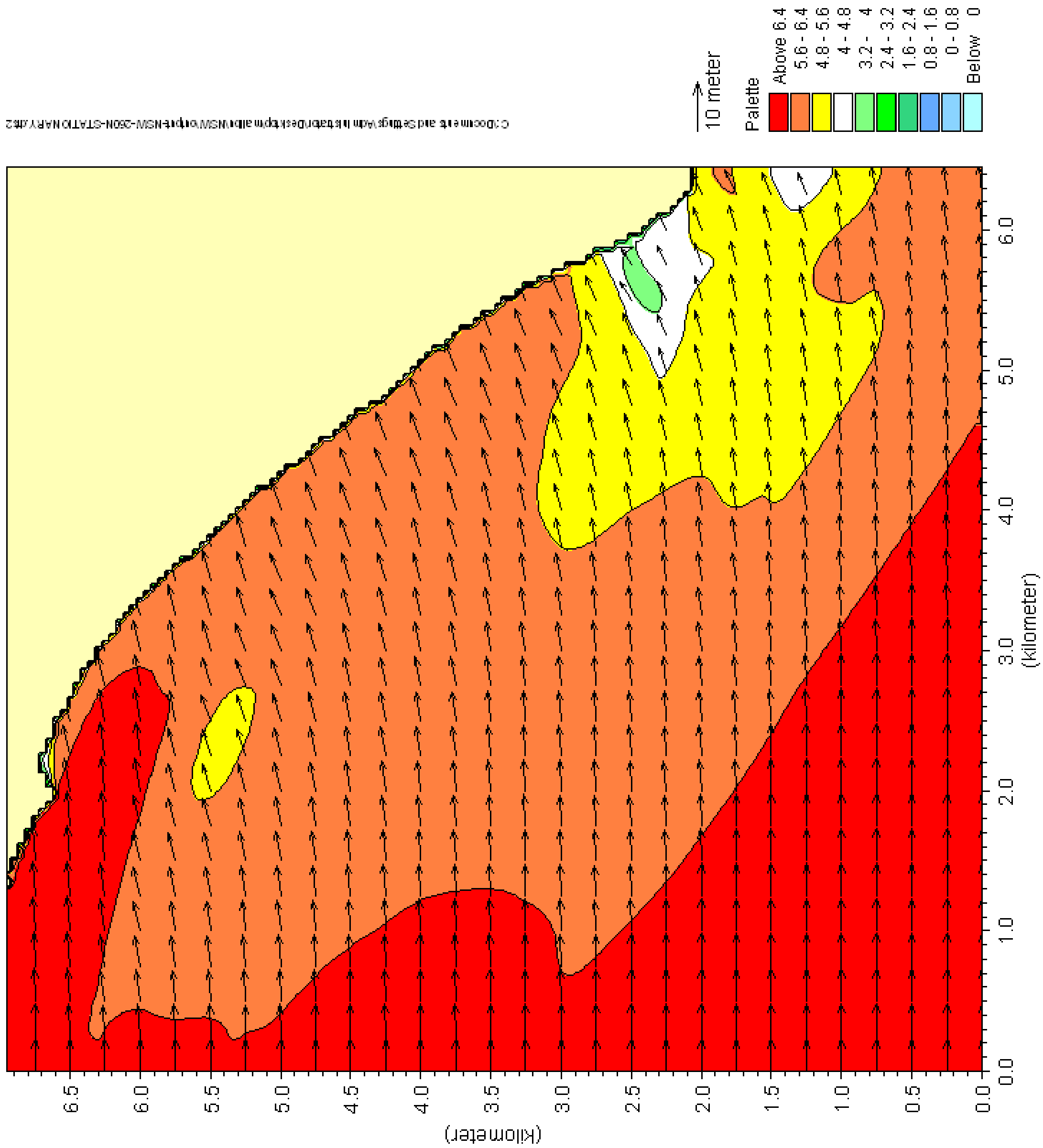


Figure 29 *Propagation plot 25 years return period wave (angle 260°N).*

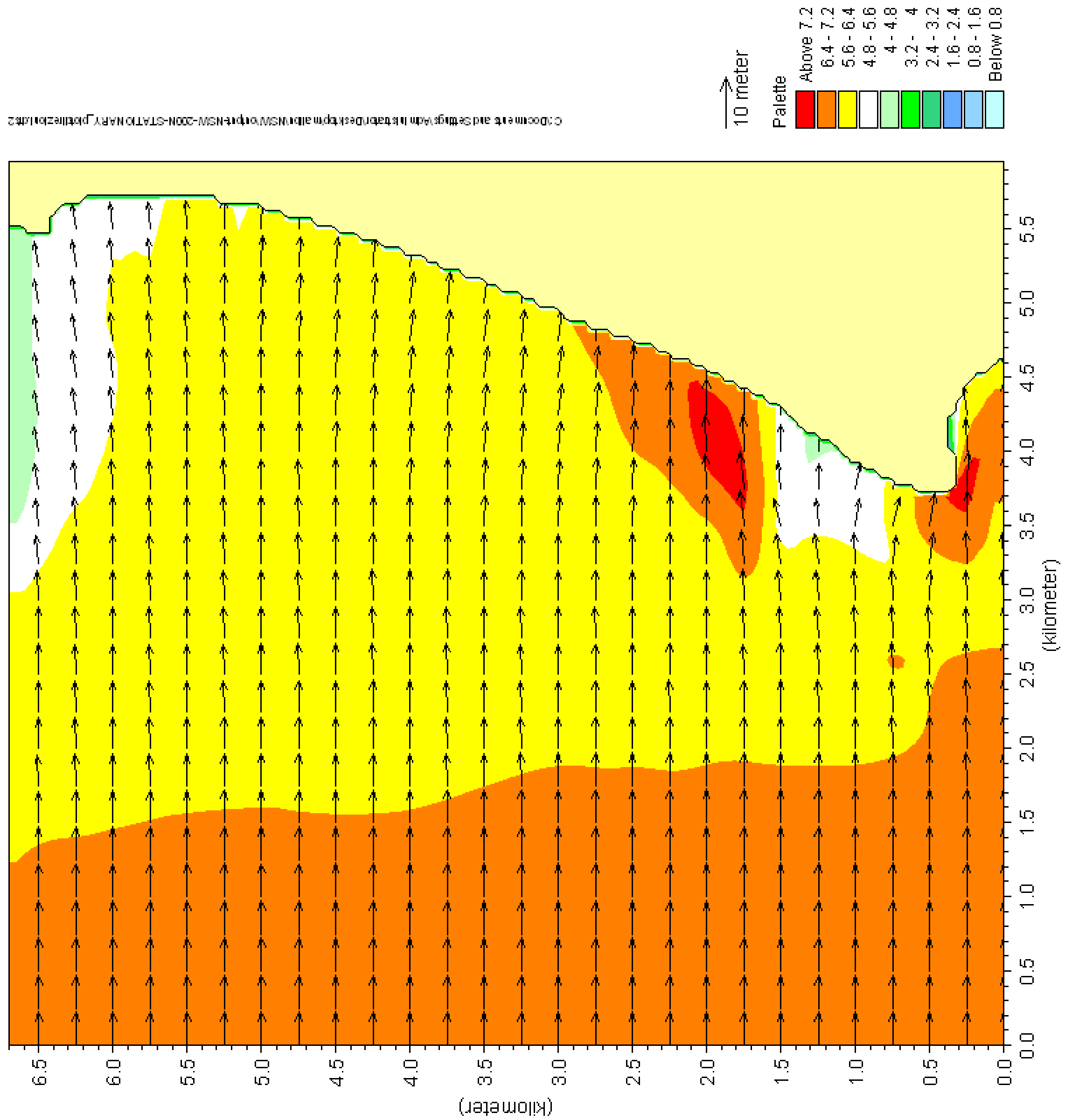


Figure 30 *Propagation plot 25 years return period wave (angle 200°N).*

Name	Hs (m)	Tp (s)	Dir (deg. N)	Water level from MLLW (m)
LDR equivalent	0.80	11.85	246	+0.849
25 y. Return Per.	5.78	13.44	195	+2.350
25 y. Return Per.	5.92	13.44	245	+2.350

***Table 11** Nearshore parameters.*

Nearshore wave parameters have been used as input in the sediment transport models, to assess the effect of the protective reef, as well as in the nearshore circulation study discussed below.

5.2. Nearshore Circulation study

An analysis of the wave induced currents at *Broad Beach* has been conducted via the *HydroDynamic* (*HD*) module of MIKE 21. Nearshore waves have been further propagated inshore through a propagation driver based on the *Parabolic Mild-Slope Equation* (*PMS*). Once the propagation has been extended up to the coast, the value of the Radiation Stress Tensor (wave thrust) are evaluated at each point of the calculation grid. Finally, Radiation Stress are used as forcing term in the MIKE's *HD* module, to solve the *non linear shallow water equations*, which gives magnitude and direction of the wave-generated currents.
As partially shown in Figure 31 and, much more clearly in Figure 32, when waves reach the coast from the west (260°N) a longshore current is produced, whose magnitude tends to increase towards the east. This inevitably produces an erosion of the beach. Interestingly, it is seen that a violent wave attack almost normal to the coast (200°N) may cause the occurrence of a rip current, fed by two strong longshore currents moving oppositely to each other (Figure 33). This may also represent a source of sand loss for *Broad Beach.*

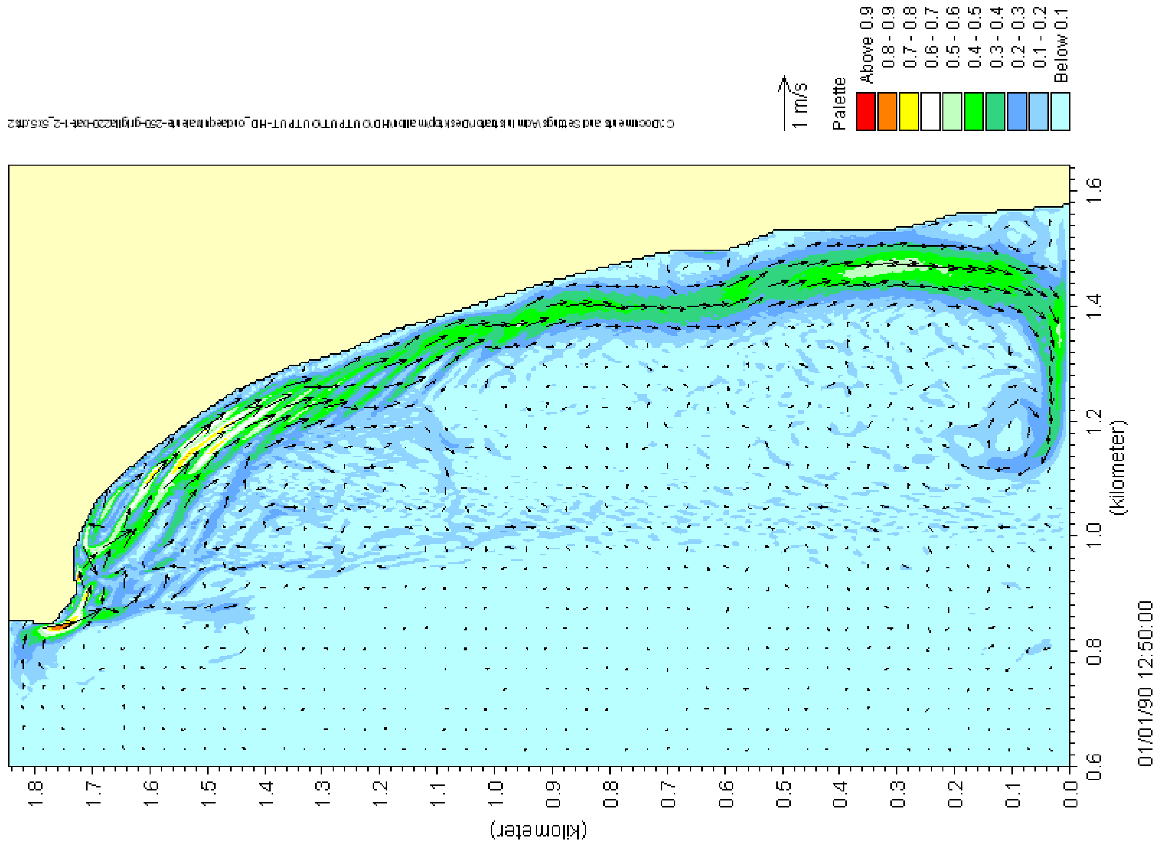


Figure 31 *Nearshore Circulation for the LDR equivalent wave.*

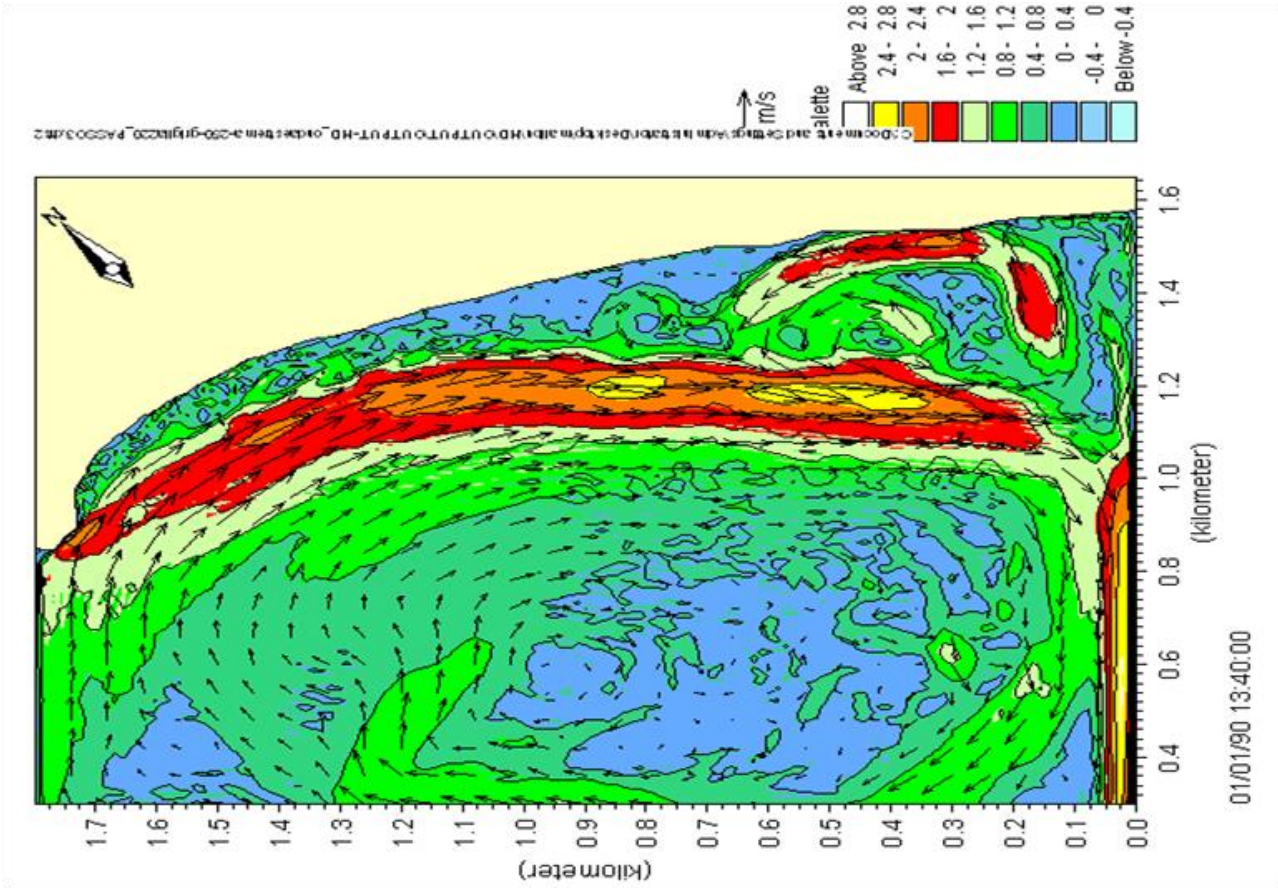


Figure 32 *Nearshore Circulation for the 25y return period (offshore angle 260°N).*

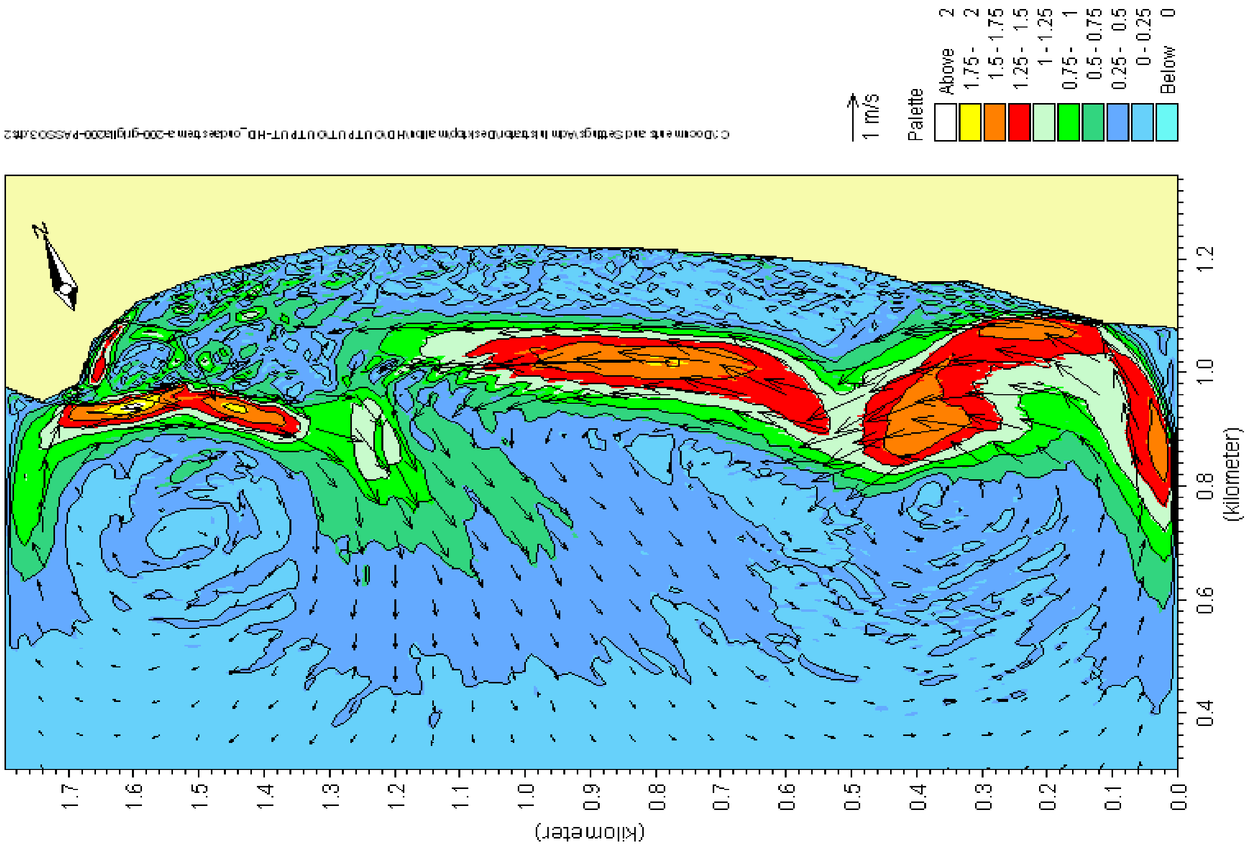


Figure 33 *Nearshore Circulation for the 25y return period (offshore angle 200°N).*

6. SEDIMENT TRANSPORT STUDY

A sediment transport study has been carried out to assess the beach response to the design waves (in absence of reef). To this purpose the analysis system CEDAS (Veritech Enterprises, LLC) has been employed. The effect of the littoral drift has been investigated via the one-line model GENESIS (GENEralized model for SImulating Shoreline change), which is based on the CERC formula for longshore sand transport; the software SBEACH (Numerical model for simulating Storm induced BEAch CHange), developed on the basis of results of a large number of laboratory and field experiments, has been employed to study the beach response to extreme waves.

6.1. Littoral Drift study

6.1.1 The GENESIS model.

The GENESIS model assumes the cross-shore profile of the beach to coincide with the *equilibrium profile* (Section 3.3) and uses the one-line equation to simulate long term beach changes. The latter reads:

$$\frac{\partial y}{\partial t} + \frac{1}{(B+dc)} \cdot \frac{\partial Q}{\partial x} = 0 \qquad (6.1)$$

. where:

- *y* is the position of the shoreline;
- *t* is time;
- *B* is the berm height assumed equal to 2m;
- *d*c is the depth of closure assumed equal to 7.38 m (Section 3.2);
- *Q* is the (volumetric) littoral drift;
- x is the horizontal coordinate of the shoreline;

The shoreline evolution is then function of:

1. Initial position of the coastline;
2. Lateral boundary conditions;
3. The expression used for *Q*;
4. Values of *B* and *d*c;
5. Shape and length of coastal structures;

As far as the expression of *Q* is concerned, GENESIS employs a modified form of the CERC equation, which is function of 2 parameters. One is the *sediment transport coefficient K* already described in Section 4.1; the other is a secondary parameter (*K*'), which accounts for the sediment transport generated by diffractive coastal structures. Since it is customary assumed ***K' = 0.5 K*** , the littoral drift formula is actually dependent on the sole *sediment transport coefficient K.*

6.1.2. Model Calibration

The first step of the study aims at setting an appropriate value of *K* for our model can reproduce the past evolution of *Broad Beach*. In particular we set as target an average erosion rate of 15,291 cubic meters/year (20,000 cuy/year) in a period of 40 years (Section 4). Notice that the most recent acceleration of the sand loss (up to 35,000 cuy/year) has been not considered at this stage, since it is based on a very short time series (5 years, from 2004 to 2009).

As shown in Figure 34, the reach of shoreline included between *Lechuza Point* and *Point Dume* has been reproduced. Since both these sites are rocky, the shoreline cannot recede (*pinned points*), although we assumed sand can enter and exit. The simulations have been carried out assuming a water level of +0.849, corresponding to MSL, and using the *LDR* equivalent wave.

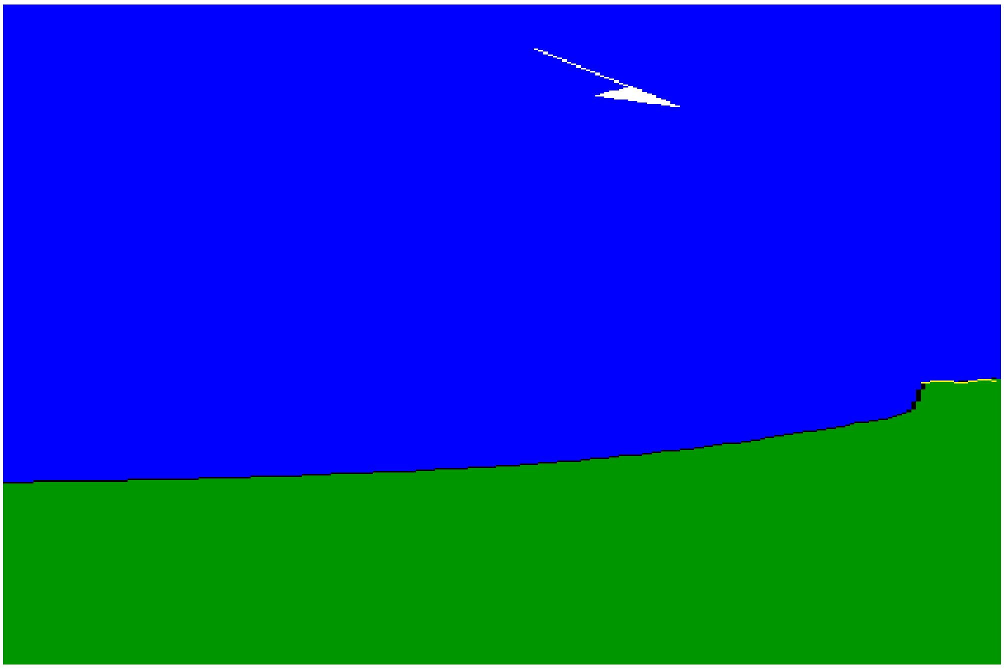


Figure 34 *Broad Beach of shoreline simulated with GENESIS.*

It has been found out that for **K = 0.005**, *Broad Beach* experiences an average erosion of 15,961 cum/y over 40 years (Figure 35), which is rather close to the target (less than 5% difference). Figure 36 shows the final shoreline position.

6.1.3. Effect of Revetment

As a second step of the analysis, an unerodable line has been inserted 56 m (on average) rear the shoreline, to simulate the presence of the revetment as well as the (un-protected) houses in the most western part of *Broad Beach* (Figure 38). This second simulation accounts the fact that, at present, only a limited strip of sand is available for longshore transport. Results are shown in Figures 39-41.

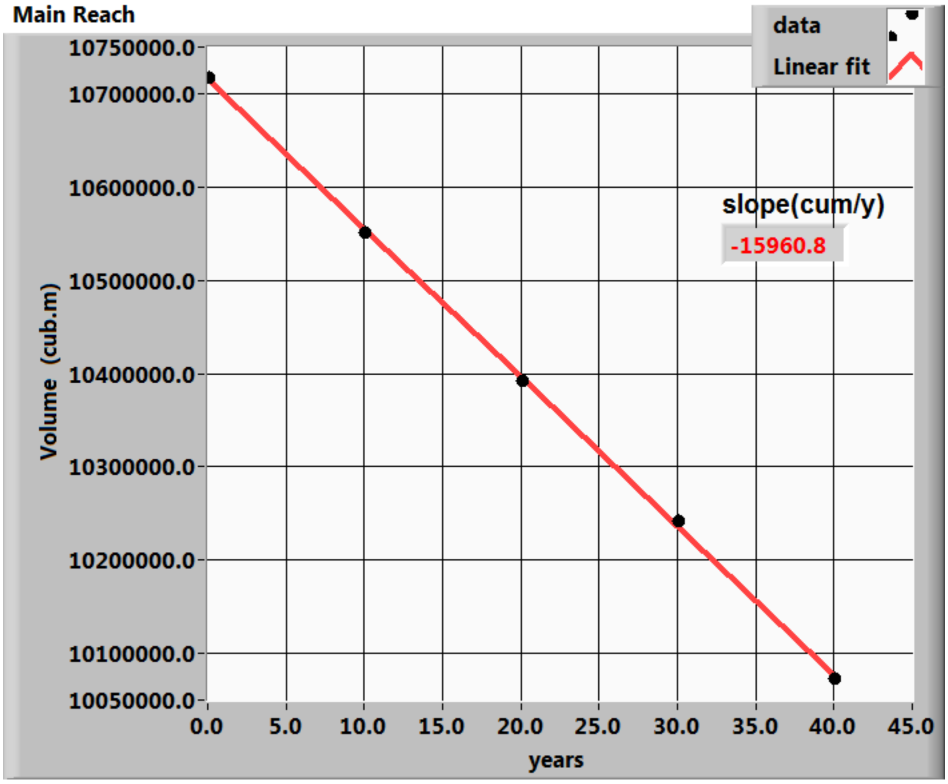


Figure 35 *Volume variation of Broad Beach. GENESIS simulation with K =0.005.*

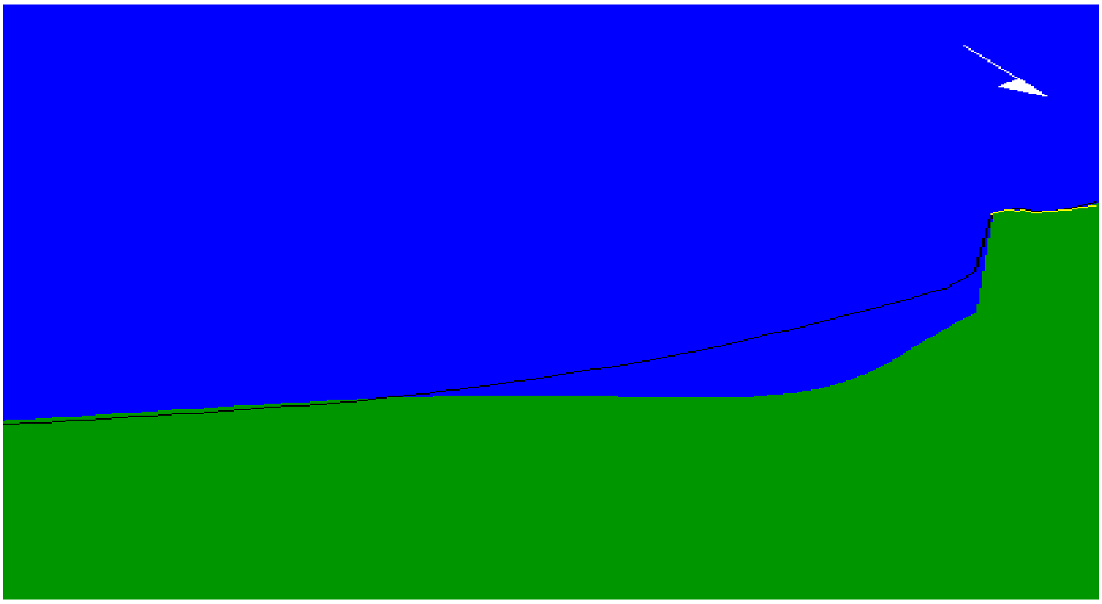


Figure 36 *Variation of the shoreline position at Broad Beach. GENESIS lasting 40 years simulation with K =0.005.*

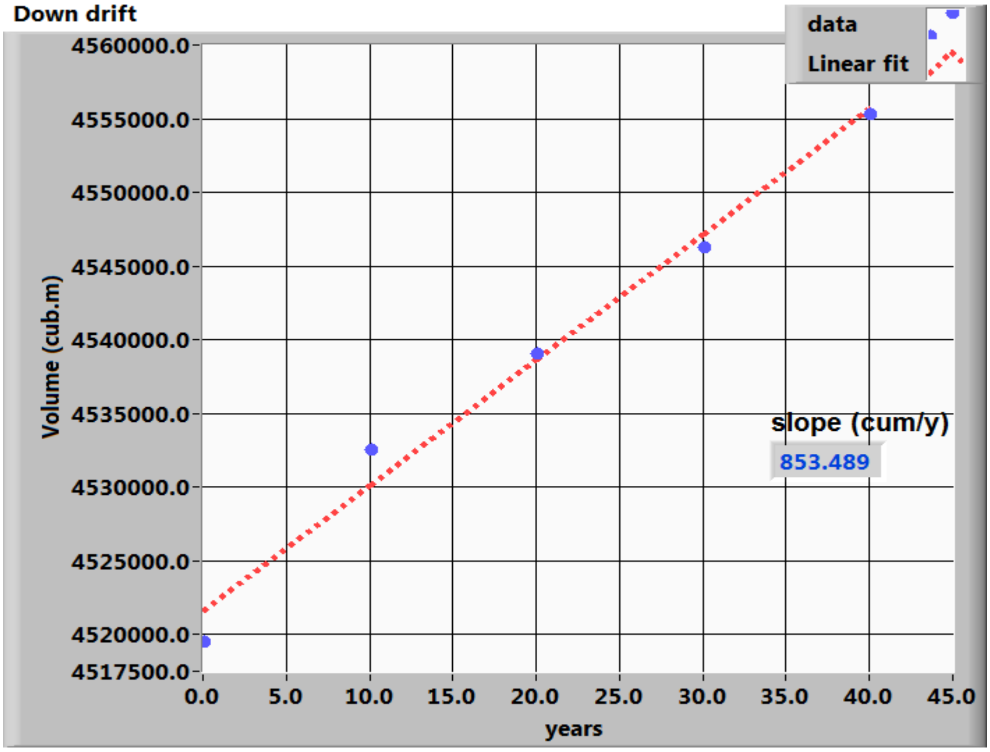


Figure 37 *Volume variation for a reach of coast extending 1 km downdrift of Broad Beach. GENESIS simulation with K =0.005.*

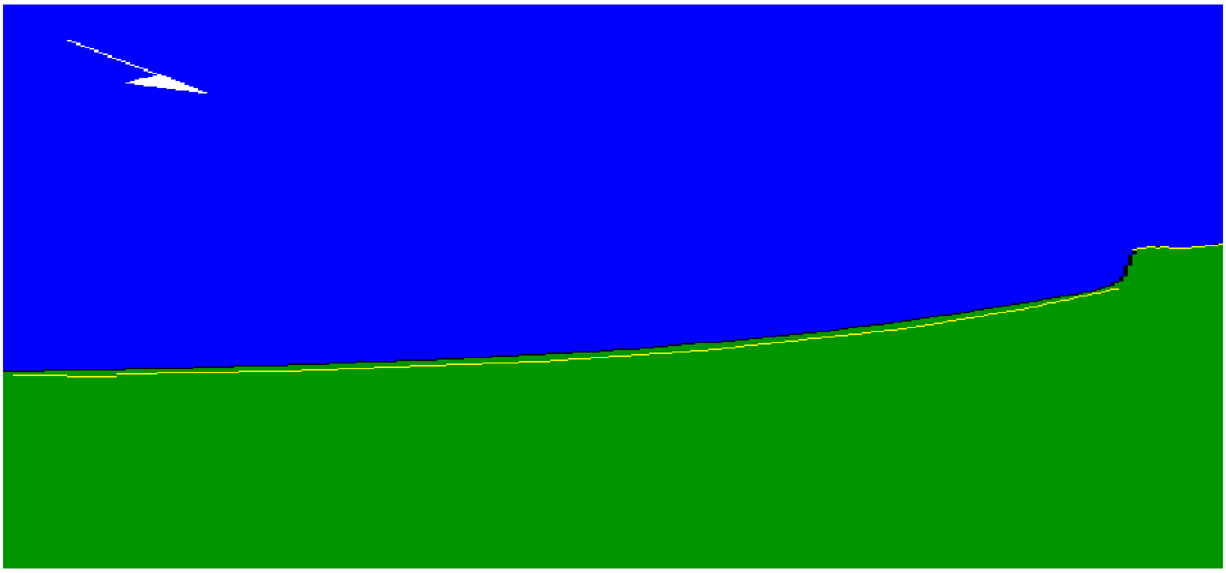


Figure 38 *Inclusion of the unerodable line in the GENESIS model (Broad Beach)*

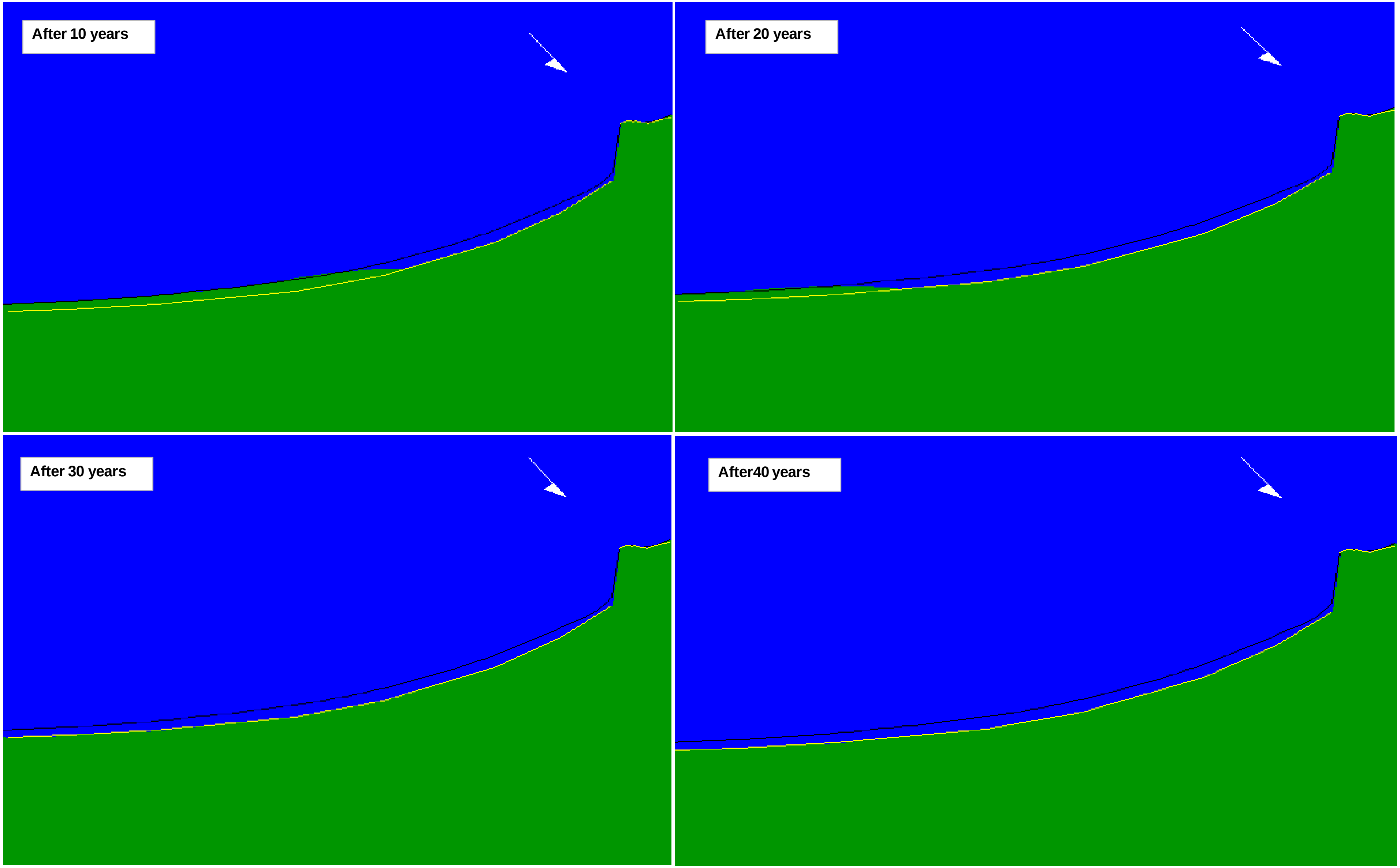


Figure 39 *Effect of the unerodable line (revetment) on the long term shoreline change of Broad Beach.*

It is seen the shoreline to be progressively eroded up to the "revetment". Compared to the early simulation, the erosion rate of *Broad Beach* is slightly reduced (Figure 40), essentially because the presence of the revetment reduces the amount of sand available for transport.

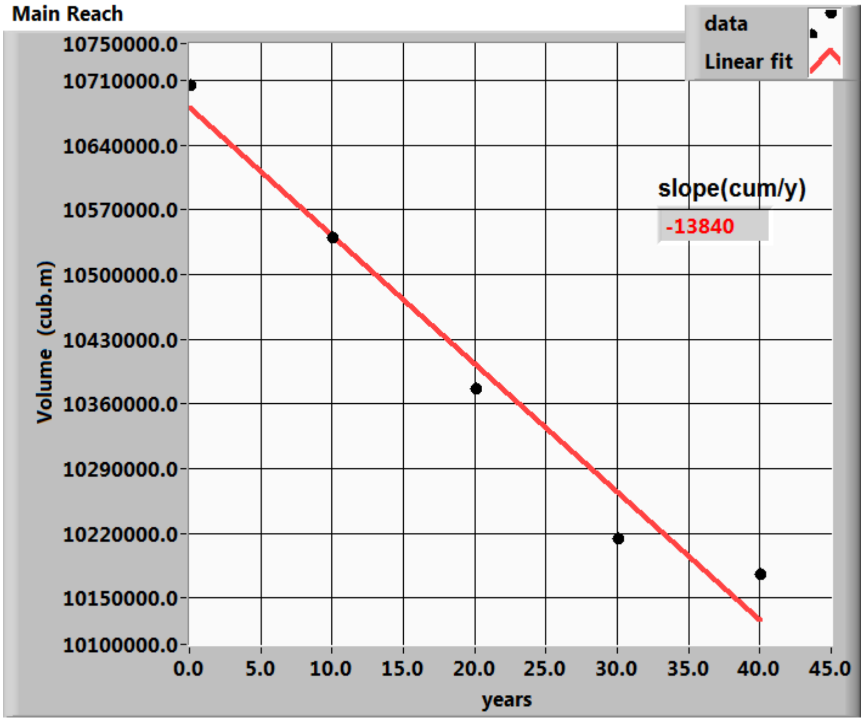


Figure 40 *Volume variation of Broad Beach in presence of revetment.*

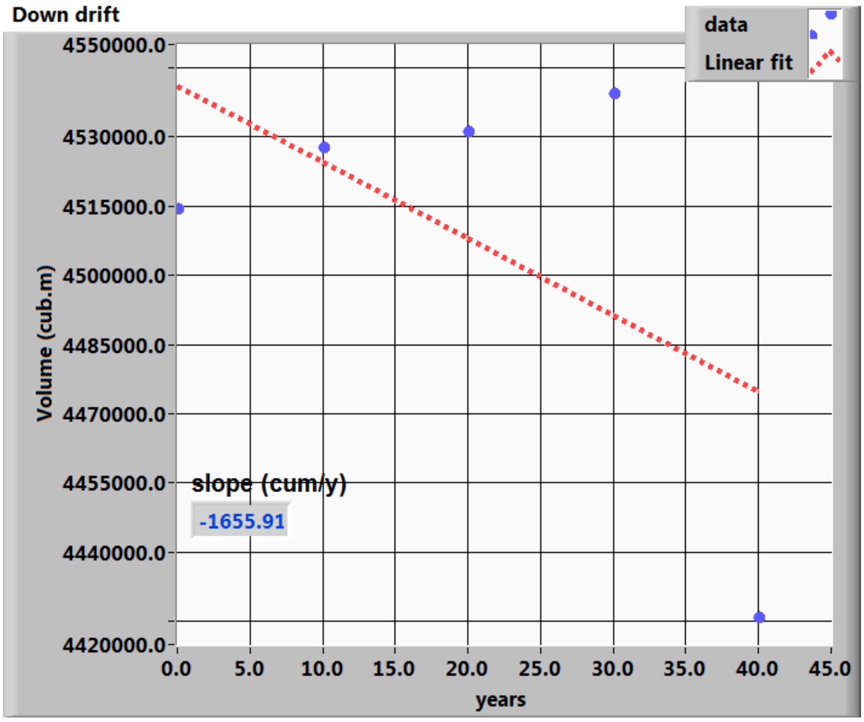


Figure 41 *Volume variation for a reach of coast extending 1 km downdrift of Broad Beach. Simulation with revetment.*

6.2. Storm effects

A qualitative analysis of storm effects has been carried out using the *SBEACH* model, which integrates the cross-shore sediment balance equation:

$$\frac{\partial d}{\partial t} = \frac{\partial q}{\partial x} \qquad (6.2)$$

where:

- *d* is the water depth below the MLLW;
- *t* is time;
- *q* is the (volumetric) cross-shore sediment transport rate;
- *x* is the cross-shore coordinate of the beach.

SBEACH couples a <u>wave module</u>, in which wave breaking is simulated through the method of Dally Dean and Dalrymple (1985), and a <u>sediment transport module</u>, essentially semi-empirical, where the transport of sand is assumed proportional to the wave power dissipated per unit of volume.

6.2.1. <u>Simulations.</u>

An uniform wave attack has been simulated, where the 25 years return period wave (Table 11) has been assumed to load the beach for 6 and 12 hrs respectively under a fixed water level (+2.350m from MLLW). <u>The BB Fall 2011 beach profile</u> (Figure 17) has been conservatively employed, as it is steeper and then more sensitive to wave attacks. As far as the effective grain size is concerned, a value of 0.20mm has been used, <u>corresponding to fine sand</u>. This because in most of samples collected during the on-site visit, the sand resulted equally shared between coarse sand and very fine sand. An example of simulation is shown in Figure 42, whereas Table 12 summarizes all the obtained results. Although the conditions under which the tests have been conducted are quite cautious, the outcomes clearly indicate that violent storms may produce severe damage to the beach, with shoreline recessions of order of 10m and tens of cu.m./m sand loss in few hours.

Hs (m)	**Tp (s)**	**Dir (deg. N)**	**Duration (hrs)**	**Volume of sand lost (cu.m/m)**	**Shoreline retreat (m)**
5.78	13.44	195	6	24.0	10.5
5.78	13.44	195	12	43.3	15.5
5.92	13.44	245	6	20.0	9.5
5.92	13.44	245	12	37.5	14.5

Table 12

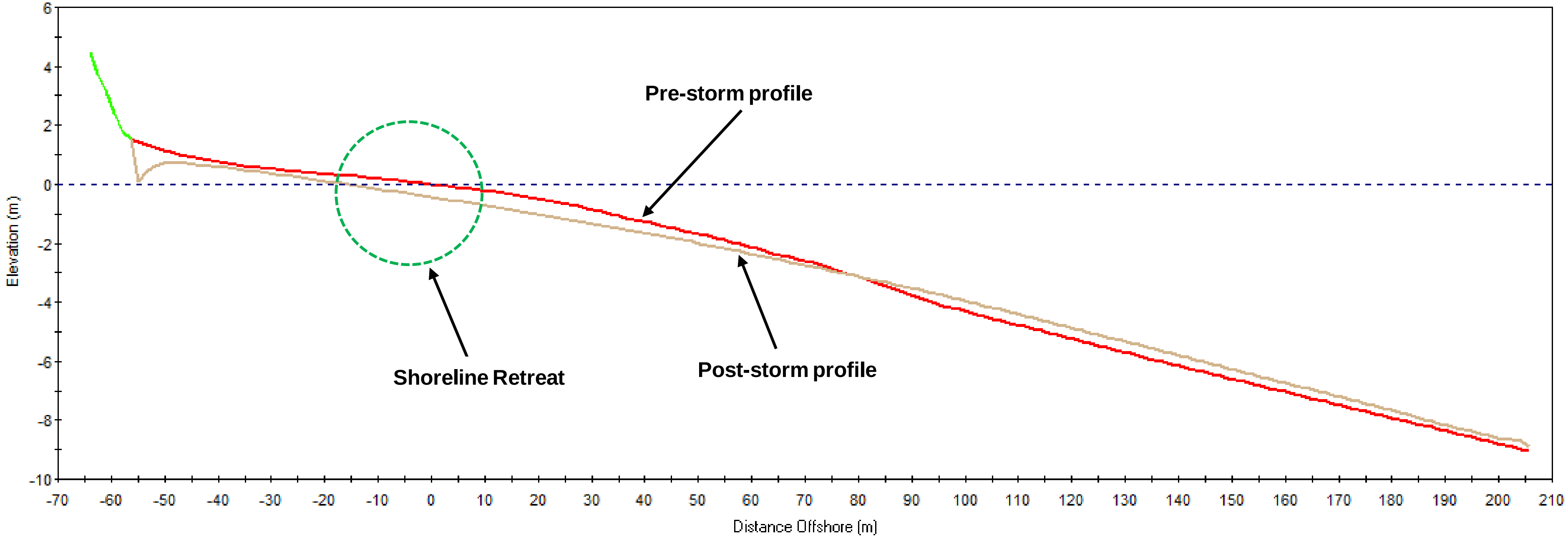


Figure 42 *Example of SBEACH simulation (Hs = 5.78m; Tp = 13.44s; Dir = 195°N; duration 6hrs.*

7. REEF DESIGN

In this Section, a preliminary design of an artificial reef consisting of Reef Ball modules is carried out, with main purpose of mitigating the long term erosive trend of *Broad Beach* (Section 6.1). The main variable involved in the design process are:

1. Height of the reef (submergence);
2. Reef width (number of RB rows used);
3. Distance of the structure from the shoreline;

In the following previous quantities are defined based on hydraulic, construction and environmental constraints.

7.1 Height of the reef (submergence)

The main constraint for the height of the reef its intrusion in the landscape. After the *Reef specialist debrief* held on Wednesday 2017/6/28, it was decided to set the top of the structure at MLLW. This implies a submergence of 0.84m for littoral drift analysis and 2.35m for extreme waves. According to Table 6, the expected exposure time of the reef is 1.2 hrs per day.

7.1.1 Wave transmission

Once the reef height has been established, the rate of wave attenuation can be obtained via the *transmission coefficient*, K_t., i.e. the ratio between the wave height just shoreward of the structure (Hs_t) and wave height just in front of it (Hs_i):

$$K_t = \frac{Hs_t}{Hs_i} \tag{7.1}$$

To calculate wave transmission at submerged breakwaters made of *Reef Balls*, two formulae have University of Napoli "Federico II", based on more than 1,400 physical random wave experiments (Del Vita, 2016). The first is valid for waves arriving at the reef without breaking and has a mathematical shape originally suggested by Armono (2003). It reads:

$$K_t = \frac{1}{1 + 0.67 \cdot \left(\frac{Hs_i}{gTp^2}\right)^{0.37} \cdot \left(\frac{n_r \cdot D_{RB}}{gTp^2}\right)^{-0.28} \cdot \left(\frac{hs}{n_r \cdot D_{RB}}\right)^{-0.86} \cdot \left(\frac{hs}{d}\right)^{3.45}} \tag{7.2}$$

where:

- Hs_i is the significant wave height in front of the structure;
- Tp is the peak period of the incoming waves;
- g is gravity;
- D_{RB} is the base diameter of Reef Balls;

- n_r is the number of rows employed;
- *hs* is the height of the structure;
- *d* is the water depth.

The second equation assumes incoming waves to break prior reaching the reef and derives from the “conceptual approach” by *Buccino and Calabrese* (2007). For deeply submerged structures it reduces to:

$$K_t = \frac{1}{1.05 + 0.14 \cdot \left(\frac{Hs_i}{d - hs}\right)^{1.5} \cdot \left(\frac{B'}{\sqrt{Hs_i Lp_0}}\right)} \tag{7.3}$$

in which:

- $B' = (n_r - 1)\, D_{RB}$;
- $Lp_0 = gTp^2/2\pi$ is the deep water wavenlength.

The Eq. (7.2) is suited for the *LDR equivalent wave* (*Table 11)*, and hence for littoral drift analysis. After setting:

- Hs_i = 0.8m;
- *Tp* =11.85s;
- *hs* = 1.52m, equaling the height of a Goliath Ball;
- *d =hs + 0.84*m;
- D_{RB} = 1.83m, which is the base diameter of a Goliath Ball.

the values of K_t reported in Table 13 are obtained, in function of the number of rows employed.

The Equation (7.3) can be used to compute wave transmission for extreme seas. Assuming a return period of 25 years, a water level of +2.350m is expected (Table 11). Then the water level at the toe of the reef is approximately *d* = 1.52m + 2.35m. Thus, the incident wave height, Hs_i can be calculated with the formula of Kamphuis (1991) :

$$Hs_i = 0.56 \cdot \exp(3.5\, m) \tag{7.4}$$

where *m* is the beach slope. If we assume, conservatively, a value of *m* = 0.04, corresponding to the average beach slope for the *BB Fall 2011* profile (Figure 18), then a value of **2.49**m is derived. As for the other variables we set:

- *Tp* =13.44s;
- *hs* = 1.52m, equaling the height of a Goliath Ball;
- *d =hs + 2.35*m;
- D_{RB} = 1.83m, which is the base diameter of a Goliath Ball.

The values of K_t are reported in Table 14.

# of rows	K_t	Attenuation [%]
1	***0.94***	***6***
2	***0.91***	***9***
3	***0.89***	***11***
4	***0.87***	***13***
5	***0.86***	***14***
6	***0.85***	***15***
7	***0.83***	***17***
8	***0.82***	***18***
9	***0.81***	***19***
10	***0.80***	***20***
11	***0.79***	***21***
12	***0.79***	***21***
13	***0.78***	***22***
14	***0.77***	***23***
15	***0.76***	***24***
16	***0.76***	***24***
17	***0.75***	***25***
18	***0.74***	***26***
19	***0.74***	***26***
20	***0.73***	***27***

Table 13 *Transmission Coefficients for littoral drift analysis.*

It is noticed that, due to the relevant submergence of the structure, the rates of attenuation under extreme waves are rather low.

7.1.2 <u>Number of RB rows and distance of the reef from the shoreline</u>

As already mentioned, the highest RB module (*Goliath Ball*) measures about 1.52m; however, with the use of rings it can reach up to 2.5m. Hence, the portion of beach suited to artificial reef placement is that included between 1.5m and 2.5m (from MLLW). The use of a rocky berm beneath the modules cannot be considered as an option, since anchoring is difficult and at present not reliable. The horizontal distance between 1.5m and 2.5m water depth is about 23m for the *BB Fall 2011* profile and 32m for the *Army Corps* one. Hence a number of rows ranging from 10 (in the worst case) to 17 (in the most favorable case) could be placed.

From the inspection of Tables 13 and 17, it is seen that passing from 10 to 17 rows a gain in wave attenuation of 5% is obtained for the *LDR equivalent wave* and 6% under extreme seas. So, a significant increase of rows (and of costs) produces only a limited reduction of K_t. For this reason the structure has been assumed to consist of 10 rows, leading to a K_t = 0.80 for littoral drift analysis and 0.88 for storms.

<u>Under the above constraints, the most onshore row of RB is placed approximately 100m offshore the toe of the revetment.</u>

Table 15 and Figure 43summarize the characteristics of the designed reef.

# of rows	K_t	Attenuation [%]
1	**0.95**	***5***
2	**0.94**	***6***
3	**0.94**	***6***
4	**0.93**	***7***
5	**0.92**	***8***
6	**0.91**	***9***
7	**0.90**	***10***
8	**0.89**	***11***
9	**0.88**	***12***
10	**0.88**	***12***
11	**0.87**	***13***
12	**0.86**	***14***
13	**0.85**	***15***
14	**0.85**	***15***
15	**0.84**	***16***
16	**0.83**	***17***
17	**0.82**	***18***
18	**0.82**	***18***
19	**0.81**	***19***
20	**0.80**	***20***

Table 14 *Transmission Coefficients for extreme waves.*

Reef submergence from MLLW (m)	# of RB rows	Reef width (m)	Depth of Placement (m)	Min.Distance from toe of Revet. (m)	Kt (LDR)	Kt (Extreme)
0.00	10	21	1.5-2.5	100	0.80	0.88

Table 15 *Reef Characteristics.*

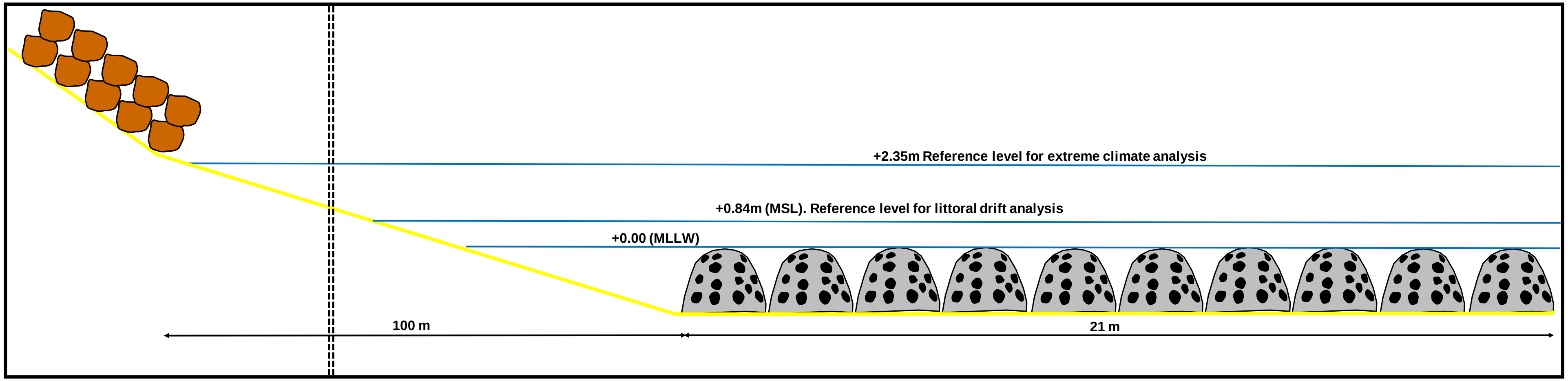


Figure 43 *View of the designed reef (QUALITATIVE DRAWING).*

8. BEACH RESPONSE TO THE REEF PLACEMENT

8.1. Interaction with littoral drift

The designed reef has been included in the GENESIS as a detached breakwater protecting *Broad Beach*, with a transmission coefficient equal to 0.8 and an (average) distance from the revetment of 110m (Figure 44). A new run has been then performed, for a period of 40 years. Figures 45 and 46 compare the shoreline response with and without reef.

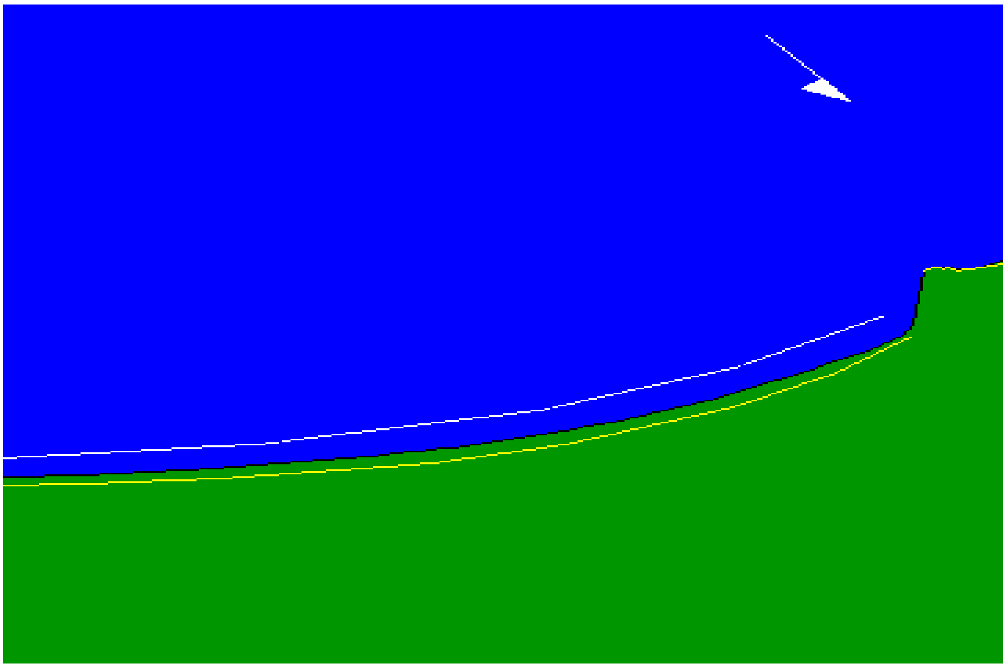


Figure 44 *GENESIS simulation on Broad Beach, with the inclusion of the reef.*

The effect of the structure is twofold:

- From the one side, the erosion rate of *Broad Beach* is reduced; this can be easily recognized by comparing the area in which the shore reaches the revetment, with and without the reef;
- From the other side, the presence of the reef anticipates and amplifies the downdrift erosion.

However, no stable shoreline development has been observed, but for the most eastern part of the protected beach.

The above results can be globally visualized in Figures 47 and 48. The former refers to *Broad Beach*, while the latter considers a reach of coast extending 1 km downdrift. It is seen that with the reef placement the erosion rate of *Broad Beach* is practically halved, passing from 13840 cu.m/y to

7500 cu.m/y (Figure 47). Neverhless, the erosion downdrift starts immediately and the sand deficit induced by the structure amounts to about 6340 cu.m/y

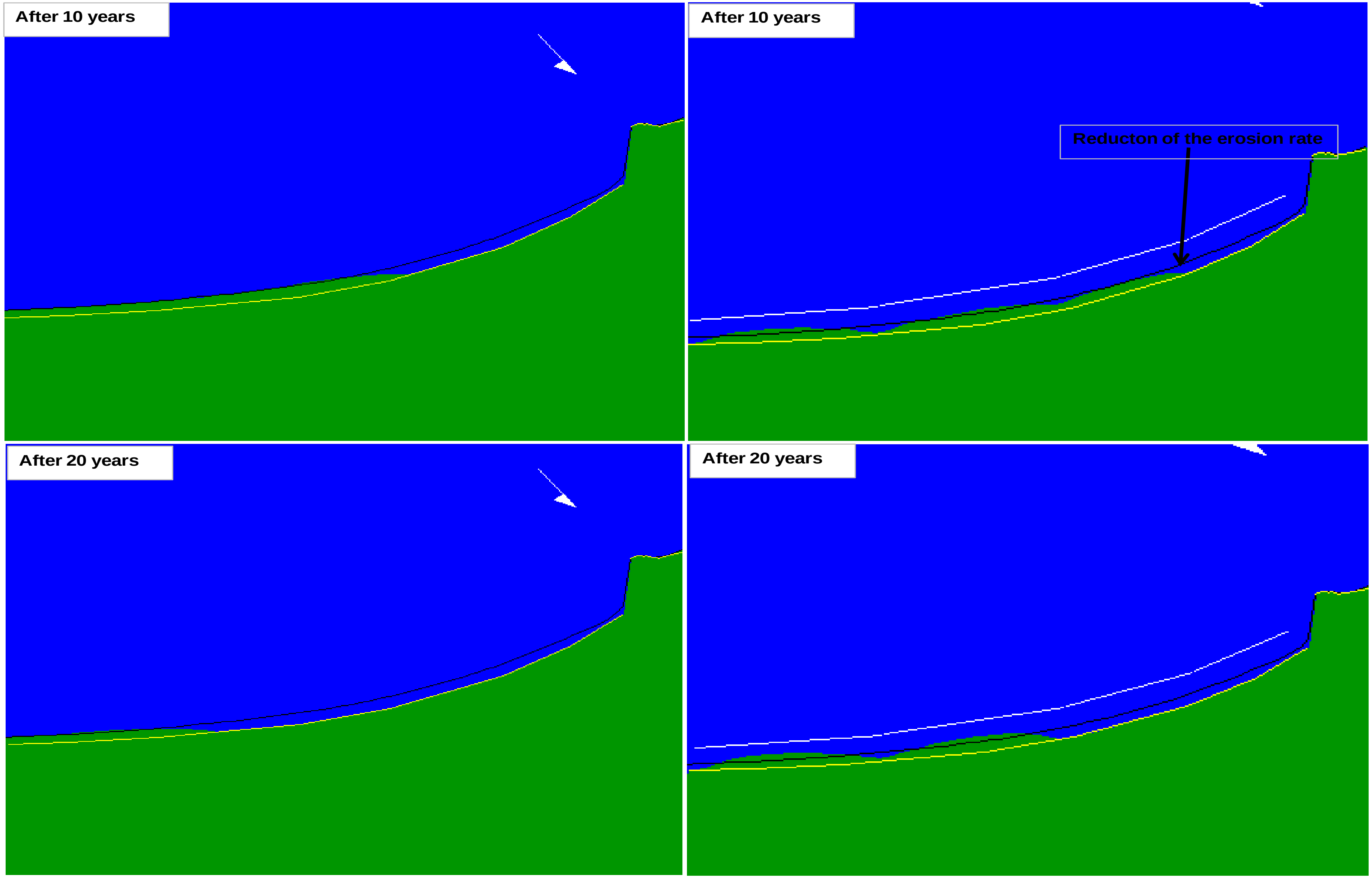


Figure 45 *Effect of the reef placement on the long term shoreline change at Broad Beach (10 and 20 years).*

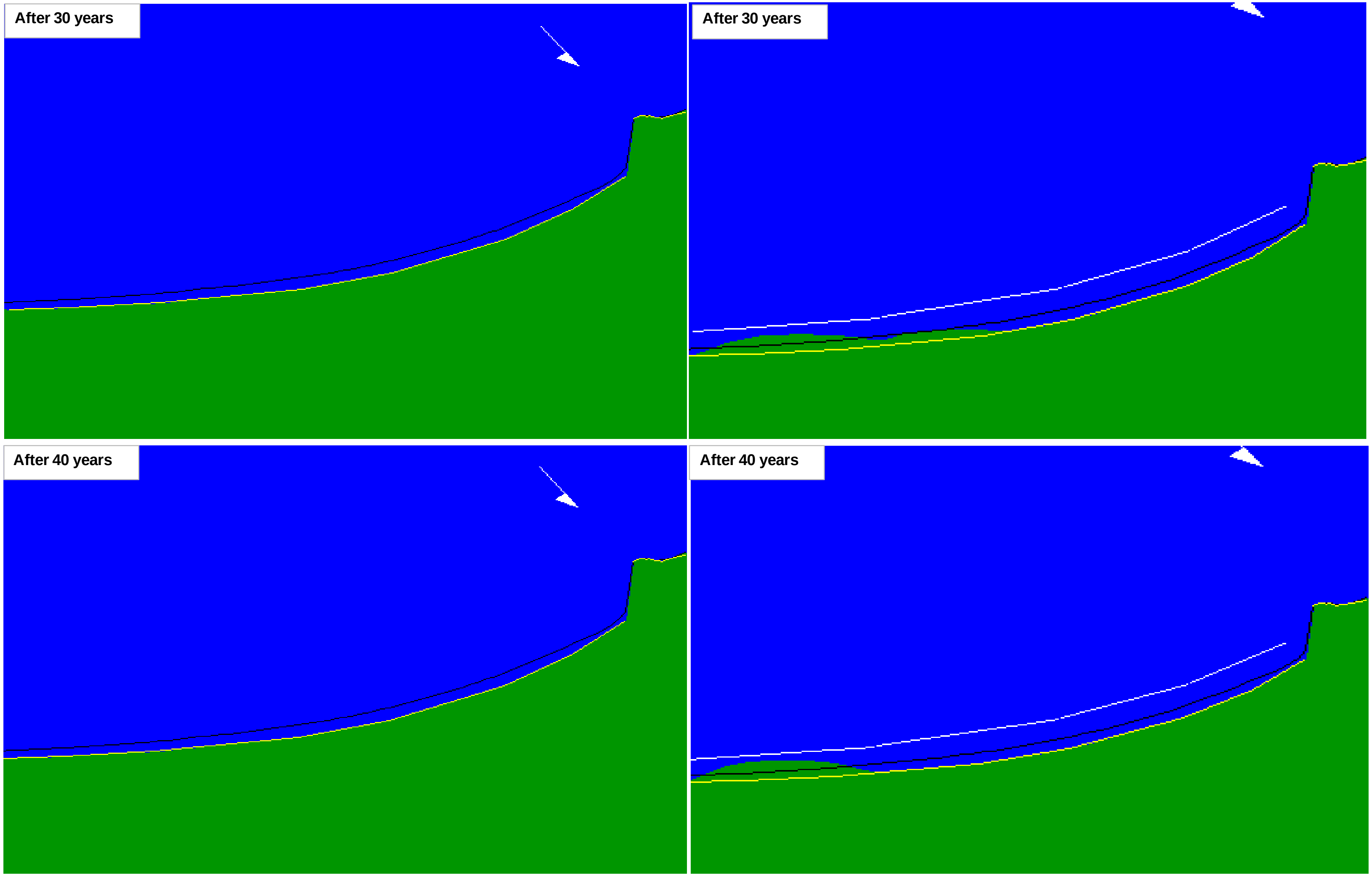


Figure 46 *Effect of the reef placement on the long term shoreline change (30 and 40 years).*

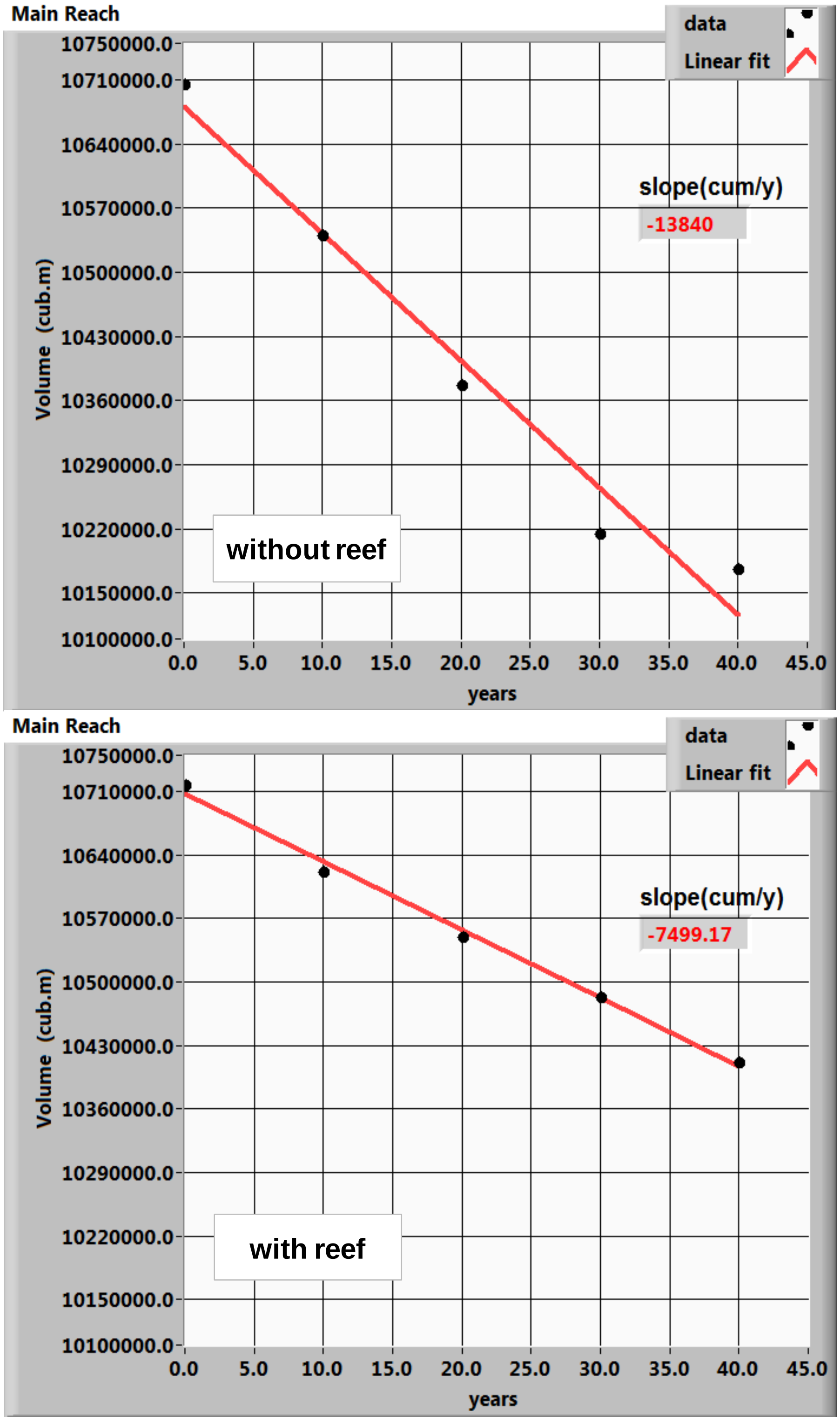


Figure 47 Volume variation of Broad Beach in with and without the reef.

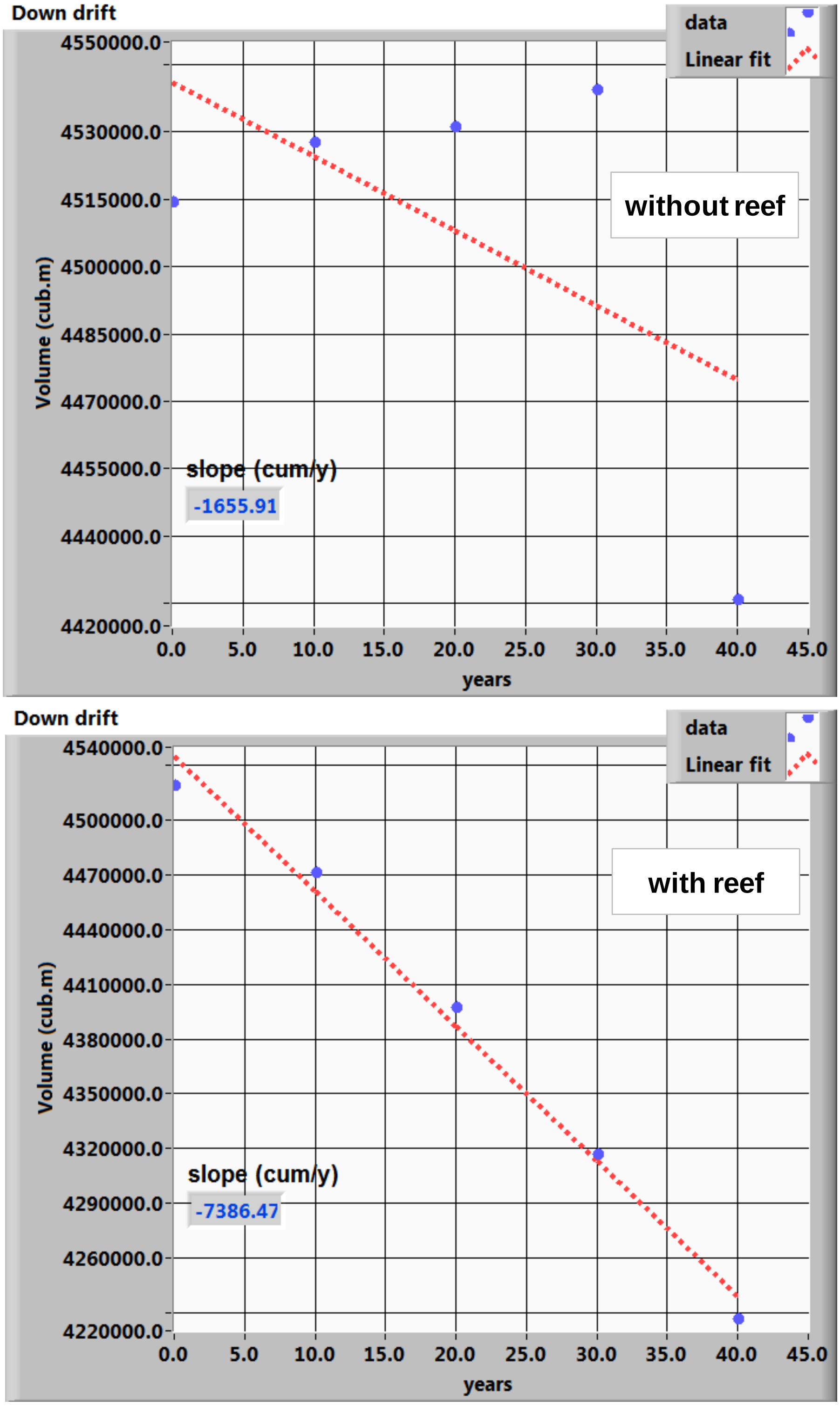


Figure 48 *Volume variation of a reach of coast extending 1 Km downdrift Broad beach. With and without the reef.*

8.2. Effects on storms

To assess the effect of the design reef on storms, simulations with SBEACH model described in Section 6 have been repeated with a wave height reduced by 12%, corresponding to the expected wave attenuation (Table 14). Results are reported in Table 16, along with the variation relative to the no-reef condition (Table 12). As expected, the effect of the structure on storms are relatively weak.

Hs (m)	**Tp (s)**	**Dir (deg. N)**	**Duration (hrs)**	**Volume of sand lost (cu.m/m)**	**Var. [%]**	**Shoreline retreat (m)**	**Var. [%]**
5.78	13.44	195	6	19.7	-18	9.0	-14
5.78	13.44	195	12	37.4	-14	15.0	-3
5.92	13.44	245	6	15	-25	9.0	-5
5.92	13.44	245	12	29.4	-22	14.0	-3

Table 16 *Effects of reef on storm events.*

9. CONCLUSIONS

Based on available information on wave climate and beach morphology, the conceptual design of an artificial reef consisting of Reef Ball modules to protect the site of *Broad Beach* has been carried out. Construction and Environmental constraints, as well as an inspection of the expected performance of the reef in terms of wave attenuation, suggested the optimal number of Reef Ball rows to be employed is 10.

Numerical modeling of the shoreline response to the structure placement highlighted that:

- The reef reduces significantly (approximately by 50%) the long term erosion rate of the beach, but induces a sand deficit downdrift of 6340 cubic meters/year. This is basically due to the fact that the reef attenuates waves, reducing the alongshore sand transport from BB to Zuma.
- Due to the high tide variations, the effects of the reef on storm events are limited, although not negligible (the volume transported offshore by the storms reduces up to 25%).
- It is reasonable to assume that a conventional reef breakwater would be more efficient either in reducing the long term sand deficit at BB or in mitigating the erosion induced by storms. This basically because conventional structures are less permeable than Reef Balls. However, downdrift effects should be accurately verified.
- Due to construction constraints (Section 7.1.2), the reef designed in this study is located quite close to the shoreline. Accordingly, it reduces the height of the waves and the longshore sand transport only in a small portion of beach. For this reason, a way of increasing the structure effectiveness may be to move it seawards, so to protect a larger area. This point deserves to be deeply investigated in future studies.

10. REFERENCES

Armono, H. D. 2003.“Hemispherical shaped artificial reefs.”Ph.D.Thesis, Queen’s Univ., Kingston, ON, Canada.

Buccino, M., and Calabrese, M. 2007.“Conceptual approach for pre-diction of wave transmission at low-crested breakwaters.”J. Waterway,Port, Coastal, Ocean Eng., 10.1061/(ASCE)0733-950X(2007)133:3(213), 213–224.

Dally, W. R., Dean, R.G., Dalrymple, R.A., 1985. Wave height variation across beach of arbitrary profile. Journal of Geophysical Research, vol. 90, No C6.

Dean, R.G., 1977. Equilibrium Beach Profiles: US Atlantic and Gulf Coasts. Dept. of Civil Engineering, *Ocean Engineering Report 12,* University of Delaware, Newark, Delaware.

Hallermeier, R. J., 1981. “A profile zonation for seasonal sand beaches from wave climate,. Coastal Engineering 4, 253-277.

Kamphuis, J.W., 1991. Incipient wave breaking. Coastal Engineering 15,185–203.

Walton, T.L., 1973. Littoral drift computations along the coast of Florida by means of ship wave observations. Technical Report No. 15, University of Florida, Department of Coastal and Oceanographic Laboratory, Gainesville, FL.

Walton, T.L., Dean, R.G., 2010. Longshore sediment transport via littoral drift rose. Ocean Engineering (37), pp. 228-235.

APPENDIX I. CONVENTIONAL (JAPANESE) ARTIFICIAL REEF

A.I. Conventional (Japanese) artificial reef

As an alternative to the use of Reef Balls, a Conventional Artificial Reef (CAR) is here considered. The structure, shown in Figure A1, has a 50m wide crown width and is located nearly 150m offshore the revetment toe, at a water depth of- 4.0m from the MLLW. Wide crown reef breakwaters are typical of the Japanese design practice; As an example, Figure A2 displays the case of the barrier defending Niigata coast.

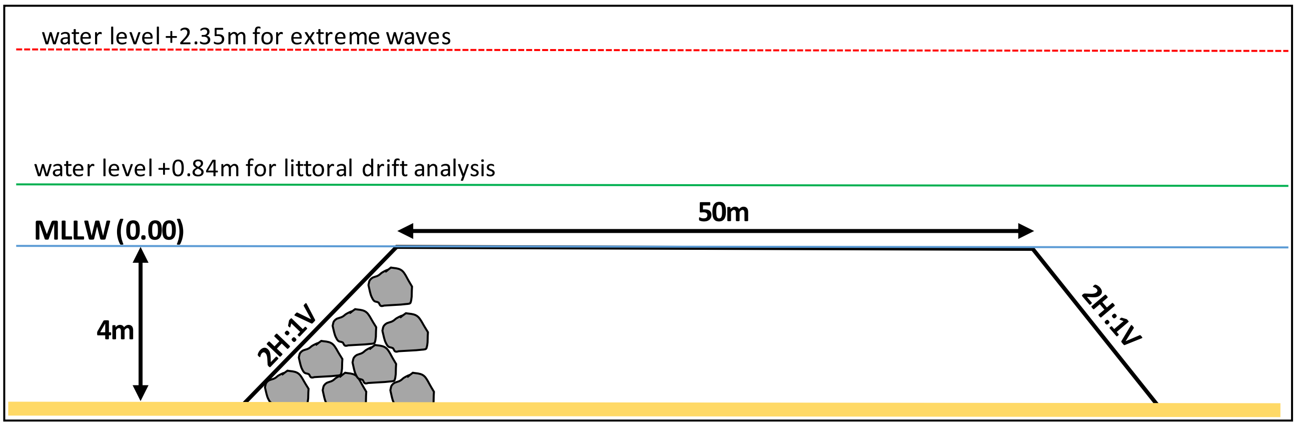


Figure A1. Conventional Artificial Reef

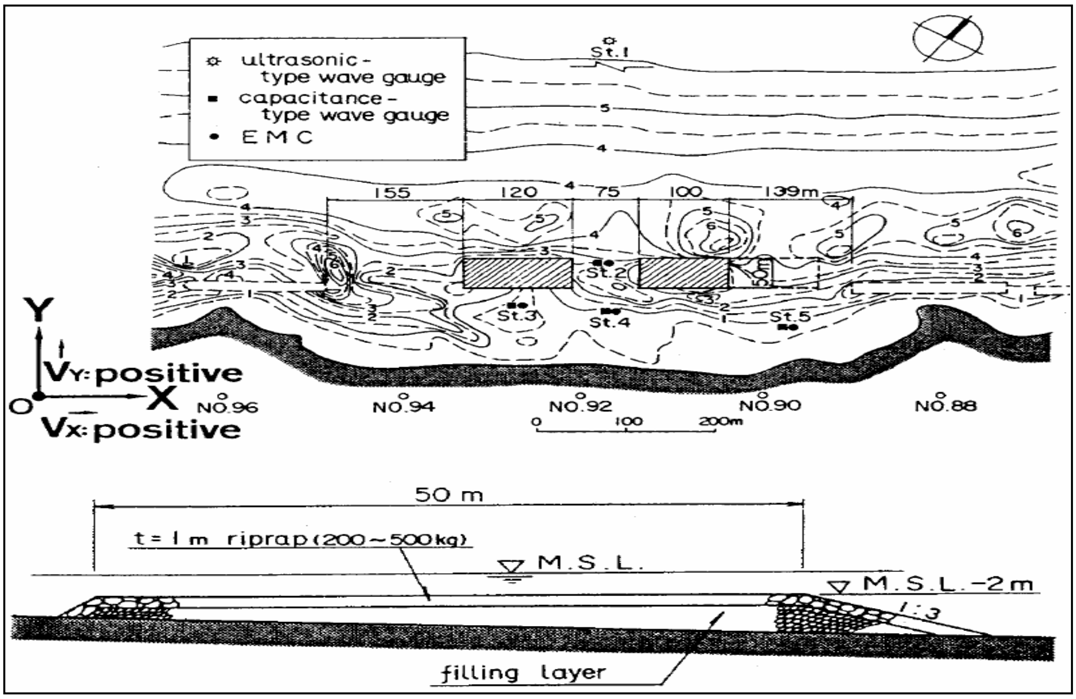


Figure A2. Conventional Artificial Reef at Niigata coast (Japan)

Using the Buccino and Calabrese (2007) transmission formula, it has been found *the structure above to have a 0.40 transmission coefficient* under both the average (littoral drift) and the extreme wave conditions.

A.II. Effect on littoral Drift

The conventional reef reduces the longshore sand loss rate of *Broad Beach* at 2227 cu.m./year (Figure A3 lower panel). Relative to the unprotected beach (revetment only), the new structure reduces the erosion rate by nearly 84%, whereas respect to the Reef Ball solution (Figure A3 upper panel) the reduction is of 70%.

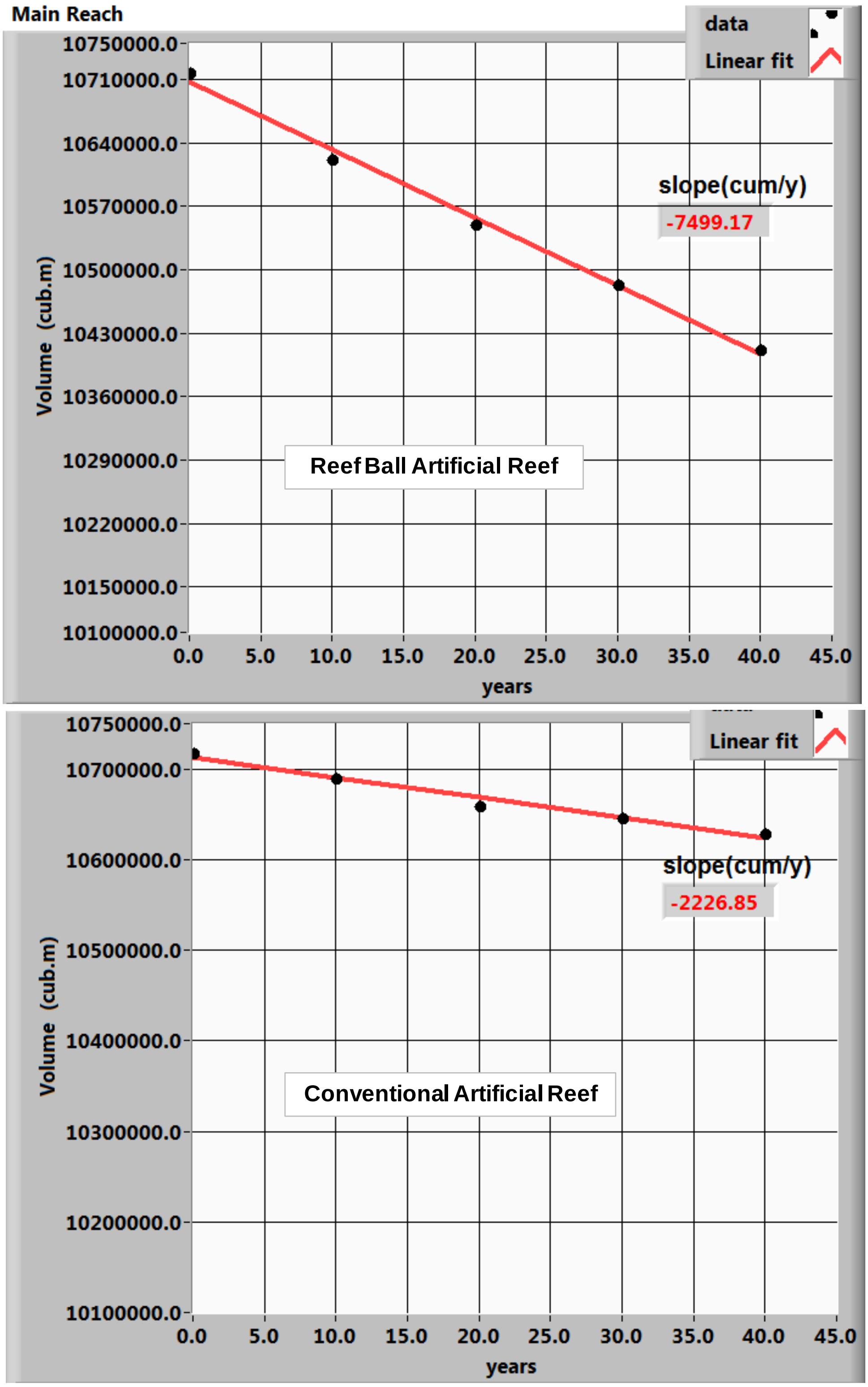


Figure A3. Longshore response of the Reef Ball barrier (upper panel) and the Conventional Artificial Reef (lower panel) for Broad Beach

The Figures A4 and A5 compare the unprotected beach versus the conventional reef.

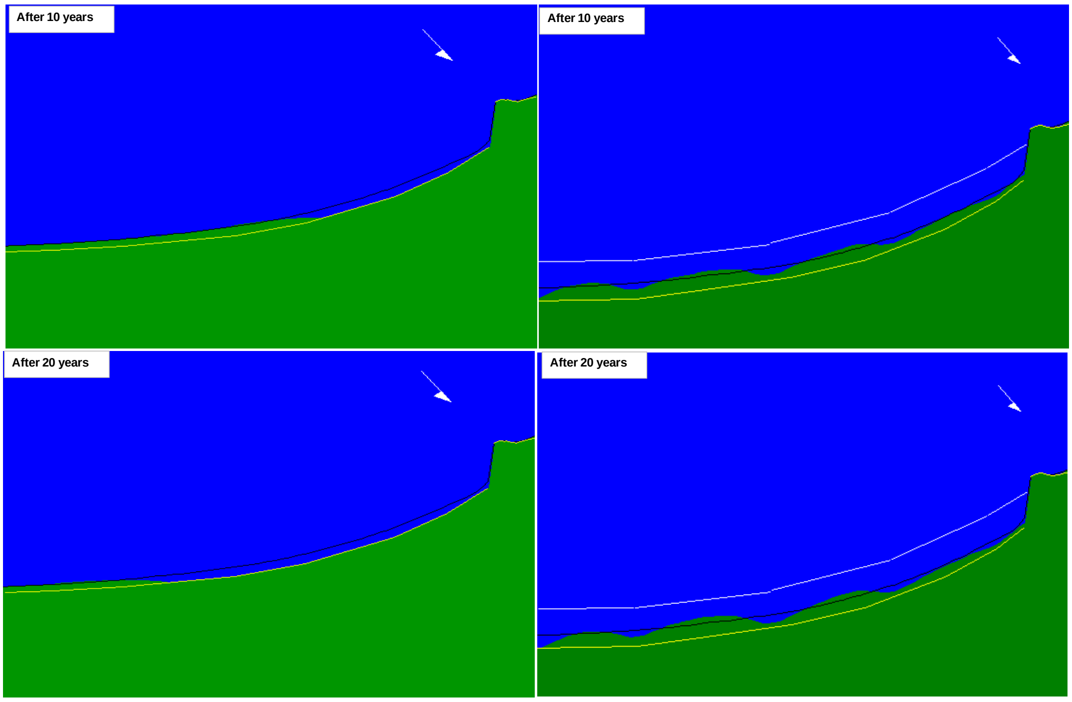


Figure 4. Unprotected beach vs. Conventional Artificial Reef for Broad Beach (10 and 20 years)

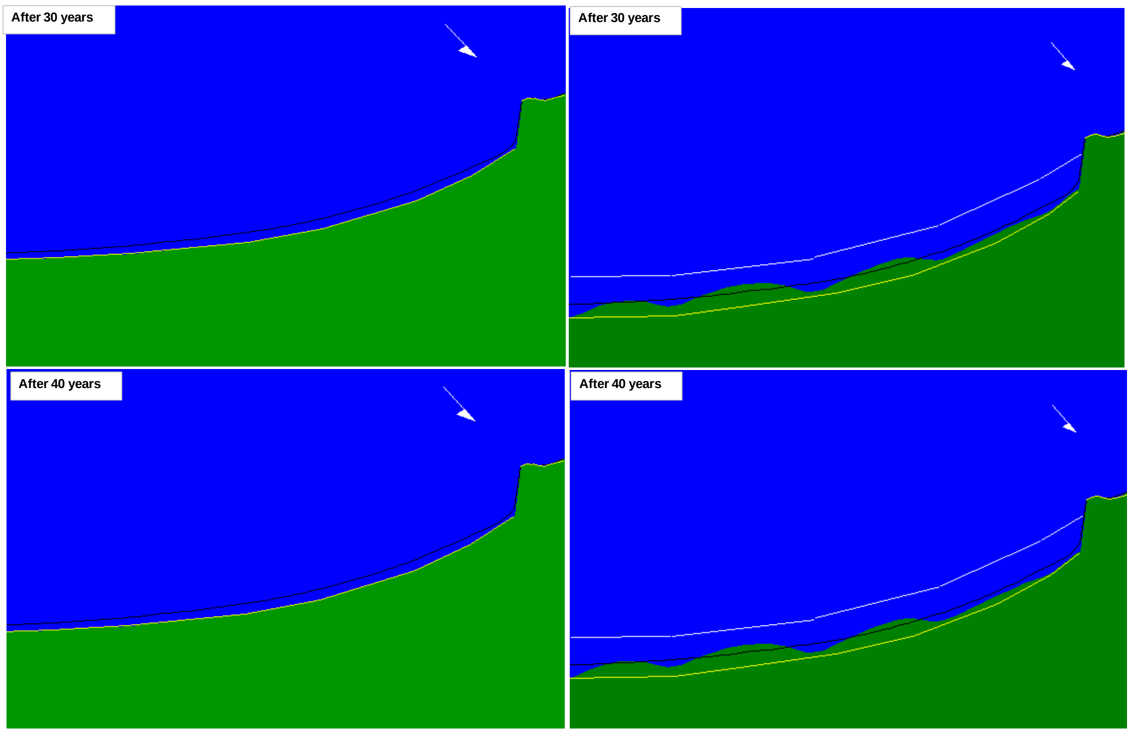


Figure A5. Unprotected beach vs. Conventional Artificial Reef for Broad Beach (30 and 40 years)

The wide conventional Artificial Reef would basically lead to the stabilization of _Broad Beach_.

AIII. Effect on storms

Table A.I summarizes the effect of the new structure on storm events. Compared to the case of unprotected beach, the retreatment of coastline reduces by 30/40%, with a substantial lowering of the sand volume lost .

Hs (m)	Tp (s)	Dir (deg. N)	Duration (hrs)	Volume of sand lost (cu.m/m)	Var. [%]	Shoreline retreat (m)	Var. [%]
5.92	13.44	245	6	2.958	-85	6.5	-31.5
5.92	13.44	245	12	6.646	-82	9.0	-38

Table A.I. Effect of Conventional Reef on storm events and comparison with the case of unprotected beach