ASR America
Marine Consulting and Research
P.O. Box 320599, Cocoa Beach, Florida 32932, USA
Ph. +1 321 613-2528, jhearin@asr-america.com
www.asr-america.com

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ASR America Comments Regarding Brevard County

MPASR Feasibility Study: Interim Report 2

Section 1.1

MPASR Function:

We do not agree that the erosion control benefits of the reef will be secondary to recreational benefits. The county and state has stipulated that coastal protection would be the primary function of the reef. The conceptual design we submitted for this feasibility study was developed as a coastal protection structure with recreational benefits as a secondary consideration.

Surfing Skill Level of Reef:

The chart you utilized for assessing the surfing skill level is actually the chart developed by Dr. Kimo Walker in 1974. In the JCR special issue #29, Hutt et al. (2001) demonstrated that this chart will often under-estimate the surfing skill level required. In that same article they presented a revised method for assessing surfing skill which has been widely accepted and cited by the coastal engineering community. This wave classification method should be used in conjunction with the wave breaking intensity analysis method developed by Black and Mead (2001) to predict the types of waves which will break on the reef. The basic details of these wave assessment methods are summarized in Appendix A – The Science of Surfing.

The conceptual design for the Brevard Multi-Purpose Reef submitted by ASR America was designed to have the following properties:

Peel Angles: 80 degrees at reef focus (to facilitate take-off), reducing to 60 -30 degrees on reef arms depending on incident wave angles and periods.

Orthogonal Reef Gradients: vary from 1:5 at base to 1:40 at crest with an average value of 1:20 at typical wave breaking depths

Based on these design parameters and the methods described in Appendix A the waves breaking on the reef will have the properties listed below.

Surfing Skill Rating from Figure 3:

1 meter wave height – levels 2 thru 9 – beginner to expert

2 meter wave height – levels 3 thru 8 – intermediate to expert

Vortex Ratios and Breaking Intensity from Figure 7 and Table 2: 2.0 (very high) to 3.0 (medium)

These wave breaking properties will yield very desirable waves for experienced local and visiting surfers.

Reef Positioning for Coastal Protection:

The offshore position of the reef is the key factor in determining whether the reef will cause erosion or accretion in its lee. The methods for determining the optimum offshore position of a MPASR were described in the literature review of existing MPASR performed by ASR America and have been summarized in Appendix B. The methods developed by Ranasinghe (2006) and Black (2001 and 2003) were used to determine the offshore position of the conceptual design submitted by ASR America in March 2008. We request that you attach our conceptual design report to this interim report so that all parties may refer to it during subsequent discussions.

The surf zone width (SZW) is a function of the shoreline gradient and the wave breaking height. The gradient in Brevard County is approximately 1:100. Therefore the typical values for SZW in Brevard County vary from approximately 75m to 250 m based on Figure 3 in Appendix B.

Wave Height (m)	SZW (m)
0.5	75
1.0 (mean)	125
1.5	200
2.0	250

The conceptual reef design was positioned 300 m offshore from MSL which is more than twice the SZW for mean wave conditions and still greater than the SZW for 2m waves. The Ranasinghe method predicts that accretion will occur behind the reef for most wave conditions that occur in Brevard County.

The conceptual reef design has an effective longshore length of 96m and an offshore length of 300m which equates to a B/S ratio of 0.32 per Black. A salient with dimensions of approximately 100m cross-shore and 800m longshore is predicted to form behind the reef from based on Figure 2 of Appendix B and the relationships derived by Black.

Both methods predict that accretion will occur in the lee of the conceptual reef design if placed 300m offshore of MSL.

Section 1.3

Surfer Density:

We feel that the method used by Coastal Tech to predict the surfer density will over-estimate the number of surfers who could reasonably use the reef at any one time. The reef is designed to be ridden from the focus (take-off point) to the end of the reef without interruption during favorable wave conditions. Surfers will not spread out along the reef as they typically do at most Brevard County beach breaks but will congregate around the focus as they do on first peak at Sebastian Inlet and other quality reef breaks around the world. Surfers will catch waves and ride to the end of the reef then paddle back to the focus for their next wave. The density of the crowd is regulated by the frequency of the waves and the time required to paddle back into position. Based on our personal experience with similar reef breaks around the world we predict that the reef could support approximately 50 surfers at any one time (25 on each arm of reef).

Lengthening the arms of the reef will not increase the surfer density but it will actually decrease the overall wave quality as there is a law of diminishing returns when it comes to reef cross-shore length. As the wave propagates down the reef it will lose size and reduce in peel angle due to refraction. Extending the reef's arms will increase the cost of the reef without increasing the surfer density.

Advantages of Multiple Reef Configurations:

The solution to increasing surfer density and increasing the length of protected shoreline is to build multiple reefs. Since the primary factor in geo-textile reef cost is the overall volume, we have found that it is more cost effective to build a series of smaller reefs rather than one large reef. The benefits of multiple reef configurations are:

- total reef(s) volume may be held constant to maintain budget requirements
- a wider longshore footprint means more beach is protected from erosion
- smaller reefs may be placed closer to shore which reduces volume and cost
- Placing reefs closer to shore will reduce paddle out distance and improve viewing during surf contests
- creates more surfing breaks which increases number of surfers possible

ASR America strongly urges Brevard County to consider the option of using a multiple reef configuration for this coastal protection project.

Surfing Days:

According to Table 1 in Interim Report 2, the waves in Brevard County will only exceed 1.3 feet approximately 180-230 days per year. This figure seems low compared to other wave data sets we have seen for Brevard County. Also the significantly increased gradient of the reef coupled with the depth at which this will occur (approximately 15 feet in present design) should increase the shoaling effect and produce more surfable waves/days.

Section 1.4

We would not suggest choosing the top-ranked reef site based solely on a slightly better wave climate. The economic considerations of the reef will have a strong influence over the amount of public support and private funding that will be available for the design and construction phase. The EDC, who provided the funding for the Economic Impact Assessment, should be consulted prior to finalizing the site.

We look forward to discussing these issues and the rest of the feasibility study with the contractors and Brevard County.

Sincerely,

John M Hearin

John Hearin

President
ASR America

Appendix A - The Science of Surfing

The scientific investigation into what makes a good surfing wave began in the 1970's with the research performed by Dr. James "Kimo" Walker at the University of Hawaii. Since then his work has been greatly expanded upon by the members of the Artificial Reefs Project (ARP) at Waikato University in New Zealand and their commercial offshoot, ASR Limited. The science of surfing was highlighted in Special Issue Number 29 of the *Journal of Coastal Research* (2001) and there have been three International Surfing Reef Symposiums, the latest in June of 2003. The *Journal of Coastal Research* and the proceedings of the Third International Surfing Reef Symposium were the primary sources for the information presented in this section (Mead, 2003; Mead and Black, 2001a and 2001b; Hutt, Black and Mead, 2001).

Surfing Wave Terminology

The basic terminology of a surfing wave is shown in Figure 1. Ideally surfers attempt to ride inside the tube or pocket of the wave. This is the steepest most intense part of the wave and where the highest surfing speeds are attained. A good surfing wave will peel either right or left at a rate that allows the surfer to stay ahead of the break and maximize the length and speed of the ride. The rate at which the wave peels is primarily determined by the shape of the seabed. The steepness or intensity of the wave is primarily determined by the seabed gradient. These aspects of seabed shape and gradient are the primary factors in determining a good surfing wave.

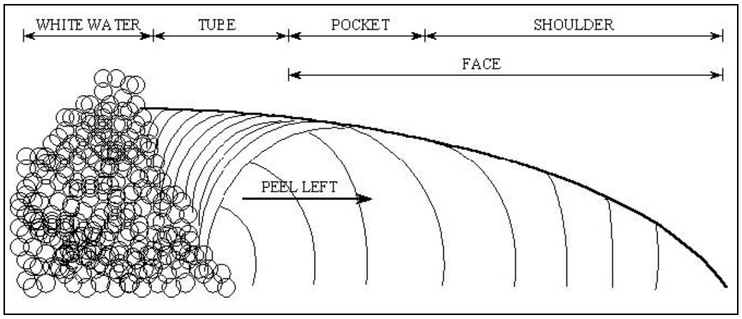

Figure 1 Description of a Surfing Wave (Hutt et al., 2001)

Wave Peel Angle

The rate at which a wave breaks is determined by the peel angle. The peel angle is defined as the angle between the wave crest and the vector describing the path of the breaking part of the wave as it propagates towards shore. The peel angle is illustrated in Figure 2.

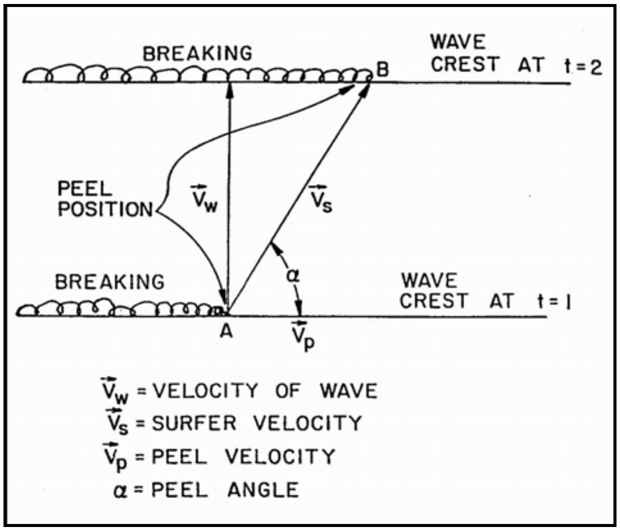

Figure 2. Wave Peel Angle (Hutt et al., 2001)

Peel angles vary from 0-90 degrees with small angles equating to fast surfing waves and large angles to slow waves. A wave with a very low peel angle is called a “close-out” because it is not possible to surf fast enough to stay ahead of the break. Conversely a wave with a very high peel angle is considered too slow for good surfing.

Surfing Skill as a function of Peel Angle and Wave Height

The classification of peel angles as it relates to surfing quality was the subject of much research by ASR Limited in the late 1990’s. They compiled a database of surfing characteristics for over 40 of the most popular surf breaks around the world. From this database and the results of previous research they developed a method for classifying the surfing skill required to surf various waves as a function of the peel angle and the height of the wave. The definitions of surfer skill ratings are listed in Table 1 and the classifications of surfing skill versus peel angle and wave height are shown in Figure 3.

Table 1. Rating of the Skill Level of Surfers. (Hutt et al., 2001)

Rating	Description of Rating	Peel Angle Limit (deg)	Wave Height Min / Max (m)
1	Beginner surfers not yet able to ride the face of a wave and simply moves forward as the wave advances.	90	0.70 / 1.00
2	Learner surfers able to successfully ride laterally along the crest of a wave.	70	0.65 / 1.50
3	Surfers that have developed the skill to generate speed by 'pumping' on the face of the wave.	60	0.60 / 2.50
4	Surfers beginning to initiate and execute standard surfing maneuvers on occasion.	55	0.55 / 4.00
5	Surfers able to execute standard maneuvers consecutively on a single wave.	50	0.50 / >4.00
6	Surfers able to execute standard maneuvers consecutively. Executes advanced maneuvers on occasion.	40	0.45 / >4.00
7	Top amateur surfers able to consecutively execute advanced maneuvers.	29	0.40 / >4.00
8	Professional surfers able to consecutively execute advanced maneuvers.	27	0.35 / >4.00
9	Top 44 professional surfers able to consecutively execute advanced maneuvers.	Not reach	0.30 / >4.00
10	Surfers in the future	Not reach	0.3 / >4.00

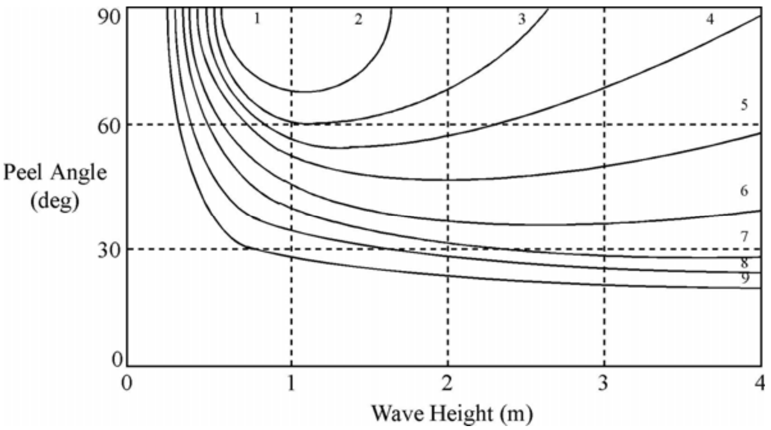

Figure 3. Classification of Surfing Skill versus Peel Angle And Wave Height (Hutt et al., 2001)

ASR Limited determined that the peel angle lower limit for professional surfers is currently around 27° while most surfers would benefit from peel angles between 30° and 60°. They also noted that for a given peel angle the waves get more difficult to ride as the wave height decreases.

Wave Breaking Intensity

The wave steepness or breaking intensity is primarily a function of the seabed gradient (Battjes, 1974; Sayce, 1997 – cited Mead, 2003). The four main classifications of breaker types are illustrated in Figure 4.

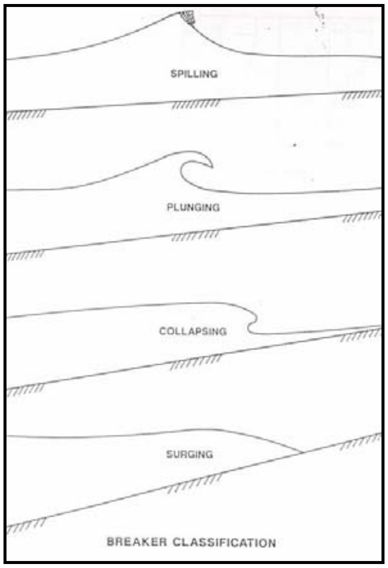

Figure 4. Breaker Classifications (Mead, 2003)

Spilling breakers occur on low seabed gradients. Plunging breakers occur on moderate gradients while collapsing and surging breakers occur on higher gradients. Collapsing and surging breakers are not suitable for surfing. Spilling breakers are surfable but not desirable due to their low intensity. Plunging breakers are the preferred classification for quality surfing waves.

Wave Height and Period Influence on Breaking Intensity

The wave height and period (or associated wavelength) also has an effect on the wave breaking intensity. The CEM describes a method of correlating the breaker type to the seabed gradient, wave height and wave length using the surf similarity parameter, also known as the Irribarren number (ξ_b).

$\xi_b = m / (H_b/L_0)^{½}$ m – seabed gradient
H_b – Breaking wave height
L_0 – Deep water wave length

Plunging waves occur when the Irribarren number range is between 0.5 and 3.3. It should be noted that the breaking intensity increases with increasing seabed gradient, increasing wavelength and decreasing wave height. Therefore smaller waves will break with higher intensity than larger waves over the same seabed gradient.

Wave Vortex Ratio

The Irribarren number is a good tool for determining the breaker classification however it is not very useful in differentiating the breaking intensity of waves within the plunging category (Sayce *et al*., 1999). Sayce developed a method for predicting the intensity of plunging waves using the wave vortex ratio. The vortex ratio is the ratio of the wave's vortex length to its width when viewed parallel to the wave crest. The breaking intensity is inversely proportional to the vortex ratio; the lower the vortex ratio the more intensely the wave breaks. The wave vortex parameters are illustrated in Figure 5.

Vortex Ratio = vortex length / vortex width

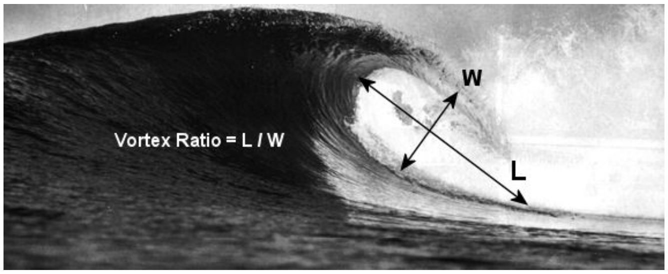

Figure 5. Wave Vortex Ratio (Mead, 2003)

Mead and Black (2001b) developed an empirical relationship between the wave vortex ratio and the seabed gradient. This relationship may be used to predict the breaking intensity of any wave given the gradient over which it breaks. Mead and Black determined that the orthogonal seabed gradient should be used in this relationship, as opposed to the contour normal gradient, since waves move in the orthogonal direction. The different seabed gradients are described in Figure 6.

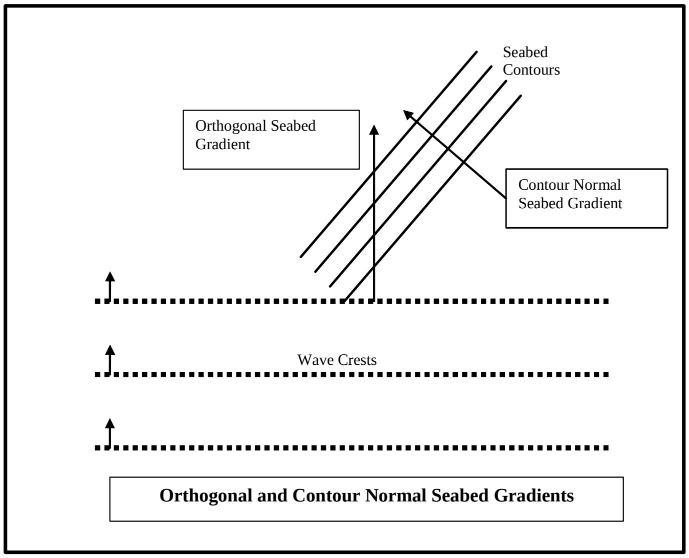

Figure 6. Seabed Gradients

The relationship between vortex ratio and orthogonal seabed gradient is given below.

$Y = 0.065\,X + 0.821$ Y – vortex ratio

X – Horizontal distance per one vertical unit of orthogonal seabed gradient (gradient = 1 / X)

Figure 7 shows a graph of the orthogonal seabed gradient versus vortex ratio over the typical range of surfing wave values. The vortex ratio reaches a practical limit of 1.5 over an orthogonal seabed gradient of nearly 0.10 (1:10). The orthogonal seabed gradient is difficult to determine empirically because the wave direction is constantly changing due to refraction. Mead and Black recommend using numerical modeling to predict the vortex ratio over any specific seabed or reef.

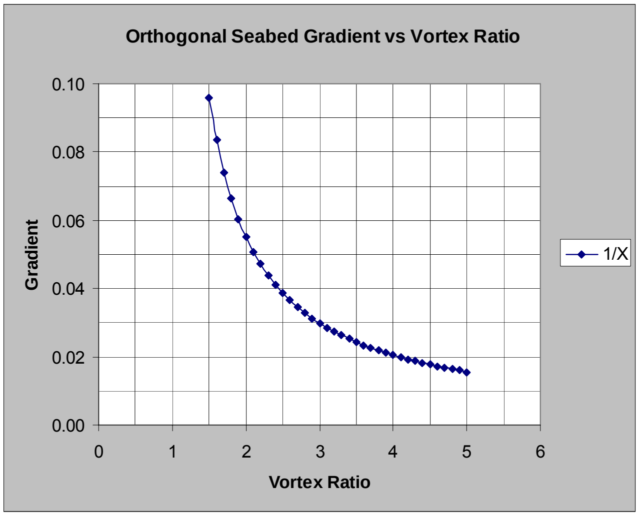

Figure 7. Orthogonal Seabed Gradient vs. Vortex Ratio

Mead and Black (2001b) analyzed the vortex ratios of the waves in their database of surfing wave characteristics to develop a classification for wave breaking intensity using the vortex ratio. Their classification is shown in Table 2. This classification is used in the design of artificial surfing reefs to predict the type of wave that will break over the reef.

Table 2. Wave Breaking Intensity (Mead and Black, 2001b)

Breaking Intensity	**Extreme**	**Very High**	**High**	**Medium/high**	**Medium**
Vortex Ratio	1.6 - 1.9	1.91 - 2.2	2.21 - 2.5	2.51 - 2.8	2.81 - 3.1
Descriptive Terms	Square, spitting	Very hollow	Pitching, hollow.	Some tube sections	Steep faced, but rarely tubing
Example Breaks	Pipeline, Shark Island	Backdoor, Padang Padang	Kirra Point, Off-The-Wall	Bells Beach, Bingin	Manu Bay, Whangamata

Convex Reef Profile for Optimized Breaking Intensity

In the previous discussion on Irribarren numbers, it was noted that the wave breaking intensity increases with increasing seabed gradient, increasing wave length and decreasing wave height. Therefore smaller waves will break with higher intensity than larger waves over the same seabed gradient. Smaller waves will also break in shallower water than larger waves (USACE, 2002). It is desirable when designing an ASR to optimize the breaking intensity over the whole range of wave heights and associated breaking depths that the reef will encounter. In order to achieve this goal Black and Blenkinsopp (2002) proposed building ASR's with variable slopes. The slope would start out high in deep water and gradually decline as the reef gets shallower. This would give the reef a convex profile as shown in Figure 8. This convex design concept will allow the reef to maintain the desired breaking intensity over a wide range of wave heights thus optimizing the surfing quality of the reef.

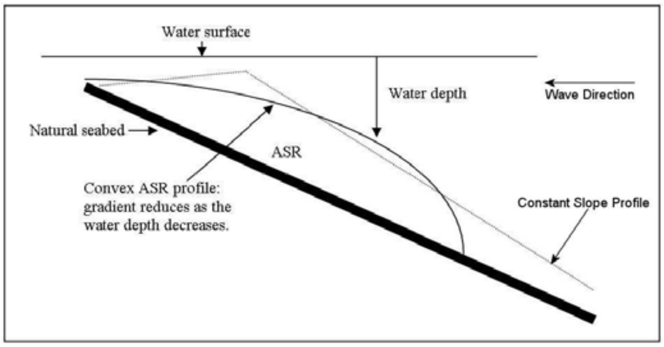

Figure 8. Convex Reef Profile (Mead, 2003)

Reef Shape and Components

As discussed earlier, the wave peel angle is the principle parameter which determines whether a wave is surfable. If the peel angle is too low the wave will break too fast to be ridden. Most typical beach breaks, such as Cocoa Beach, generate waves with very low peel angles because the seabed contours run parallel to the shoreline. These low peel angles often create closeout conditions which yield very short rides. The purpose of an artificial surf reef should be to optimize the wave quality by increasing the peel angle to desirable levels. As noted previously, peel angles between 30° - 60° are suitable for most surfers. The peel angle of any reef aligned at a constant angle to the oncoming waves will not stay constant however due to wave refraction. As the wave propagates along the reef the wave crests will refract towards the reef contours and the peel angle will decrease as demonstrated in Figure 9. In order to avoid undesirably low peel angles at the end of the ride, a reef should start with a high peel angle to allow for refraction. Another design method is to vary the reef alignment to compensate for refraction (Mead, 2003).

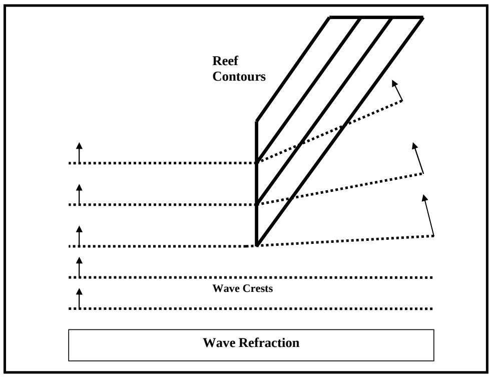

Figure 9. Wave Refraction along Reef Contours

Appendix B – The methods for determining the optimum offshore position of a MPASR

Shoreline Response Predictions from Black and Andrews

Using aerial photographs, Black and Andrews (2001a) analyzed naturally occurring salient formations in New Zealand and Australia. Their research focused on developing empirical relationships to describe salient shapes and dimensions. Additionally they used these relationships to form predictive expressions for salient size based on reef width and offshore distance. Refer to Figure 1 for the salient parameter descriptions.

Physical Dimensions:

- B - Reef width
- S - Distance offshore to landward side of reef
- Y_{off} - Salient amplitude
- X_{off} - Distance between reef and salient
- D_{tot} - Length of salient

Predictive Expressions:

- (1) $B/S \leq 0.1$ Salient may not form
- (2) $B/S > 0.1$ Salient may form
- (3) $B/S > 0.6$ Tombolo may form
- (4) $X_{off} / B = 0.498 (B/S)^{-1.268}$
- (5) $X_{off} = S - Y_{off}$
- (6) $Y_{off} / D_{tot} = 0.125 \pm 0.020$

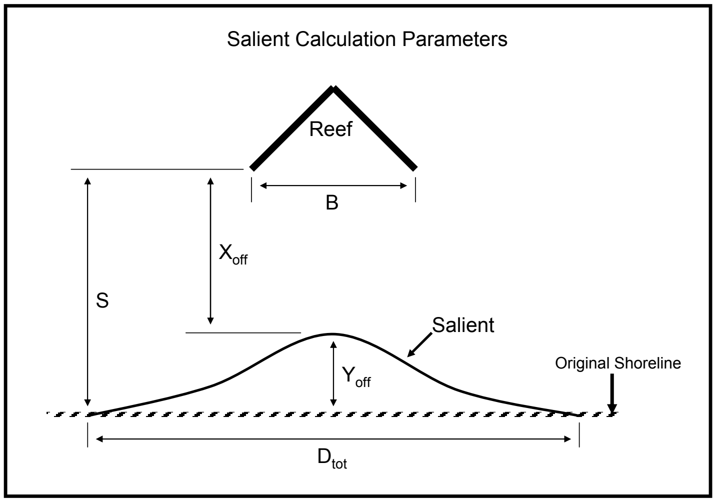

Figure 1. Salient Calculation Parameters (Black and Andrews, 2001a)

A plot of the Black and Andrews relationship between B/S and Y/B shows that the maximum salient size occurs for a B/S ratio of approximately 0.18 but drops off rapidly when the B/S ratio drops below 0.15. Black also demonstrated that if a reef was placed too close to the shoreline (B/S > 1.0) that erosion could result due to compression of the longshore currents between the reef and the natural shoreline (Black, 2003). Black (2003) recommends a design B/S ratio between 0.25 – 0.50 to minimize the total reef volume (and associated costs) while insuring good salient formation. The method developed by Black and Andrews has been confirmed by computer modeling and actual shoreline response behind the Narrowneck and Mount Maunganui Artificial Reefs (Black and Mead, 2007).

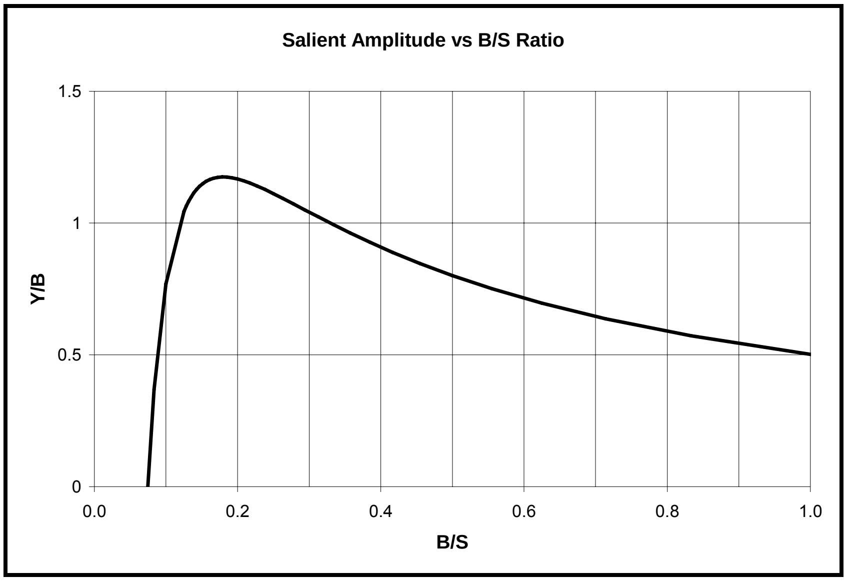

Figure 2. Salient Formation versus B/S Ratio

Shoreline Response Predictions from Ranasinghe, Turner and Symonds

Ranasinghe *et al., (2006),* performed a numerical and physical modeling study on an idealized wedge shape to develop the following relationships for predicting shoreline response behind a MPASR.

- S_a / SZW > 1.5 Accretion is expected
- S_a / SZW < 1.0 Erosion is expected

Where:

- Y – salient amplitude
- B – width of reef
- SZW – natural surf zone width
- S_a – distance offshore to apex of reef crest

Unfortunately Ranasinghe *et al.* did not define the SZW in their relationship. Black and Mead (2007) suggested that the SZW be calculated as:

- SZW = H_b/(ã tanB)

Where:

- H_b - the breakpoint height,
- ã = H_b/d_b is the breaking criterion (typically = 0.78)
- d_b - the water depth at the breakpoint
- tanB - the average beach slope

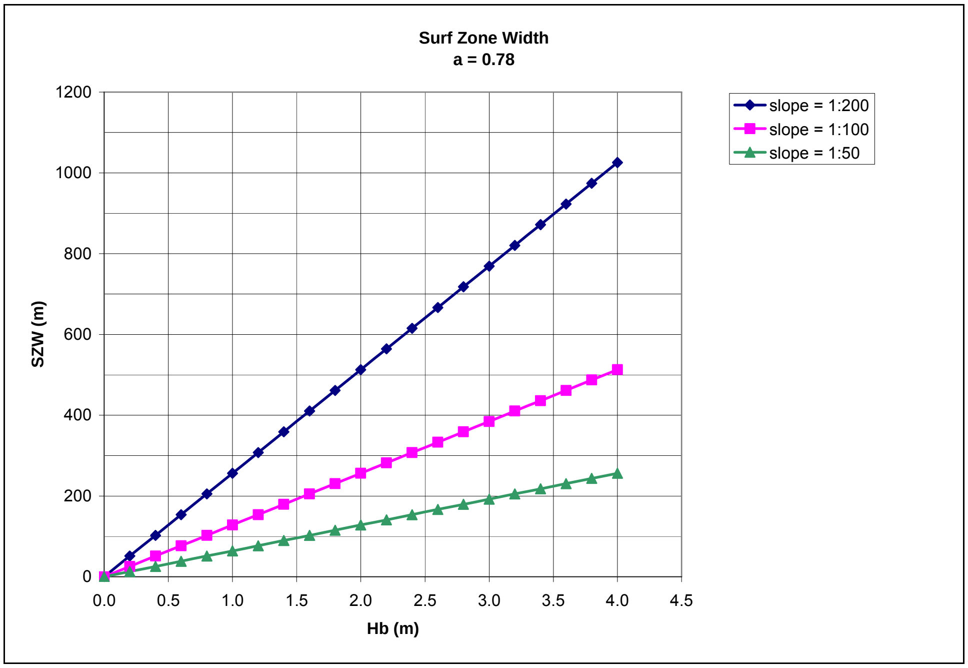

Figure 3. Plot of Typical Surf Zone Widths

Black and Mead (2007) also suggested that the distance to the base of the reef (landward end) is a more appropriate measure of the offshore parameter (S_a) since the zone between the base of the reef and the shoreline is where most of the currents induced by the reef occur. The Ranasinghe *et al.* relationship predicts that the maximum salient will occur when the reef is positioned approximately twice the natural surf zone width offshore. They also predict that erosion will occur if the reef is positioned within the natural surf zone (Figure 4).

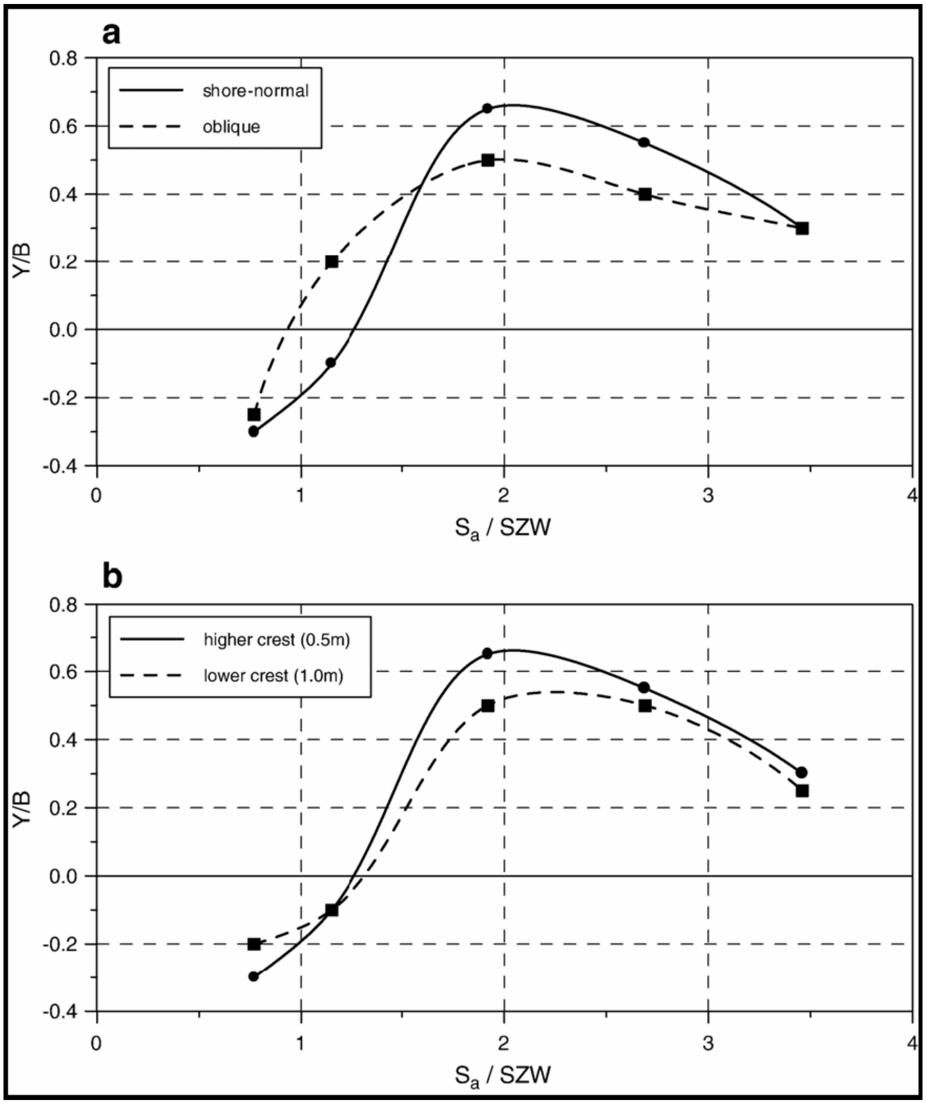

Figure 4. Shoreline Response to MPASR
(Ranasinghe et al., 2006)

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