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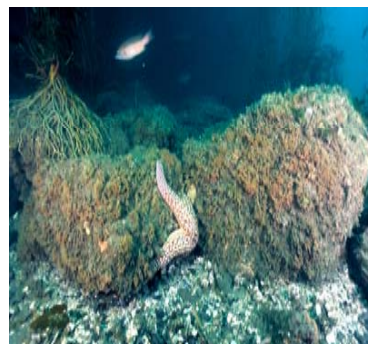
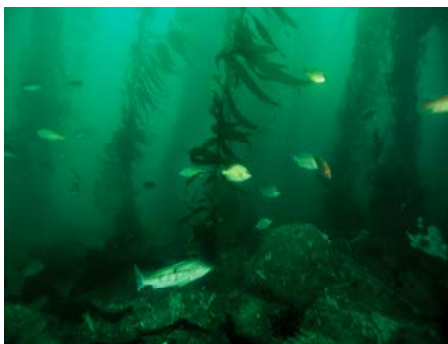
Annual Public Workshop

# Verification of Designed Specifications of the Wheeler North Reef

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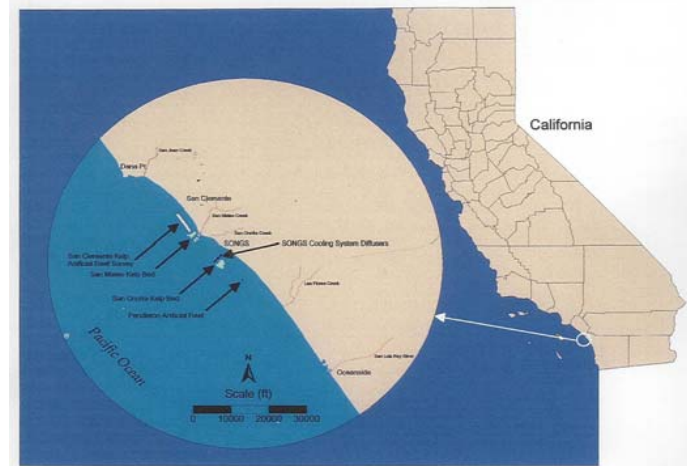
M. Hany S. Elwany, Ph.D.  
Coastal Environments

27 April 2009



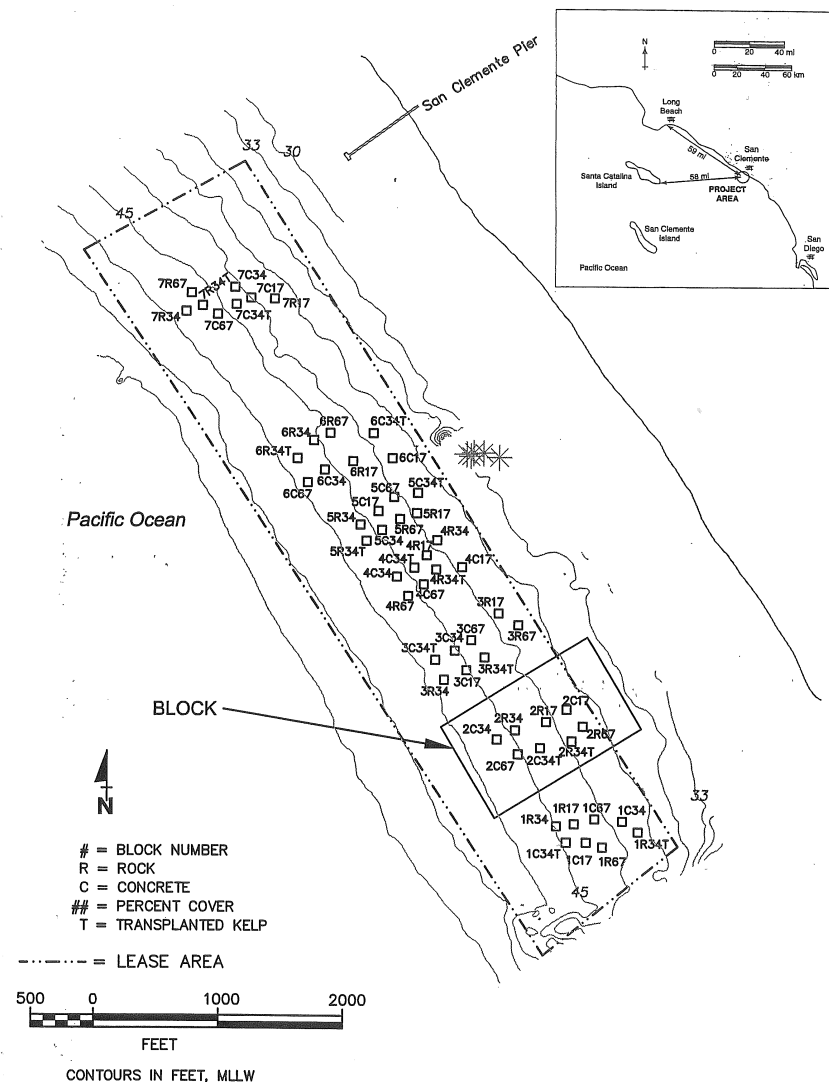
# OVERVIEW

- To mitigate impacts of San Onofre Nuclear Generating Station on kelp
- Specified performance criteria, 4 plants / 100 m<sup>2</sup> and must support the biological communities of natural reefs
- Phase 1 experimental reef (22.4 acres) completed on 27 September 1999
- Phase 2 build-out reef (152 acres) completed on 11 September 2008



# Experimental Reef - Phase 1 (18 August 1999 – 29 September 1999)

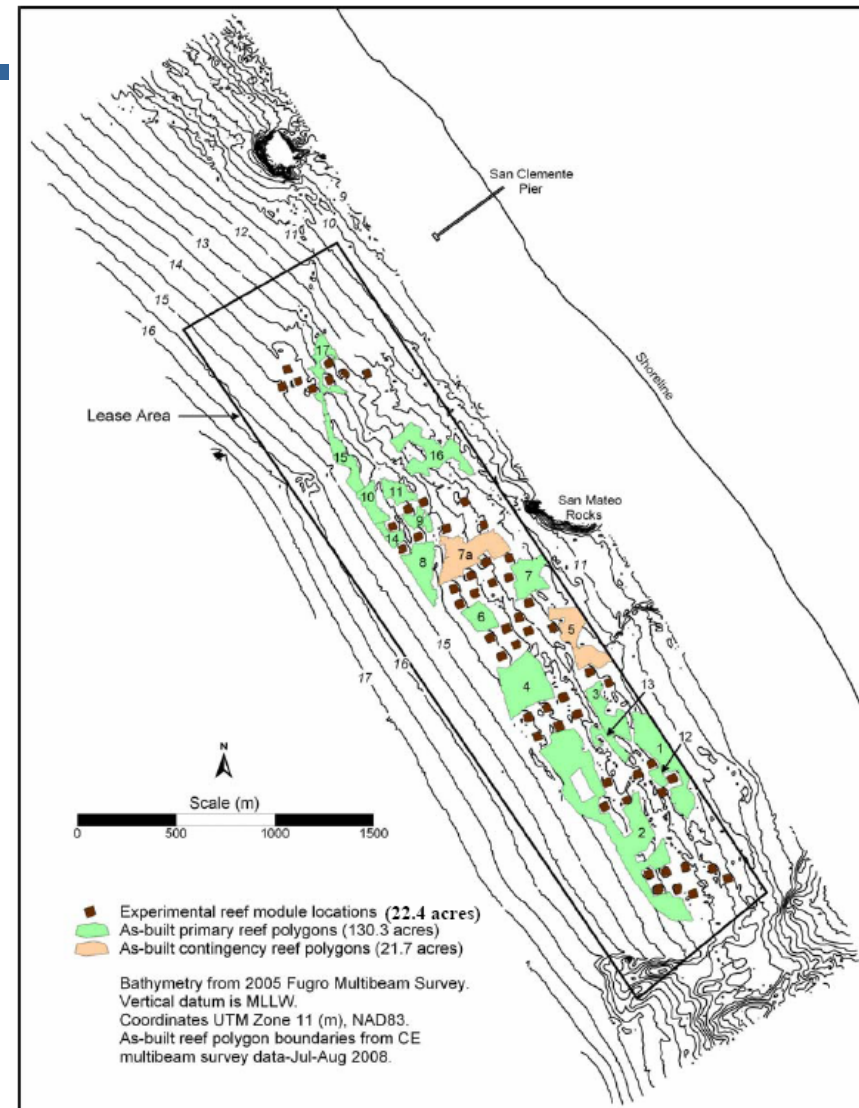
- 7 blocks, 8 modules (40 m x 40 m) per block
- 56 modules in a single layer
- Low Relief (< 1 m)
- Quarry boulders and rubble concrete
- 28 modules are quarry boulders and 28 modules are rubble concrete
- Average size = 3 x 2 x 1 ft
- Built in water depths of 11 to 15 m
- Seafloor design coverages  
Low, Medium, High



# Wheeler North Reef – PHASE 2

## 9 June 2008 – 11 September 2008

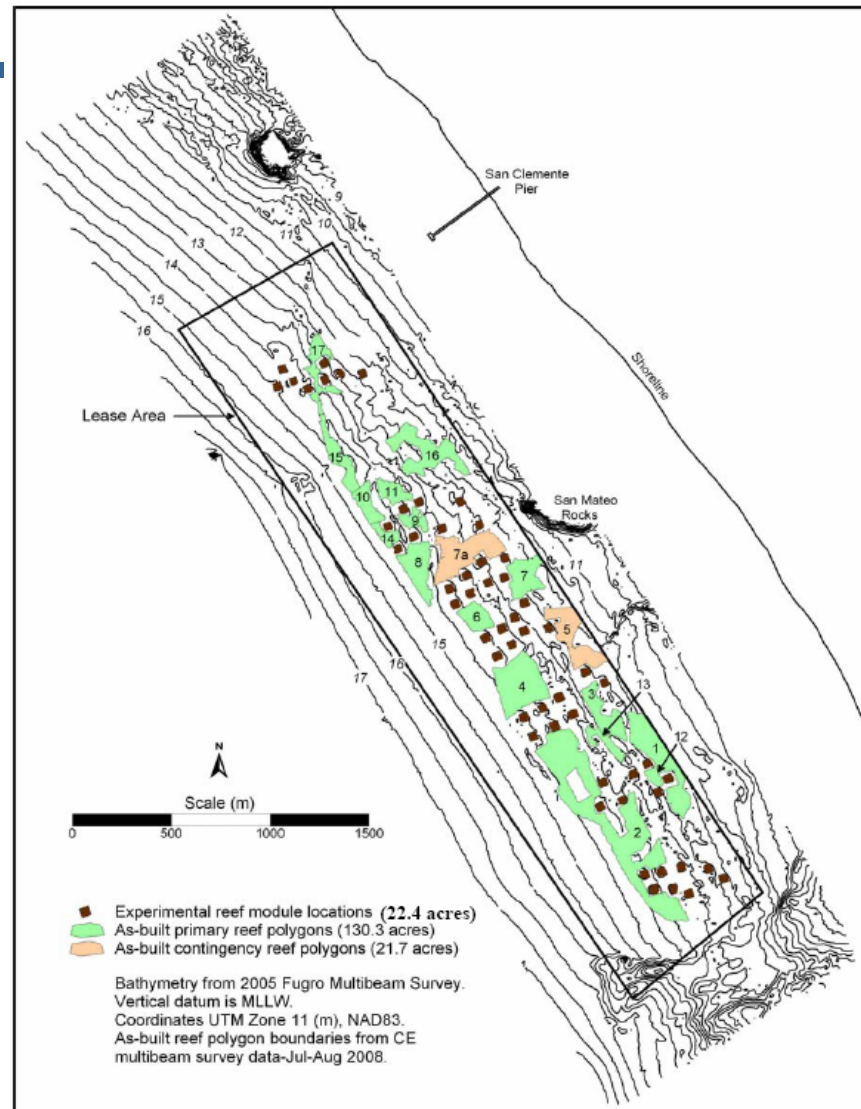
- Consists of 17 polygons
- 152 Acres
- Polygon size varies from 1.4 to 38.9 acres
- Constructed exclusively of quarry rock
- 830 tons per acre in a single layer with a height of less than 1 m



# Wheeler North Reef

## Total Constructed REEF, ACRES

- Phase 1 (Experimental Reef) **22.4 Acres**
- Phase 2 (Primary Polygons) 130.3 acres
- Phase 2 Contingency Polygons) 21.7 acres
- Total Constructed Reef **172.4 acres**
- CCC Permit required **150 acres**
- CCC approved the project in **January 2009**



# Quarry Rock Sources (Phase 2)

- Pebbly Beach quarry, 86,904 tons
- Empire quarry, 12,157 tons
- La Piedra quarry, Ensenada - 26,896 tons
- 70,000 tons stock prior to commencement of reef construction activities.
- Remainder rocks produced during construction.
- Total rocks 125,957 tons were used to construct phase 2 (152 acres).
- Average tonnage per acre is 830 ton/acre.



# Average Reef Rocks: from 75 lbs to 982 lbs



## Rock Specifications for Phase 2 WNR from Twining Laboratories (2008a,b,c)

Parameter	Test	Quarry		
		Pebbly Beach	Empire	La Piedra
Apparent Specific Gravity	ASTM <sup>a</sup> C127	2.72	2.45	2.73
Absorption (%)	ASTM C127	2.0	5.5	0.5
Abrasion <sup>b</sup> (%)	ASTM 535	28.9	32.2	11.0

<sup>a</sup> ASTM = American Society of Testing and Materials.

<sup>b</sup> Percent wear at 1,000 revolutions.

### Required Material Tests

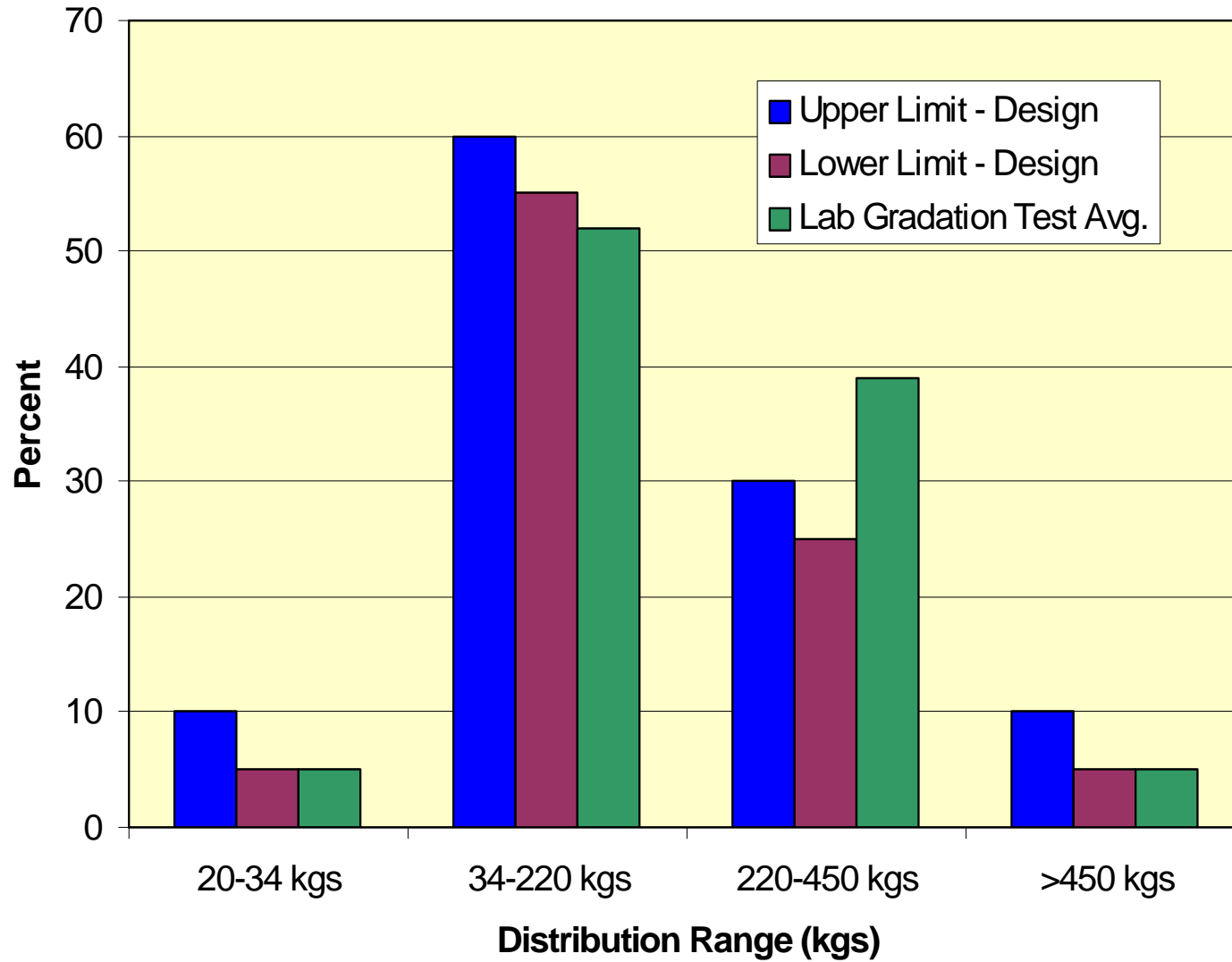
Test	California / ASTM Test	Requirement
Apparent Specific Gravity	206 / ASTM C127	2.3 minimum
Absorption	206 / ASTM C127	4.2% maximum
Abrasion (%)	ASTM C535	maximum 38% at 500 revolutions / maximum 50% at 1000 revolutions

ASTM = American Society of Testing and Materials

## Mean and Standard Deviation (STD) of Rock Dimensions

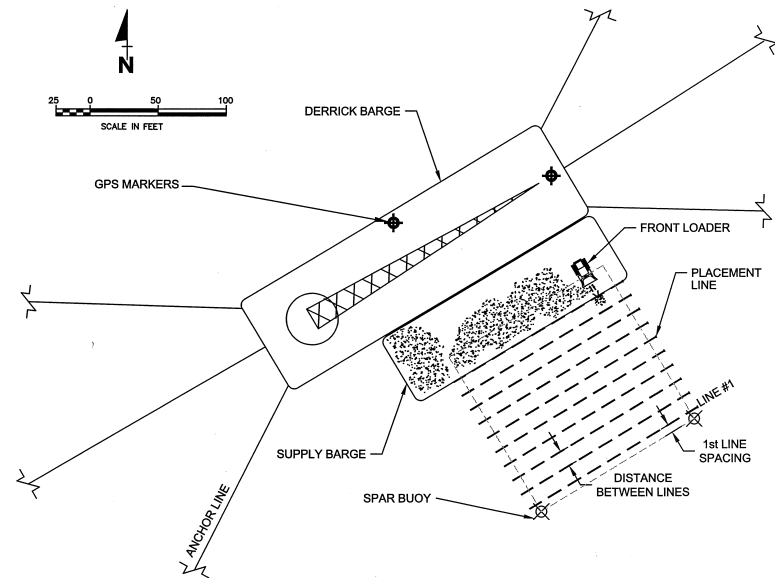
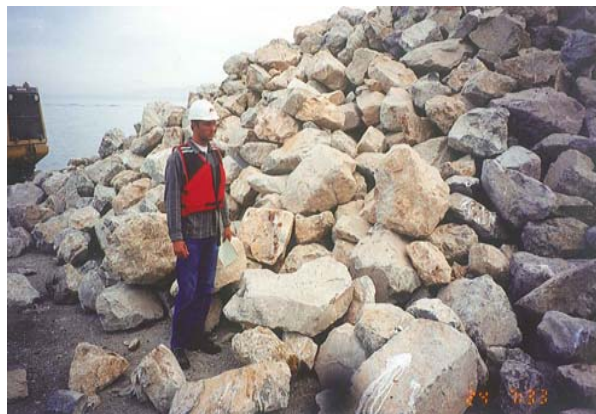
Rock Quarry Location	Sample # N	Length (ft)		Width (ft)		Height (ft)	
		Mean	STD	Mean	STD	Mean	STD
Empire	180	2.4	0.8	1.8	0.6	1.3	0.5
Ensenada	280	2.4	0.8	1.8	0.6	1.4	0.5
Pebbly Beach	960	2.3	0.7	1.8	0.6	1.4	0.5

## Rock Weight Distribution Variation by Class



# BUILT-OUT REEF

- Consists of 17 polygons
- 152 Acres
- Polygon size varies from 1.4 to 38.9 acres
- Constructed exclusively of quarry rock
- 830 tons per acre in a single layer with a height of less than 1 m



## Polygon Areas as Designed and As-built, Placed Tonnage, and tons/acre

Polygon Number	Polygon Area (Design)	Polygon Area <sup>a</sup> (As-built, acres)	Placed Rock <sup>b</sup> (Tons)	Tons/Acre <sup>c</sup> (As-built / Polygon)
1	13.3	13.83	11,444.8	827.5
2	37.5	38.88	31,872.0	819.8
3	6.5	6.61	5,093.0	770.5
4	14.1	14.05	10,996.9	782.7
5	9.2	9.48	7,046.1	743.3
6	4.1	4.24	3,208.8	756.8
7	25.8	19.03	15,541.9	816.7
8	7.5	7.64	6,087.4	796.8
9	2.4	2.52	1,967.2	780.6
10	3.8	3.89	3,838.6	986.8
11	3.5	3.48	3,094.2	889.1
12	1.3	1.35	1,258.7	932.4
13	2.8	2.85	2,600.3	912.4
14	2.0	2.12	2,008.1	947.2
15	5.3	5.54	4,642.4	838.0
16	10.9	11.19	10,440.7	933.0
17	7.0	5.32	4,816.4	905.3
<b>Totals</b>	<b>157.0</b>	<b>152.02</b>	<b>125,957.5</b>	N/A <sup>d</sup>

<sup>a</sup> Area of polygons as determined by the multibeam sonar system.

<sup>b</sup> Total tonnage placed on the polygon.

<sup>c</sup> Tonnage divided by areas as determined by multibeam sonar system.

<sup>d</sup> Not applicable

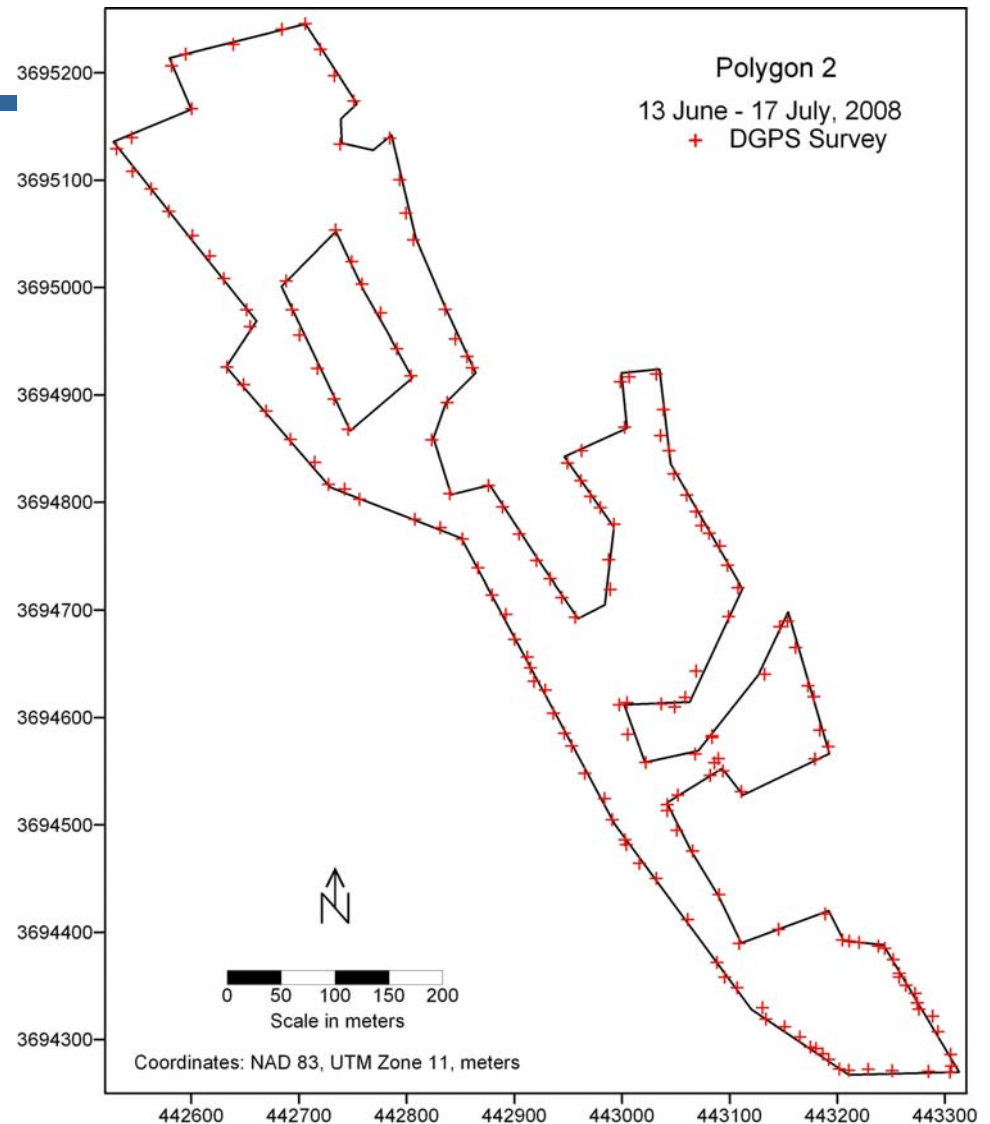
# Rock Weight Determination Method Gauging the Barrage



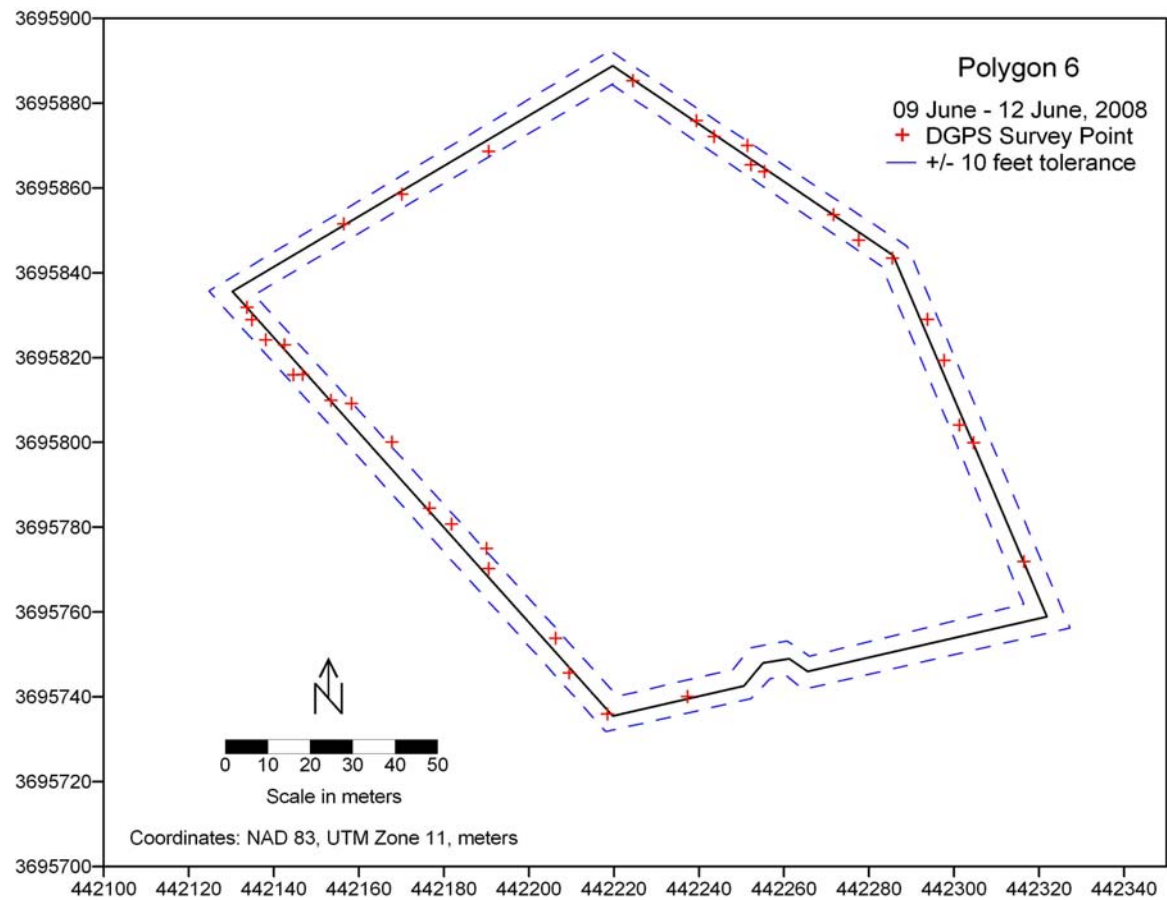
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# Verification of Polygon Boundary From Rock Barrage – Polygon 2

- As-built Polygon 2 boundary (red x's measured from vessel with DGPS) overlaid on top of designed Polygon 2 boundary (black outline).
- DGPS (Differential Global Positioning System)
- Measurements made from the surface (top of the Derrick barrage)
- DGPS accuracy is sub meter



# Comparison Between Designed and As-Built Boundary By DGPS From The Rock Barge - Polygon 6



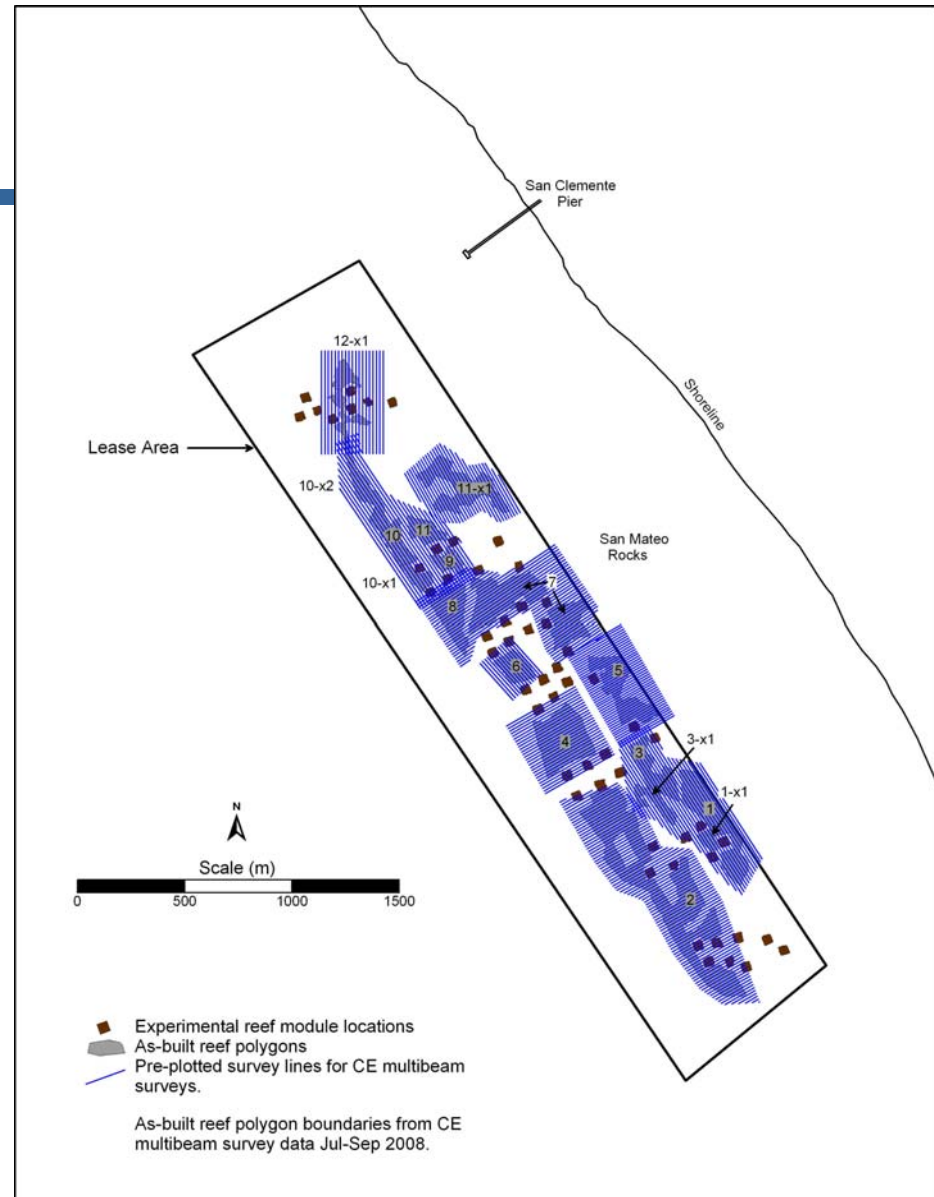
# Multi-Beam Surveys

- Odom ES3 Multi Eco-sounder
- 200 KHZ in water shallow water system.
- 2-3 times the measured water depth.
- Accompanied by motion sensor, gyro compass, sound Velocity meter, GPS heading and positioning receiver.
- Data analyzed by standard Hydrologic software.
- Survey boat track determined prior to survey.

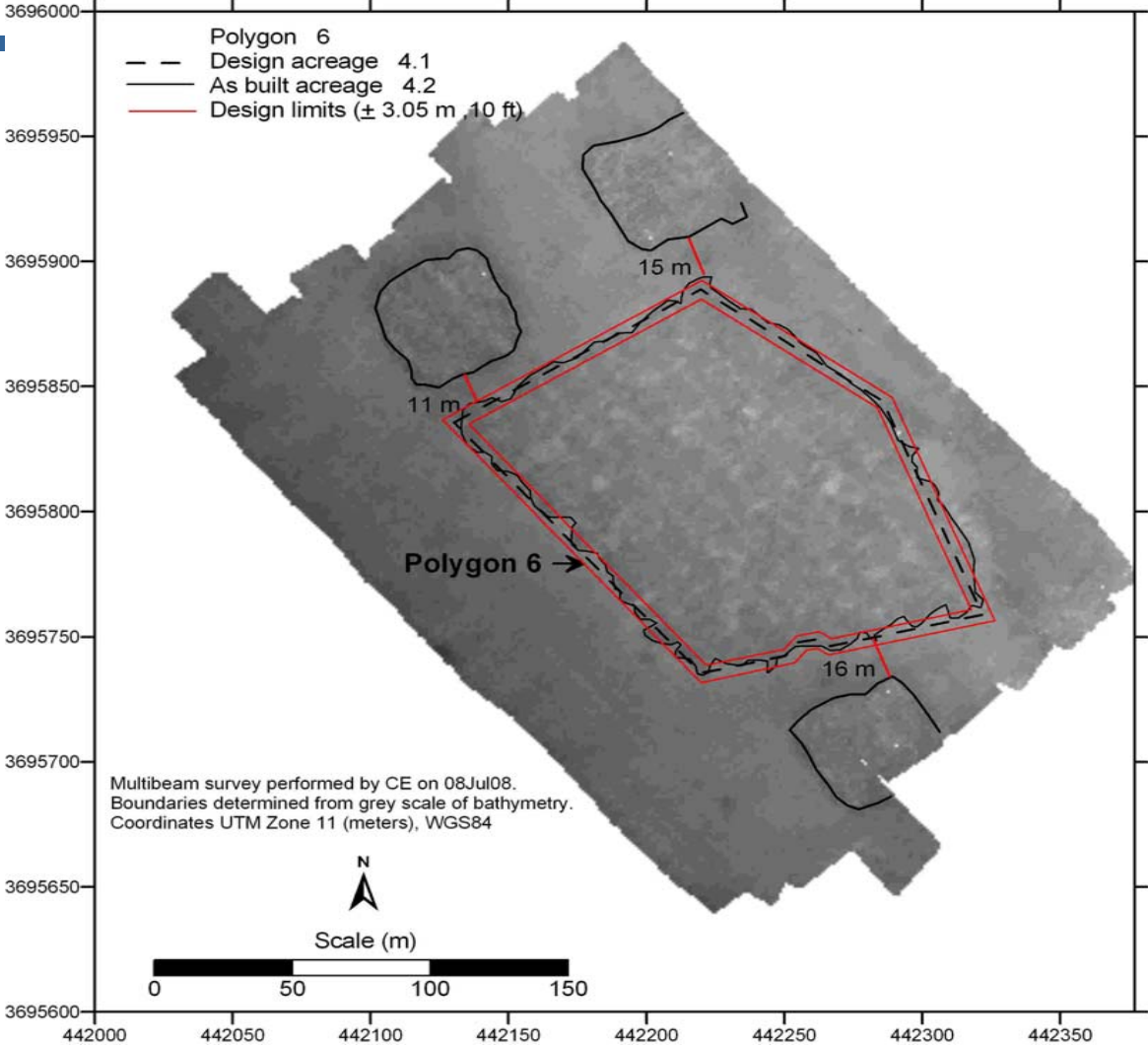


# Multi-Beam Survey

- The polygons were pre-plotted in Hypack, and parallel survey lines were set up with 12-14 m spacing depending on water depth
- Because the survey lines were spaced very closely, there was over 200 percent coverage.
- This overlapping data allowed CE to verify the results.
- Vessel speed was from 4.0 to 5.5 knots



# Verification of Polygon Boundary Using Multi-Beam system



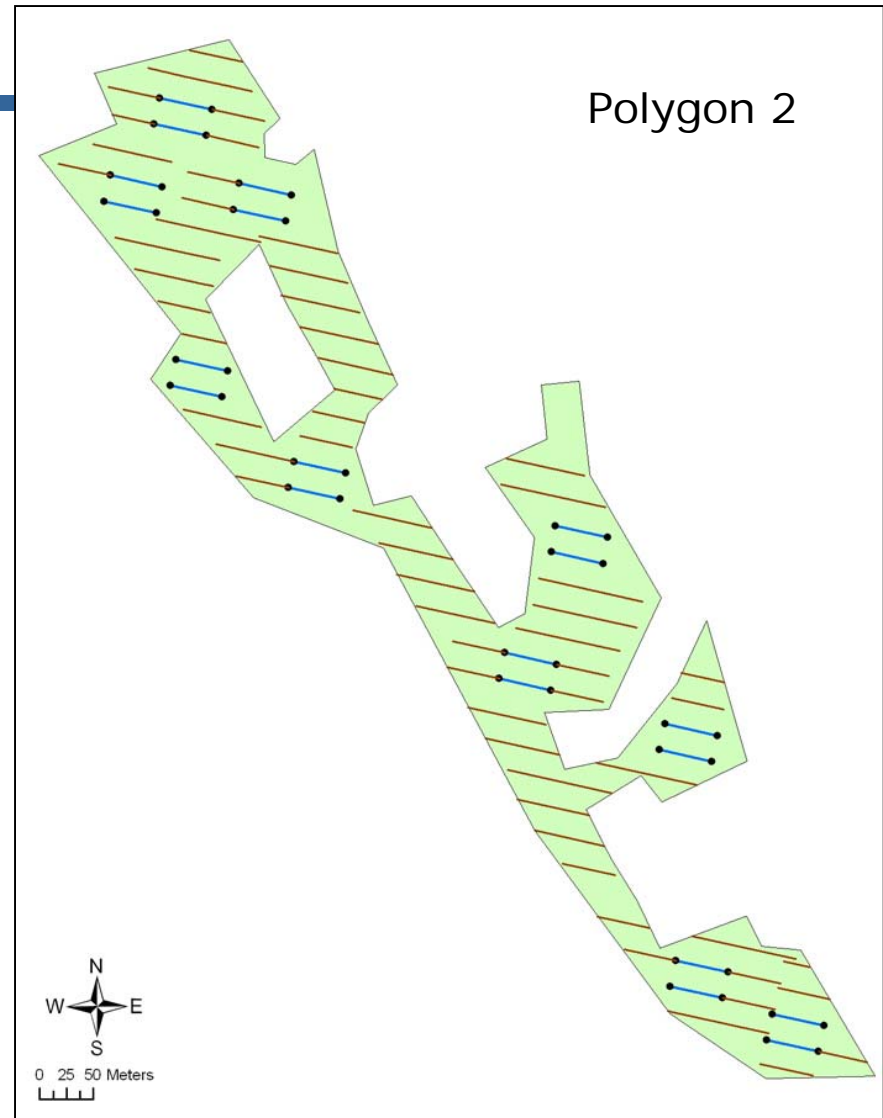
# Rock Overlap Determination

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- Polygon areas surveyed by multibeam sonar system before and after construction
- Depth differences between before and after surveys gives indication of rock overlap (rocks piling on top of each other)
- Generally differences were less than than 1-meter, indicating the overlap is minimal and within the design specification of no more than 15% rock overlap
- CCC and CE divers confirmed that overlap is minimal

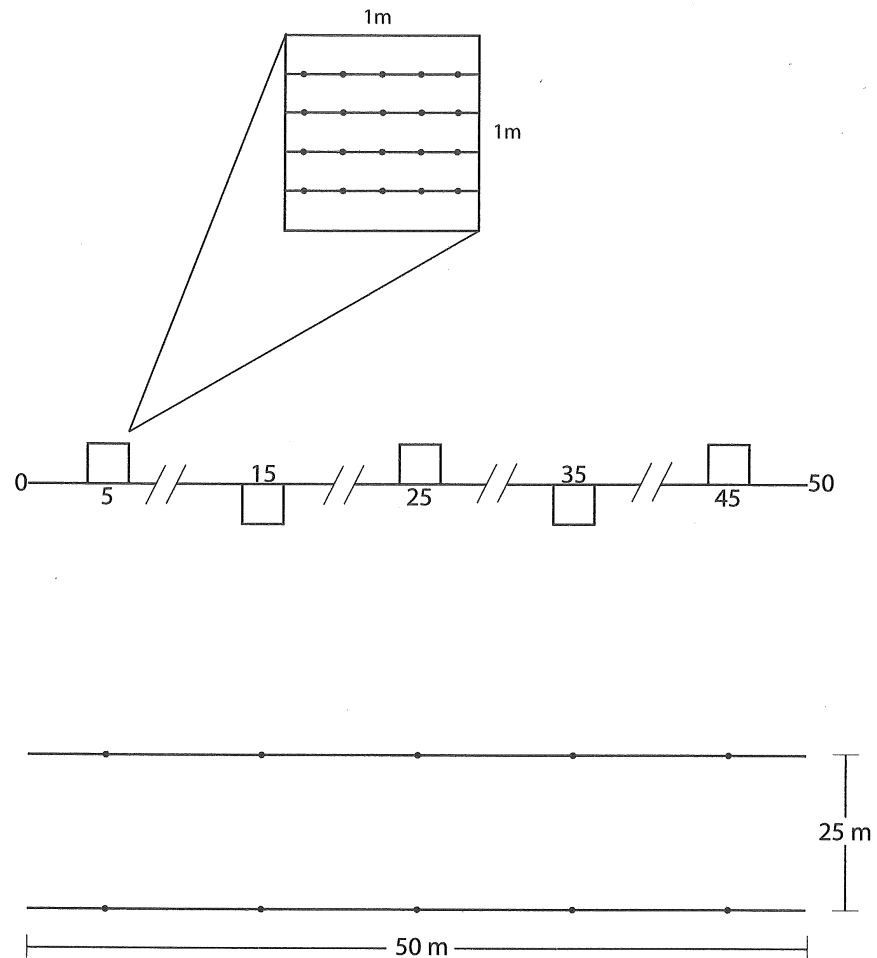
# Rock Coverage Estimates

- CCS-CS has surveyed the 17 polygons of Phase 2.
- Number of transects varied from 2 to 20 depending on the size of the polygon.
- The transects were distributed over 152 acres of the phase 2 reef.
- Averaging one transect for every two acres of reef.
- For small polygons (< 4 acres), the CCC-CS established two transects in order to have replicates.
- **Solid blue** are transects to be monitored in the future (permanent transects)



## Rock Coverage Estimates, Point Contact Method

- In each polygon, 50 m long transects were laid approximately east-west. Beginning five meters from the starting point, 1 m<sup>2</sup> quadrates were positioned every 10 meters.
- In each quadrate, substrate under each of 20 uniformly placed points was categorized as follows: whether it was sand, pebble, cobble, or boulder; and whether the hard substrate was quarry rock..
- Divers also reported whether overlap was present or absent.



## As-built Polygon Coverage from Schroeter et al. (2008)

<b>Polygon Number</b>	<b>Polygon Area<sup>a</sup> (As-built acreage)</b>	<b>Tons/Acre<sup>b</sup> (As-built)</b>	<b>Acres/ Transect</b>	<b>Percent Substrate Coverage<sup>c</sup></b>
1	13.83	827.5	2.3	42.2
2	38.88	819.8	1.9	42.3
3	6.61	770.5	1.7	37.8
4	14.05	782.7	1.8	35.4
5	9.48	743.3	2.4	33.8
6	4.24	756.8	2.1	42.5
7	19.03	816.7	1.9	33.7
8	7.64	796.8	1.9	37.3
9	2.52	780.6	1.3	53.5
10	3.89	986.8	1.9	53.5
11	3.48	889.1	1.7	42.0
12	1.35	932.4	0.7	59.0
13	2.85	912.4	1.4	45.5
14	2.12	947.2	1.1	43.0
15	5.54	838.0	2.8	39.5
16	11.19	933.0	1.9	39.3
17	5.32	905.3	2.7	65.5

<sup>a</sup> Area of polygons as determined by multibeam sonar system.

<sup>b</sup> Total tonnage placed on the polygon divided by as-built area.

<sup>c</sup> Hard substrate coverage estimated by Schroeter et al. (2008).

## WNR Hard Substrate Coverage Estimated by Weighting the Percent Coverage of Individual Polygons by Total Polygon Area (Schroeter et al., 2008)

Case #	Description	Total Polygon Area (acres)	Coverage %
1	All Polygons	152	40.8
2	Eliminating Polygons 5 & Polygon 7a	130.3	42.31

- Polygons 5 and 7a are contingency polygons **Pink color**
- Other polygons are primary polygons **green color**
- Total reef area accepted by CCC is 152.7 acres > 150 acres.







# Questions & Answers

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