Area of the *Interior Brine Mixing Zone* at the Carlsbad Desalination Project at Present and Future Sea Levels

Submitted by:
Scott A. Jenkins, Ph.D.
Technical Manager, Coastal Sciences & Engineering
Michael Baker International

Submitted to:
Poseidon Water LLC
5780 Fleet Street, Suite 140
Carlsbad, CA 92008

20 January 2017

1) Interior BMZ at Present Sea Level: Under the newly amended *California Ocean Plan* as presented in Appendix-A of SWRCB (2105), a new numeric water quality objective has been established that limits brine discharges from ocean desalination plants (whose construction are 80% complete) to no more than 2 ppt over ambient ocean salinity (*natural background salinity*) at the outer edge of a semi-circular Brine Mixing Zone (BMZ) measuring 200 m (656 ft) in radius the centerline of the end of discharge channel into the receiving waters, which is the BMZ that was analyzed in the dilution study (Jenkins, 2016), which supported the renewal application for NPDES permit # CA0109223 for the Carlsbad Desalination Project. The discharge channel is 120 ft. in width, Figure 1. The purpose of this technical note is to calculate the area of the BMZ that is outside the discharge channel and lies between the shoreline at mean sea level and the point of discharge. This area consists of an extension of the 200 m (656 ft.) radius circular arc on either side of the discharge channel until it intersects with either side of the north and south discharge jetties or the beach at mean sea level (Figure 2). This *interior* portion of BMZ depends on the length of the jetties and the beach profiles. The north jetty extends 327 ft. seaward from the Pacific Coast Highway (PCH), while the south jetty is slightly longer, extending 376 ft. seaward of the PCH, (Figure 1). Figure 3 shows the locations of the beach survey range lines for the dredge disposal monitoring program at Encina Power Station. The survey ranges closest to the CDP discharge channel are Cab I-03 immediately south of the south discharge jetty (Figure 4); and Cab I-04 immediately north of the north discharge jetty (Figure 5). The figures have been annotated to show the locations of the ends of the jetties and elevations of mean sea level (MSL) relative to the MLLW tidal datum at present sea level, (where MSL = + 2.75 ft MLLW). Figure 4 shows that there is γ_S = 166 ft. between the 2015 mean shoreline and the end of the south jetty; while Figure 5 shows that there is γ_N = 57 ft. between the 2015 mean shoreline and the end of the north jetty. Using a rectangular approximation, the portion of the *Interior Brine Mixing Zone* that lies south of the south jetty is A_S = 596 ft. x 166 ft. = 2.27 acres; while the portion lying north of the north jetty is A_N = 596 ft. x 57 ft. = 0.78 acres. Thus, the rectangular approximations to A_S & A_N give an estimate of the total area of the *Interior Brine Mixing Zone* equal to: A'_T = 3.05 acres. However, Figure 2 indicates that the A_S & A_N rectangles are slightly truncated by the circular arc of the BMZ. The areas of these rectangles that are excluded from the BMZ are calculated as follows:

$$\Delta A_S = \frac{166'[656' - 166' \tan\theta]}{2} = 1{,}772 \text{ ft}^2 \qquad \text{where } \theta = arc\cos\left(\frac{166'}{656'}\right) = 75.34^0$$

$$\Delta A_N = \frac{57'[656' - 57' \tan\theta]}{2} = 70.71 \text{ ft}^2 \qquad \text{where } \theta = arc\cos\left(\frac{57'}{656'}\right) = 85.01^0$$

Subtracting these excluded areas from the rectangular approximation, the actual total area of the *Interior Brine Mixing Zone* is $A_T(2015) = A_T' - \Delta A_S - \Delta A_N$ = 3.01 acres between the shoreline at mean sea level and the point of discharge (according to latest 2015 beach profiles).

2) Future Sea Level Effects: Appendix-B of the *California Coastal Commision Sea Level Rise Guidance Policy Guidance* document (CCC, 2015) permits either of two methods derived from the NRC report (NRC, 2012) for making sea level projections, 1) the *linear interpolation method*, and 2) the *best fit equation.* Sea level projection estimates using the "best-fit" equation are slightly less than estimations based on linear interpolation because the NRC's sea level curves are concave upward (sea level rise is expected to accelerate over the 21st Century). Therefore, we select the best-fit equation method for the sea level rise projections used in this study. Since the Carlsbad Desalination Project is located well south of Cape Mendocino, the appropriate best fit equation for use in the CDP analysis is:

$$SLR = 0.0093t^2 + 0.7457t = 60.5 \text{ cm (2 ft.) for } t = 50 \text{ yr. (upper-range projection)}$$

Here, *SLR* is the sea level rise in centimeters (cm) and *t* is the time in years after the year 2000 baseline. Appendix-B guidance also states, "Since there has been little, if any, measureable rise in sea level since 2000 for most locations in California (Bromirski *et al.* 2011; NOAA 2013), there is little reason or justification for adjusting sea level rise projections from the year 2000 baseline to a more current date when analyzing projects with start dates prior to about Year 2015 or 2020". The Carlsbad Desalination Project, and it marine life mitigation project, The Otay River Estuary Restoration Project (ORERP), have been designed for t = 50 year project lifespans, for which the upper range sea level rise projection is SLR = 2 ft. Based on Appendix-B guidance, this projection may be considered representative of future sea levels in year 2065.

As sea level rises in the future, the mean shoreline at the CDP discharge will move landward, as shown in Figures 4 and 5. This landward migration of the shoreline will enlarge the *interior* portions of BMZ, as shown schematically in Figure 2. Figure 4 shows that a 2 ft. rise in future sea levels will increase the distance between the mean shoreline and the end of the south jetty from $\gamma_S(2015)$ = 166 ft.to $\gamma_S(2065)$ = 193 ft.; while Figure 5 shows that the distance between the mean shoreline and the end of the north jetty increases from $\gamma_N(2015)$ = 57 ft.to $\gamma_N(2065)$ = 97 ft. Consequently, the portion of the *Interior Brine Mixing Zone* that lies south of the south jetty increases by the rectangular approximation to A_S = 596 ft. x 193 ft. = 2.64 acres; while the portion lying north of the north jetty increase to A_N = 596 ft. x 97 ft. = 1.33 acres. The rectangular approximation of the area of the *Interior Brine Mixing Zone* by year 2065 becomes

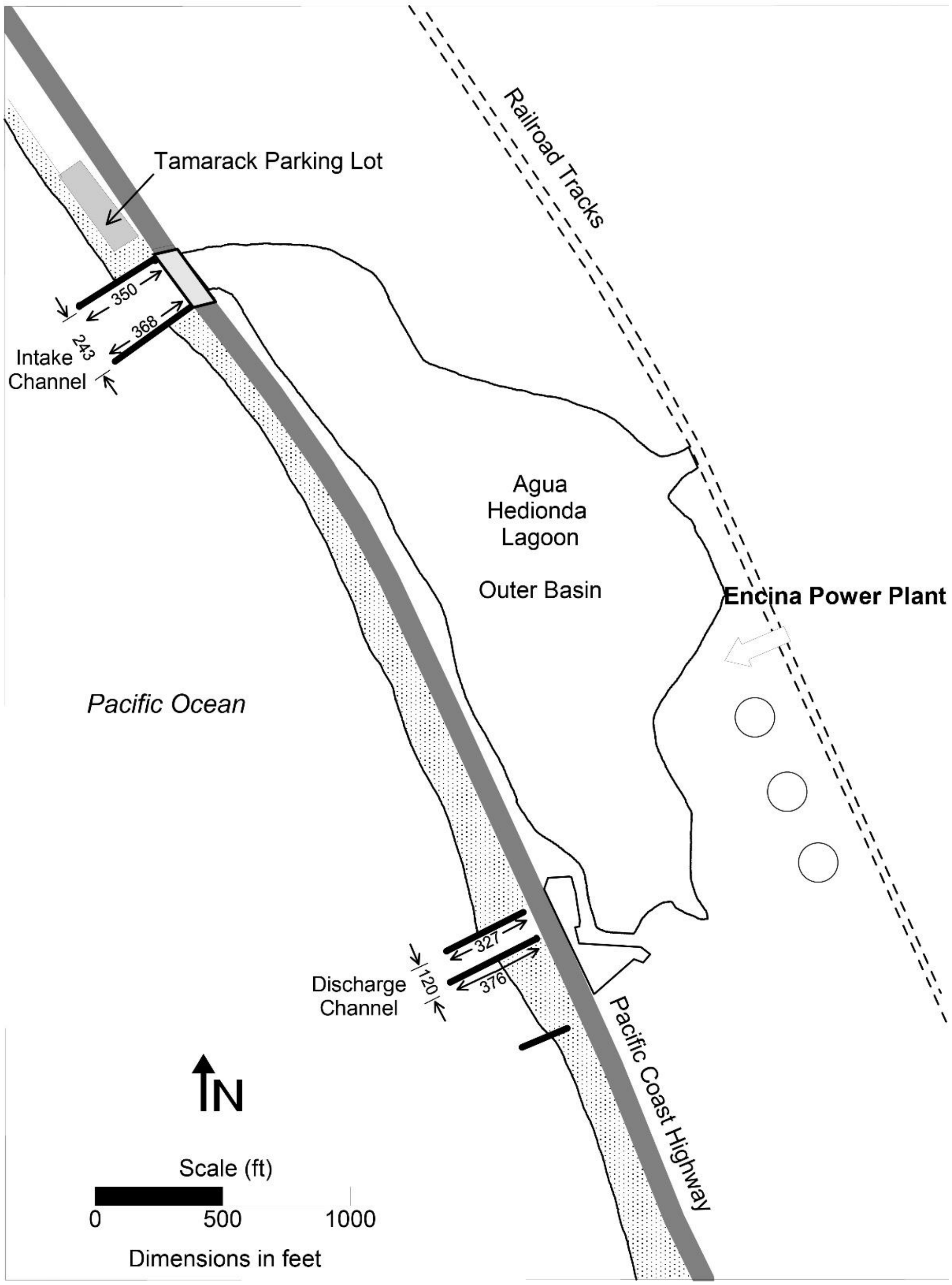

Figure 1: Dimensions of the inlet and discharge channels at Agua Hedionda Lagoon, (from El Wany, et al., 2005)

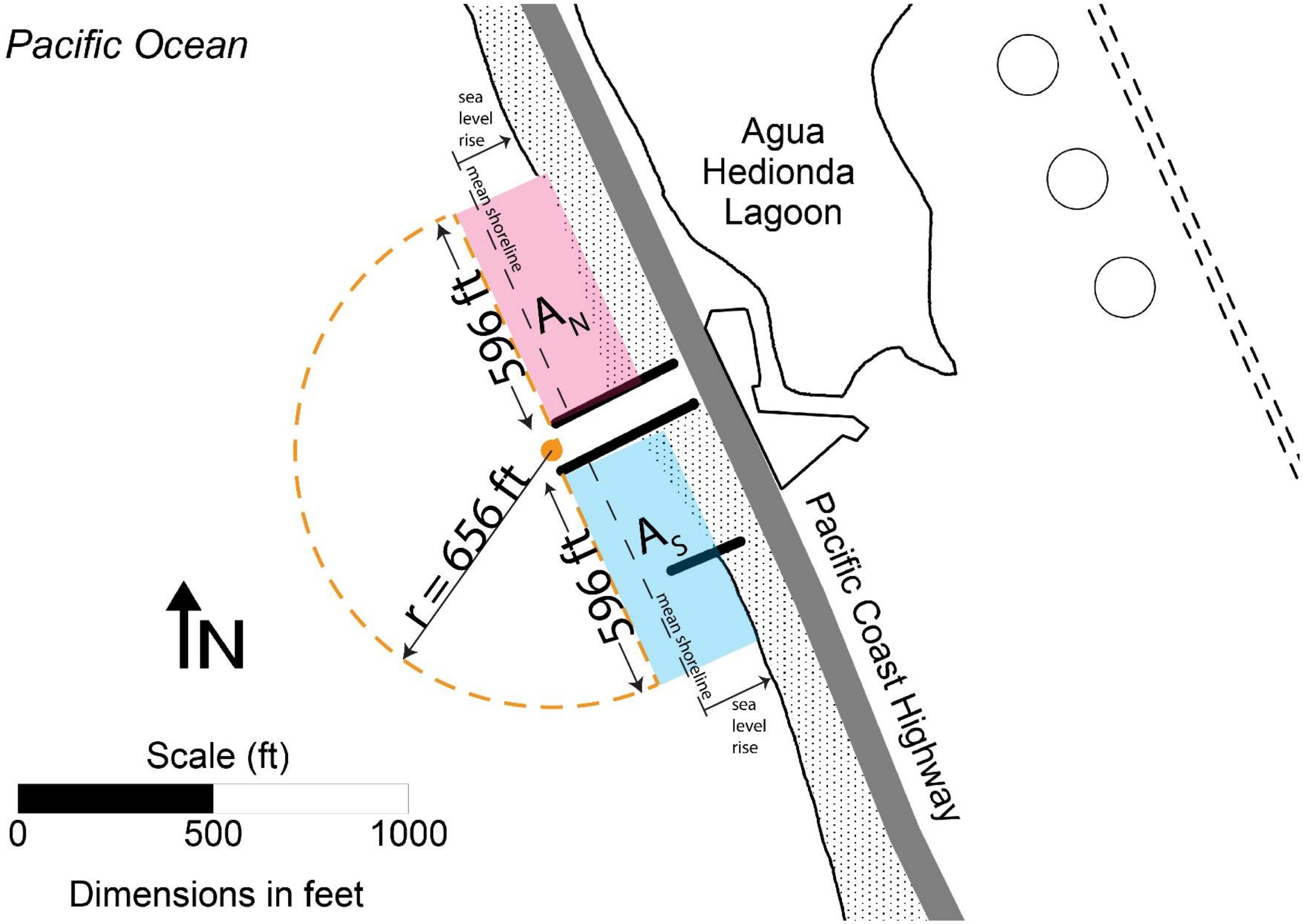

Figure 2: Dimensions of the brine mixing zone (BMZ) at Agua Hedionda Lagoon. Point of discharge for dilution modeling shown as orange point. Boundaries of the seaward portion of the BMZ shown as orange dashed lines. Areas of the interior BMZ shown as colored rectangles, where A_S (blue) is the area of the south-jetty portion of the interior BMZ, and A_N (pink) is the area of the north-jetty portion.

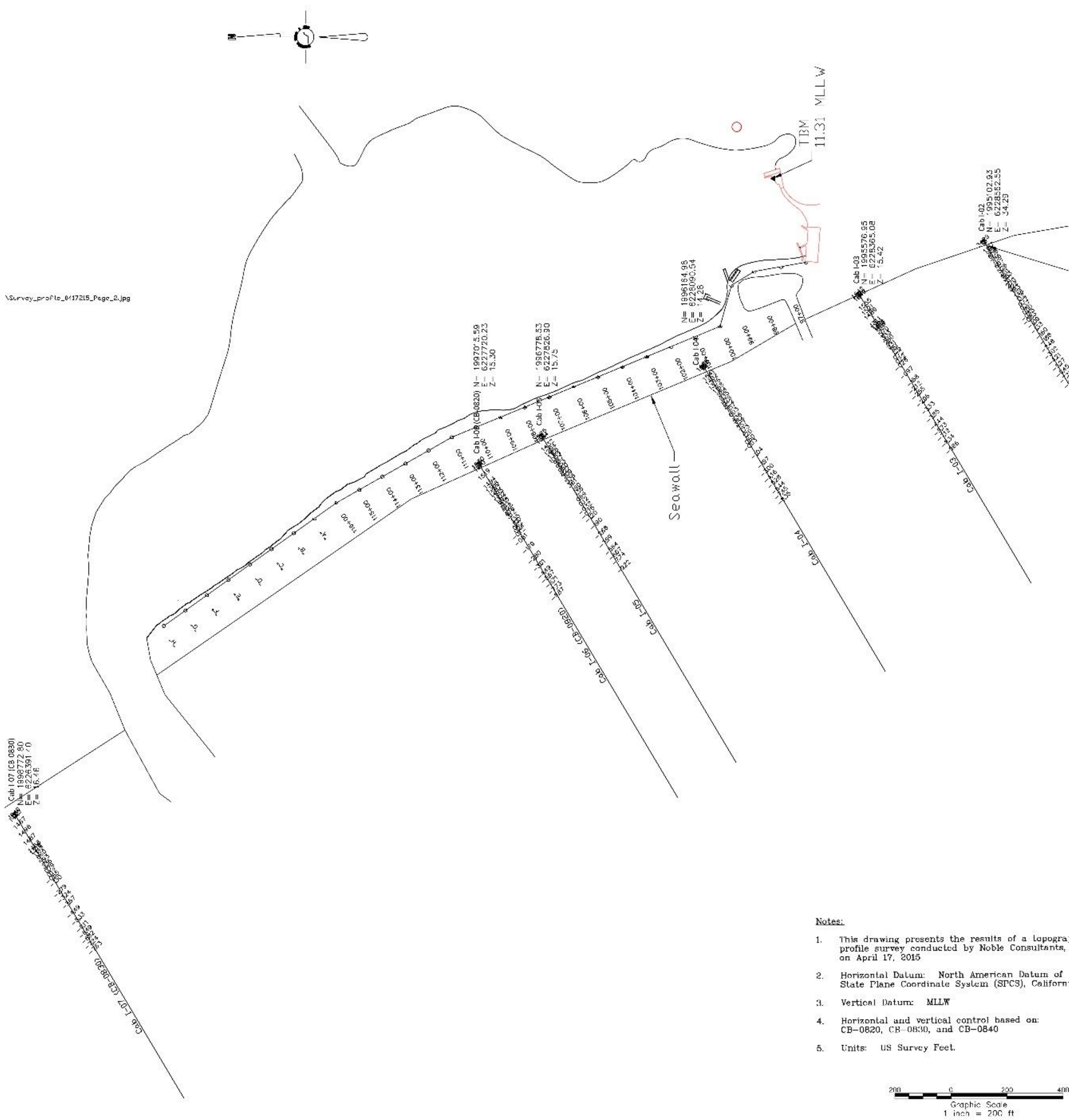

Figure 3: Beach survey range lines for the dredge disposal monitoring program at Encina Power Station, Carlsbad, CA. (data courtesy Sheila Henika, Cabrillo Power, LLC.)

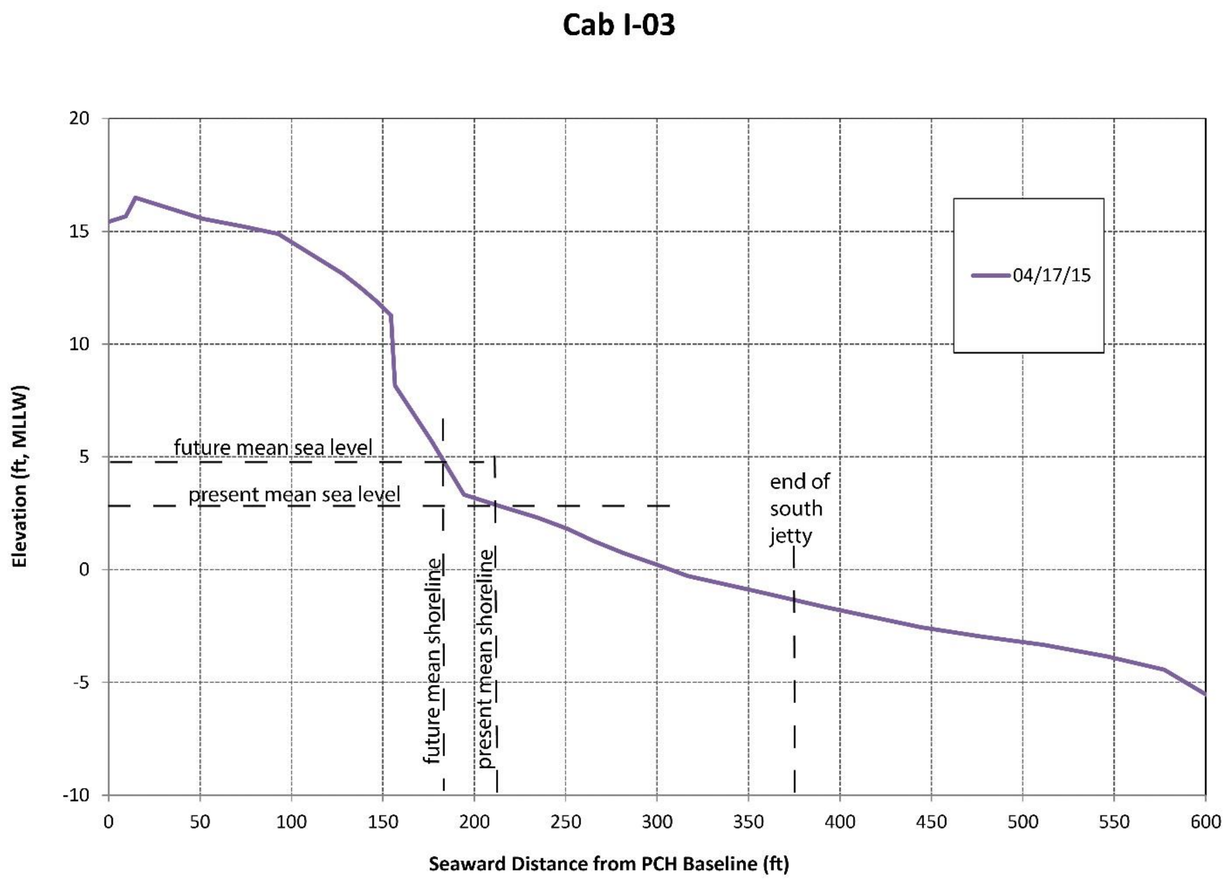

Figure 4: Beach profiles measured at survey range Cab I-03 immediately south of the south discharge jetty. Surveys from the dredge disposal monitoring program at Encina Power Station, Carlsbad, CA. (data courtesy Sheila Henika, Cabrillo Power, LLC.)

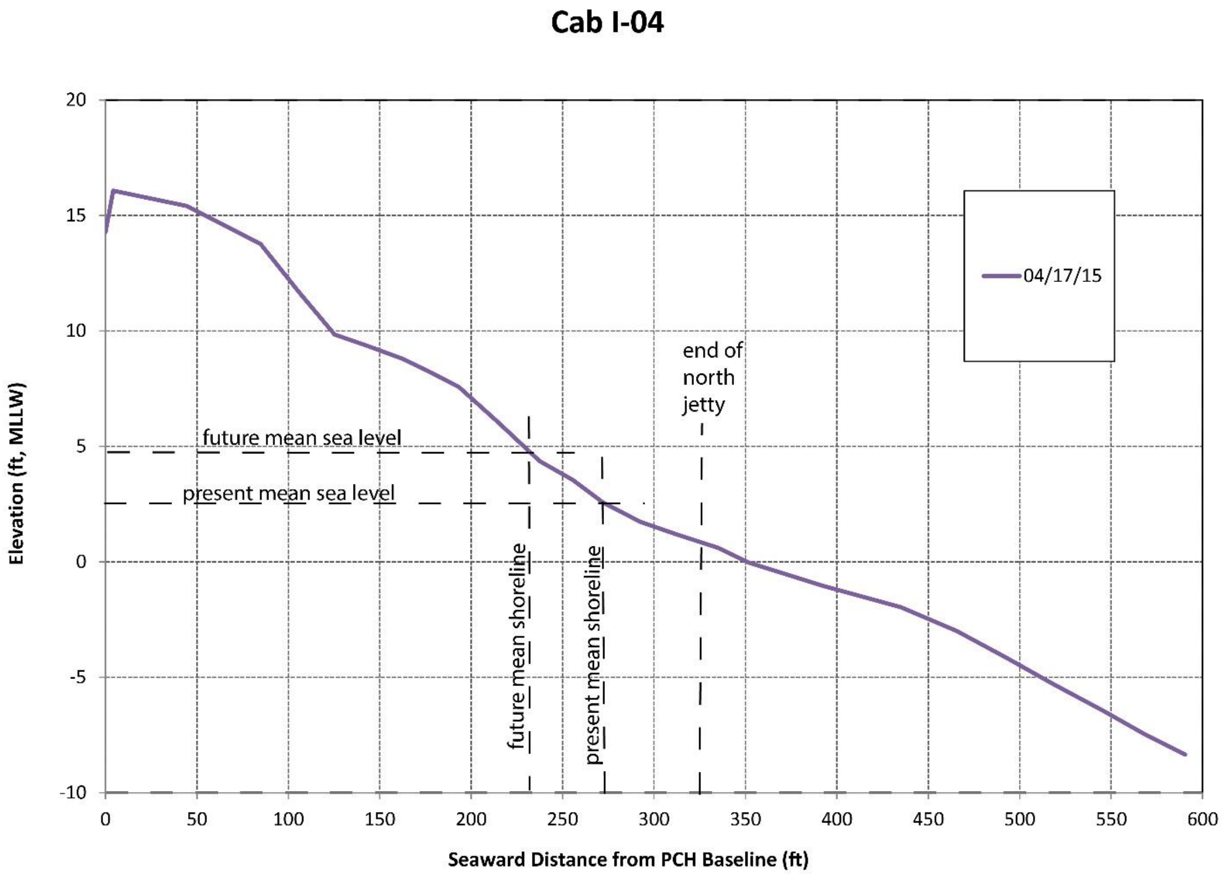

Figure 5: Beach profiles measured at survey range Cab I-04 immediately north of the north discharge jetty. Surveys from the dredge disposal monitoring program at Encina Power Station, Carlsbad, CA. (data courtesy Sheila Henika, Cabrillo Power, LLC.)

A_T' = 3.97 acres, an increase of $\Delta A_T'$ = 0.92 acres over the estimate for 2015 sea levels. Applying the circular arc corrections to the rectangular approximation gives the following correction increments for 2065 sea level:

$$\Delta A_S = \frac{193'\left[656' - 193'\tan\theta\right]}{2} = 2{,}802 \text{ ft}^2 \qquad \text{where } \theta = arc\cos\left(\frac{193'}{656'}\right) = 72.89^0$$

$$\Delta A_N = \frac{97'\left[656' - 97'\tan\theta\right]}{2} = 349.7 \text{ ft}^2 \qquad \text{where } \theta = arc\cos\left(\frac{97'}{656'}\right) = 81.50^0$$

Subtracting these excluded areas from the rectangular approximation, the actual total area of the *Interior Brine Mixing Zone* at 2065 sea levels is $A_T(2065) = A_T' - \Delta A_S - \Delta A_N$ = 3.89 acres, located between the shoreline at mean sea level in year 2065 and the point of discharge. Thus sea level rise over the projected 50 year lifespan of the CDP will increase the area of the *Interior Brine Mixing Zone* by $\Delta A_T = 0.88$ acres. However, this increase is offset by gains in the size of the wetlands of the ORERP mitigation project caused by sea level rise. Comparing Tables 3 and 4 below, we find that the total habitat created by ORERP Subtidal Alternative increases by ΔA_T = +3.54 acres as a consequence of sea level rise between 2018 and 2065. On the other hand, Tables 1 & 2 show that new habitat created by sea level rise is only ΔA_T = +0.69 with ORERP Intertidal Alternative. This disparity arises because most of the new habitat created in response to sea level rise occurs in the Pond-15 complex of the ORERP, where more disposal of dredged material from the Otay Floodplain Basin is placed with the Subtidal Alternative, which subsequently becomes functional salt marsh at higher sea levels.

Table 1: Intertidal Alternative Predicted Habitat Distribution, acres 2018

Vegetation Community to be Created	Otay River Floodplain Site Acres	Pond 15 Site
SubTidal	0.00	9.53
Mudflat – Frequently Flooded	4.45	16.36
Mudflat – Frequently Exposed	0.70	1.57
Low Marsh	10.34	15.73
Mid Marsh	10.99	34.47
High Marsh	3.23	5.61
Total Marsh	29.26	80.68
Transitional	0.45	2.59
Total Created Habitat	**29.71**	**83.27**

Table 2: Intertidal Alternative Predicted Habitat Distribution, acres 2065

Vegetation Community to be Created	Otay River Floodplain Site Acres	Pond 15 Site
SubTidal	0	9.35
Mudflat – Frequently Flooded	8.84	17.06
Mudflat – Frequently Exposed	2.21	1.85
Low Marsh	7.91	17.32
Mid Marsh	10.36	35.38
High Marsh	0.52	2.87
Total Created Habitat	**29.84**	**83.83**

Table 3: Subtidal Alternative Predicted Habitat Distribution, acres, 2018

Vegetation Community to be Created	Otay River Floodplain Site Acres	Pond 15 Site
Subtidal	4.48	9.17
Mudflat – Frequently Flooded	5.26	14.70
Mudflat – Frequently Exposed	1.79	1.32
Low Marsh	8.64	11.77
Mid Marsh	7.90	33.25
High Marsh	1.64	11.78
Total Salt Marsh	29.71	82.00
Transitional	0.45	2.15
Total Created Habitat	**29.26**	**79.85**

Table 4: Subtidal Alternative Predicted Habitat Distribution, acres, 2065

Vegetation Community to be Created	Otay River Floodplain Site Acres	Pond 15 Site
Subtidal	4.48	9.0
Mudflat – Frequently Flooded	110.01	15.28
Mudflat – Frequently Exposed	1.70	1.58
Low Marsh	5.43	12.68
Mid Marsh	6.71	41.20
High Marsh	0.52	3..06
Total Created Habitat	**29.85**	**82.80**

References:

Elwany, M. H. S., R. E. Flick, M. White, and K. Goodell, 2005, "Agua Hedionda Lagoon Hydrodynamic Studies," prepared for Tenera Environmental, 39 pp. + appens.

CCC, 2015, "*California Coastal Commision Sea Level Rise Guidance Policy Guidance",* adopted 12 August 2015, 254 pp.

SWRCB, 2015, Amendment to the Water Quality Control Plan for Ocean Waters of California Addressing: "DESALINATION FACILITY INTAKES, BRINE DISCHARGES, AND THE INCORPORATION OF OTHER NON-SUBSTANTIVE CHANGES", cf. Appendix-A: "Ocean Plan with the May 6, 2015 Final Desalination Amendment", 1303 pp.

National Research Council (NRC). 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Report by the Committee on Sea Level Rise in California, Oregon, and Washington. National Academies Press, Washington, DC. 250 pp. http://www.nap.edu/catalog/13389/sea-level-rise-for-the-coasts-of-california-oregon-and-washington.

APPENDIX: Footprint of the Discharge Jetties, Present and Future Sea Level

(photo, courtesy of Cabrillo Power, LLC.)

Rocky Footprint of South Jetty at Present Sea Level:

Length: L_S = 376 ft.

Width: W_S = 63 ft.

Total Area of Rocky Footprint: $\Psi_S = L_S W_S =$ 23,688 ft^2 = 0.54 acres

Rocky Footprint below Mean Sea Level, (cf. Figure 4):

$\tilde{\Psi}_S = \gamma_S W_S =$ 166 ft. x 63 ft.= 10,458 ft^2 = 0.24 acres

Rocky Footprint of North Jetty at Present Sea Level:

Length: L_N = 327 ft.

Width: W_N = 51 ft.

Total Area of Rocky Footprint: $\Psi_N = L_N W_N =$ 16,677 ft^2 = 0.38 acres

Rocky Footprint below Mean Sea Level, (cf. Figure 5):

$\tilde{\Psi}_N = \gamma_N W_N =$ 57 ft. x 51 ft.=2,907 ft^2 = 0.07 acres

Total Rocky Marine Habitat at Present Sea Level

$\tilde{\Psi}_T = \Psi_N + \Psi_S$ = 0.31 acres

Rocky Footprint of South Jetty at Future Sea Level (*t* = 50 yr):

Length: L_S = 376 ft.
Width: W_S = 63 ft.
Total Area of Rocky Footprint: $\Psi_S = L_S W_S =$ 23,688 ft^2 = 0.54 acres
Rocky Footprint below Mean Sea Level, (cf. Figure 4):
$\tilde{\Psi}_S = \gamma_S W_S =$ 193 ft. x 63 ft.= 12,159 ft^2 = 0.28 acres

Rocky Footprint of North Jetty at Future Sea Level:

Length: L_N = 327 ft.
Width: W_N = 51 ft.
Total Area of Rocky Footprint: $\Psi_N = L_N W_N =$ 16,677 ft^2 = 0.38 acres
Rocky Footprint below Mean Sea Level, (cf. Figure 5):
$\tilde{\Psi}_N = \gamma_N W_N =$ 97 ft. x 51 ft.=4,947 ft^2 = 0.11 acres

Total Rocky Marine Habitat at 2065 Sea Level
$\tilde{\Psi}_T = \Psi_N + \Psi_S$ = 0.39 acres