PROJECT MEMORANDUM
HUNTINGTON BEACH DESALINATION PLANT - PROPOSED MODIFICATIONS

Date: May 24, 2017
To: California State Lands Commission
From: Dr. Peter Raimondi
Subject: Review of Applicant-provided information on operational effects of the Huntington Beach Desalination Plant Lease Modifications to marine biology

In response to a request from the California State Lands Commission (CSLC), I reviewed information provided by Poseidon Resources (Applicant) on operational impacts to marine biological resources from the proposed modifications to the Huntington Beach (HB) Desalination Plant. The 2010 project proposed to use the existing open ocean intake and the existing discharge structure, which had no cap or diffuser. The proposed modifications include:

- Installation of four wedgewire screens, with 1 millimeter (mm) spacing, at the end of the existing HB Generating Station intake line, approximately 1,840 feet offshore.
- Retrofit the existing HB Generating Station discharge line (outfall) at its end (approximately 1,500 feet offshore), by installing a three-valve duckbill diffuser with an additional discharge port, to ensure that salinity meets the requirements of the Desalination Amendment.
- In the stand-alone operational scenario, the currently proposed project would require 106 million gallons of water (MGD) per day of seawater, reduced from 152 MGD.

This memo provides the results of my objective review of the effects of the proposed modifications. I understand that the conclusions in this memo will be used to support the preparation of CSLC's Supplemental Environmental Impact Report, which is being prepared in compliance with the California Environmental Quality Act.

A comparison of impingement and entrainment data for the 2010 project and the proposed modifications is presented in Table 1 at the end of this memo.

1. Scope and Limitations of Review

The following are the key limitations on the scope of this review:

- This memo is not intended to present an overall review of impacts from the entire Huntington Beach Desalination Plant. Instead, it supports the CEQA analysis of potential impacts from proposed modifications to the project that was approved in 2010. It may inform, but is not intended to address consistency with, policies or regulations of the California Coastal Commission (CCC) or State Water Resources Control Board.
- Assessment of the proposed modifications relied on data collected in 2003-2004. The empirical transport model (ETM), which was used for the Applicant's analysis, is considered to be much more robust for analysis of year to year variation in species-specific entrainment than other approaches to estimation of entrainment effects. However, an assumption is made that the approach applied to data over a decade old (e.g., from 2003-2004) yields reliable and currently informative results. It is important to note that there was an assessment of the community composition from sampling in 2014-2015 relative to that in 2003-2004 (Tenera 2015B). The conclusion of that report was that the composition was similar in the two periods. No evaluation of this conclusion was made for this review. This is because the metric that is important with respect to evaluating impact is the output of

the ETM/APF assessment, which could not be done because of the difference in sampling design for the two studies.

- Newer models for ETM and area of production foregone (APF) are starting to use a CODAR[1]-based modeling approach to develop the oceanographic framework for defining dispersal and source water bodies for the organisms that could be entrained. A CODAR-based model was not used to estimate ETM/APF. It was used by the Applicant to analyze impacts to Marine Protected Areas (MPAs) pursuant to Ocean Plan requirements. Although impacts to MPAs are considered under CEQA, detailed modeling is not required for the EIR; therefore, review of the CODAR-based model implementation and results is beyond the scope of this review.

2. Background on Assessing Entrainment

Entrainment impact resulting from once through use of water has usually meant impact resulting from loss of planktonic organisms. There are two types of planktonic organisms: (1) holoplankton, which are typically small organisms that are planktonic for their entire life (e.g., phytoplankton and dinoflagellates), and (2) meroplankton, which have a planktonic stage followed by a separate morphologically different post-settlement adult stage (e.g., rockfish, abalone and kelp). Most non-holoplanktonic marine species, not including mammals, birds and reptiles, have a meroplanktonic dispersing stage. It is typically assumed that holoplankton are not subject to impacts due to entrainment.

A simplifying assumption (and one that is used in regulatory policy and important in assessing the effect of screens) is that entrained planktonic organisms in the reverse osmosis process feedwater suffer 100% mortality irrespective of species, size or age. Accordingly, the initial estimation of loss is simply the number of planktonic organisms that are entrained (because it is assumed that all die).

The next step in assessing entrainment effects is the translation of loss to impact (see Appendix 1 for more detailed description). In a general sense, "impact" has been thought of as a spatially scaling estimate of the consequence of some sort of action (e.g., entrainment via use of once through water). In California, for entrainment, the estimate has typically involved a coupled modeling process referred to as ETM/APF. ETM converts species specific estimates of entrainment loss into species specific estimates of proportional mortality (Pm) over some species spatial scale called source water body (SWB). This estimation is done for very few species, usually the ones where there are high-quality data (i.e., many observations) and which as a group cover a reasonable range of life history characteristics (primarily, analysts are interested in the planktonic period). The set of assessed species are considered to represent all entrained species, which are thought to be potentially impacted by entrainment (i.e., those with a meroplanktonic stage).

The final step is to scale Pm and SWB into a currency that is both understandable but also that could be used to determine compensatory mitigation. This step is the calculation of the APF. Species-specific APF is simply the product of SWB and Pm. The units are based in area – typically acres. The species specific APF is the area that would need to be added to the system in order for full compensation of the ecosystem resources provided by that species. This means the species itself and its contribution to the ecological community. APF is calculated for the set of assessed species and some metric of the combined set (e.g. the 95% confidence limit) is used to represent the area that would need to be provided for there to be a 95% or better likelihood of full or higher compensation for all lost ecosystem resources, direct or indirectly lost by entrainment.

[1] CODAR: Coastal ocean dynamics applications radar

3. Intake Effects

Impingement

With the addition of proposed wedgewire screens, and the estimated intake velocity, impingement loss will for all practical purposes be avoided.

Entrainment Effects of the 2010 Project

Co-located operation. The impacts for the co-located operations are based on 127 MGD intake volume. The estimated total number of entrained fish larvae (from 2003 - 2004) was 88,255,368. This number does not include fish eggs. No estimates are available for the total number of meroplankton propagules or eggs (e.g., species other than fish with meroplanktonic stage).

Stand-alone operation. The impacts for the stand-alone operation are based on 152 MGD intake volume. The estimated total number of entrained fish larvae (from 2003 - 2004) was 103,303,290. This number does not include fish eggs. No estimates are available for the total number of meroplankton propagules or eggs (e.g., species other than fish with meroplanktonic stage).

Entrainment Effects of the Proposed Modifications

Reduction in intake volume. For stand-alone operations the intake volume would be 106 MGD, which is less that the previously-approved project. For stand-alone operations, this level of intake should lead to a reduction in the estimated total number of entrained fish larvae (based on 2003-2004 sampling) from 103,303,290 under the project as proposed in 2010 to ~74,000,000 (refer to Table 1), which is approximately 29,303,290 fewer fish larvae entrained per year. While the total number of meroplankton entrained has not been estimated, it is likely that the total number of meroplankton entrained should scale directly with reduction of fish larvae entrained.

Addition of wedgewire screens. In contrast with intake volume, the effect of the use of wedgewire screens (WWS) with respect to change in impact is much more difficult to estimate. This is primarily because of the violation of the primary simplifying assumption noted above (i.e., "…that entrained planktonic organisms suffer 100% mortality irrespective of species, size or age.")

The effectiveness of WWS with respect to precluding entrainment of planktonic organisms is determined by four factors: (1) larval behavior (e.g. swimming speed, response to water motion), (2) hydrodynamic effects of the screening (e.g. turbulence, boundary effects), (3) the screen size (opening dimensions) and (4) the maximum two-dimensional body axis. Assume there are three dimensions in a planktonic organism: Length (L), Width (W) and Depth (D). This means that there are three body planes: LW, LD and WD. If the maximum body axis for all of the three planes exceeds the screen size then the organism will not be able to get through the screen. Given a screen size of 1 mm, most meroplanktonic species will be able to pass through the screens at some age (they are less than 1 mm in all axes up to some age) and many or most will be able to pass though at all planktonic ages (they never get to be 1mm in all axes). Moreover, because the relationship between age and size differs within and between species, there is no easy way to model (vs measure) age-specific vulnerability, which will be probabilistic and species specific. Given the limited availability of species specific age based size distributions of meroplankton, there is no current methodological approach that leads to the general ability to quantitatively estimate the reduction in impact caused by addition of WWS – other than that presented below.

Summary of Changes in Intake Effects Resulting from the Proposed Modifications

Reduction in intake volume. Given the discussion above, it is clear that ETM/APF estimates will directly scale with intake volume. Hence the reduction in intake volume will result in a reduction in APF estimate, which is a net benefit with respect to impact.

Addition of wedgewire screens. Impact assessment using an ETM/APF design, where species are mainly or entirely fish, will be uninformative for all entrainable meroplanktonic species. This is for two reasons. First, and most importantly, most meroplankton are not fish and these invertebrates and algae typically have much smaller planktonic stages than fish (most such species have planktonic stages that rarely or never get bigger than 1mm). Second, even for fish, because as shown in the reviewed WWS study, vulnerability is very species specific and probabilistic across a range of sizes. This leads to the concern that the sampled species may not be representative of the suite of fish species entrained.

Information on the relative concentration of fish versus other meroplankton in coastal waters would provide context to this discussion; however, because meroplankton concentrations are highly variable in time and space, such data are rarely documented. The limited information available suggests that a reasonable estimate (from Tenera 2015d and Highfield et. al. 2010, note that these are different studies done in different locations) is that the ratio of nonfish to fish meroplankton is on the order of 1000:1. This is based on the estimated concentration of icthyoplankton in Tenera 2015d (418.51 per 1000 m^3) and the concentration of non-fish meroplankton in the Highfield study (536.98 per m^3), which is a ratio of 1282:1.

Recall that most of the non-fish meroplankton will be less than 1 mm and thus entrainable even with the use of 1mm wedgewire screening. Hence, based on the Highfield information and an estimated reduction in entrainment for the 6 assessed species of between 60 - 68%, a conservative reduction in entrainment for all meroplankton would be between 0.06% and 0.068%.

The numbers above should not be interpreted as indicating that there would not be a reduction in entrainment due to the use of 1mm WWS. There would be a reduction, particularly for fish. More important is that whatever reduction there would be in overall entrainment, this reduction is not currently translatable into an estimate of reduction in impact using ETM/APF.

Evaluation of Poseidon's APF Calculations for Intake Entrainment Effects

APF calculations for the project modifications are presented in Table 1 (at the end of this memo). I note again that that the calculations are based on data from 2003 - 2004. Based on the information provided, I agree with the calculations for the following reasons:

- The APF calculations follow approaches that have been vetted and used routinely (Appendix 1).
- The use of the confidence interval approach (i.e., 95% CI) is consistent with recent cases.
- The translation of impact to sandy bottom species to estuarine habitat using a ratio (10:1) has precedent.

4. Discharge Effects

Entrainment from the Proposed Diffuser

Prior to operation of the HB Desalination Plant, Poseidon proposes to install a diffuser with three 36-inch duckbill valves and one 54-inch central port; the diffuser would be installed on the HBGS discharge tower. Because a discharge diffuser was not proposed in 2010, all diffuser entrainment effects are new impacts, and are not compared with results of previous analyses.

The Substitute Environmental Documentation (SED) prepared by the State Water Resources Control Board in support of the Desalination Amendment states in section 8.6.2.2.1 that "organisms that are entrained into the brine discharge may experience high levels of shear stress for short durations, which is thought to cause some mortality." As cited in the SED, modeling results from Foster et al. (2013) indicated that "the volume of water that is entrained for dilution that is subject to relatively high turbulence intensities and shear stresses is about 23 to 38% of the total entrained volume" and more specifically, the State Water Resources Control Board (SWRCB 2014) states in the SED that "we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence". It is worth noting that the value, "23%" is simply an estimate and one that is expected to be more refined with as more data become available (SWRCB 2015 on pg 85-86)[2]. One key improvement to the estimation of the rate of diffuser entrainment mortality would be modeling specific to the proposed diffuser under review. This should be conducted by someone with the appropriate qualifications to run such a model. In the absence of this information, I've made no assumptions about the mortality rate for organisms entrained as part of discharge of water through diffusers and give estimates across a range of values (e.g. APF is calculated for mortality rates ranging from 0 -100%, Figure 1).

Because entrainment scales with volume, we can use entrainment estimates from the intake studies to provide at least a relative estimate of loss due to discharge entrainment due to shear effects. The estimate for 127 MGD intake volume was 88,255,368 entrained fish larvae. This number does not include fish eggs or any other meroplankton propagules or eggs (e.g., species other than fish with meroplanktonic stage).

Co-located Operation. Based on a discharge volume subject to entrainment of 77 MGD and under the assumption of a 23% mortality rate, it is estimated that approximately 121 million fish larvae would die from entrainment. If mortality rate was 100%, the number of entrained (leading to death) fish larvae would increase to approximately 529 million. Both estimates are subject to the assumption that larval concentrations would not be different from those based on 2003-2004 sampling.

It is worth noting that the discharge volume for co-located operation (77 MGD = 21 MGD ambient salinity + 56 MGD of Brine) is greater than standalone operation (only 56 MGD of Brine). The co-located jet velocity for this discharge is estimated at 11.9 ft/sec, which is about 20% greater than the velocity under stand- alone operations. Although the discharge volume is approximately 37% greater than stand-alone operations and jet velocity is 20% greater than in stand-alone operations (using the same diffuser design), the estimate of entrained water is less (762 vs 782 MGD, Table 1). This is because the entrainment estimation is based on a mass balance equation that solves for the volume of water needed to dilute the discharge water to 2 ppt above ambient (that is +2 ppt above 33.5 ppt), which is very sensitive to the salinity of the discharge water (55.3 ppt for co-located vs 63.4 ppt for stand-alone). This may lead to inaccuracy when comparing shear-related mortality rates for operational scenarios having different discharge salinities. Here it is possible that the actual impact would be worse for co-located operations than stand-alone operations. This points out the potential problem of the unquestioned

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[2] From SWRCB 2015: "However, until additional data is available, we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence. The actual percentage of killed organisms will likely change as more desalination facilities are built and more studies emerge. Future revisions or updates to the Ocean Plan may reflect additional data that becomes available."

approach of using 23% as the standard for mortality rate. In my opinion, it is extremely unlikely that 23% is a reasonable value for both standalone and co-located operations.

Stand-alone Operation. Based on a discharge volume subject to entrainment of 180 MGD and under the assumption of a 23% mortality rate, it is estimated that 125,086,348 fish larvae are likely to be entrained. If mortality rate was 100%, the number of entrained fish larvae would increase to approximately 543,000,000. Both estimates are subject to the assumption that larval concentrations numbers would not be different from those based on 2003-2004 sampling.

Evaluation of Poseidon's APF Calculation for Discharge Effects

APF calculations for the project modifications are presented in Table 1. One thing that should be noted is that the calculation of the 95% confidence estimate for CIQ goby complex (Table 4 in Appendix T – Memo Poseidon HBDF Diffuser APF 2016.0301) is very different from that for the Intake calculation (Table 2 in Appendix V – HB Intake APF Calculation 2015.07.01). The mean values should differ based on differences in entrained volume (180 MGD vs 106 MGD), but the calculation for the standard error should be similar with respect to percent of mean. They are not. The intake standard error is 1.1 acres, which is 22% relative to the mean value of 5. The discharge standard error is 0.03 (units not specified) or about 0.3% of the mean value of 9.08 acres. If the standard error for the discharge CIQ goby APF was similar to that for the intake calculation (~22 % of the mean or 9.08) the APF would increase by almost 2 acres. There is no way to determine if the calculations are correct without assessment of the calculations made by Poseidon.

APF for the proposed diffuser is based on the following (this assumes the calculations discussed above were done correctly):

- The currently proposed diffuser design (see comments on diffuser design below)
- A dilution ratio of 13.9 (to a level within 2 ppt of ambient)
- A discharge volume of 56.7 MGD
- A constant 23% of entrainment volume subject to lethal entrainment due to shear.
- The estimated entrainment volume of ~780 MGD (56.7 X 13.9)
- The estimated entrainment volume subject to lethal entrainment of ~180 MGD (23% x 780 MGD).
- The application of ETM/APF calculations.

Figure 1 shows the relationship between APF and estimated mortality resulting from discharge related entrainment for a discharge identical to the one with the features (diffuser design, discharge volume) presented above (Figure 1 assumes that the standard error calculation for the discharge related CIQ goby APF was done correctly).

Based on my review, all are appropriate and follow accepted approaches.

I want to specifically comment on the following language that comes from the SWRCB Substitute Environmental Documentation (SWRCB 2015 on page 86).

"*However, the volume of water susceptible to high shear stress should always be less than the volume of water where salinity exceeds 2.0 ppt above natural background salinity for undiluted brine discharges. Thus, shearing-related mortality would only occur within the area that exceeds 2.0 ppt above natural background salinity, and mitigating an area equivalent to the area that exceeds 2.0 ppt above natural background salinity would also compensate for shearing-related mortality*"

This seems to imply that acreage of the footprint of the regulatory BMZ would be greater or equal to the area necessary to mitigate discharge shear-related mortality. Based on the use of ETM/APF modeling, this is incorrect. The APF for shear-related mortality is based on the mortality of organisms transiting through, rather than resident in, the BMZ. The APF calculation for this impact represents the habitat from which the propagules came from and not the footprint of the BMZ. Indeed Poseidon's own calculations indicate that the discharge-related APF is much larger than the brine-related APF (see Table 1 footnote 12).

Comparison of Diffuser Alternatives

The diffuser designs assessed by Roberts (Foster et al. 2013, Roberts 2016) were based on diffuser arrays that were designed, in part, to reduce the BMZ relative to older designs. This reduction in BMZ was accomplished through the use of higher velocity diffusers than had been previously used on other desalination projects.

The following paragraph, which was reviewed by Dr. Roberts, summarizes the modeling framework. Modelling shows that higher jet velocity and smaller port diameters lead to higher dilution and more rapid diffusion of salinity to regulatory thresholds (often 2 ppt above ambient) within the BMZ. Higher velocity jets can also lead to injury or mortality of small organisms (e.g., meroplankton). Total mortality is assumed to occur in 23% of the water entrained in the receiving water body to bring salinity to the regulatory threshold (often 2 ppt above ambient). It is widely accepted that that mortality rate will be directly affected by jet velocity; that is, the higher the velocity the greater the likelihood of injury and mortality. With the proposed diffuser design in standalone operation, 56.7 MGD of brine will be discharged through a three "valve" diffuser system with a maximum velocity of 10.1 ft/sec. In order to bring the salinity to within 2 ppt of ambient, 780 MGD of receiving water will be required as "mixing water," resulting in a dilution ratio of approximately 13.9 at a distance of 24.3 meters (distance to diffusers). This is the reference situation, or the currently proposed project.

The diffuser design initially proposed by Poseidon was a 6-port diffuser, and 4 ports were to be closed when the Huntington Beach Generating Station stopped its use of seawater for cooling. As described above, the currently-proposed diffuser would have 3 duckbill valves and a 4.5-foot central port. The central port would be open while the HBGS is operating, but it would be permanently closed after HBGS stops using once-through cooling.

Two additional diffuser alternatives can be considered that use the initially proposed Alden 6-Jet Radial Diffuser (MBI 2015):

(1) **2-port diffuser alternative.** This entails installation of the 6-port design with 4 ports closed and two 30-inch ports open. This alternative would have a maximum velocity of ~ 10 ft/sec and would attain regulatory compliance for salinity within an estimated ~21 meters (distance to diffusers). The 2 open port design is likely to have similar impacts with respect to diffuser-related entrainment mortality and area of the BMZ as the currently proposed 3-port differ design. This alternative could only accommodate stand-alone operations.

(2) **6-port diffuser alternative.** This entails installation of the 6-port design with all 6 ports open. In stand-alone operations, if all ports were open, the maximum jet velocity would be ~1.79 ft/sec. It is assumed that regulatory compliance for salinity would be achieved within 98 meters. It is likely that this design would have reduced diffuser related entrainment mortality, but a larger BMZ than the currently proposed diffuser design.

Considering the effects of the using the 6 port Alden diffuser for the co-located discharge as defined at this point (77 MGD, 55.3 ppt) is difficult because (1) we have no details for that scenario (e.g. jet velocity, BMZ area) and (2) the calculations that we would use for this alternative, in the absence of additional information, would yield identical estimates of larval loss and APF for both the 6 port and the 3 valve (current design). This equality is unlikely to be true but is mathematically inevitable because the entertainment calculation being used relies on discharge salinity and volume of discharge and assumed mortality rate - which do not change between designs. In my opinion this points to the problem of not evaluating specific designs for shear related mortality.

5. Support for CEQA Analysis of Entrainment Effects from Proposed Modifications

The CEQA analysis must conclude whether the levels of entrainment defined above would have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service or cause any affected populations to fall below self-sustaining levels. Entrainment numbers are unlikely to be informative with respect to this question. Much more important are the results of ETM/APF calculations. However, even these numbers require context. The key consideration is whether the determination is based on the results from the particular study (e.g., Pm values based on Huntington Beach) or from a cumulative impact assessment where there is an assessment of the impact of loss due to a new project added to the loss based on existing projects. This cumulative estimate could then be placed in the context of the population status of the target species. For example a proportional mortality (Pm) of 0.02 for species in a given source water body may be unimportant or very important based on: (1) the cumulative Pm from the proposed and current projects and (2) the status of the species (e.g. is it in decline, stable or growing). In my opinion, the information sufficient to address cumulative impacts quantitatively was not provided.

I have been asked to comment on entrainment impacts associated with the Huntington Beach project in the absence of any consideration of cumulative impacts. Given this limited scope, in my opinion, while entrainment would be an adverse ecological impact, this impact would not lead to populations falling below self-sustaining levels. Regarding whether there would be a “substantial adverse effect” on any special-status species, there is there is insufficient information to address the question of effects on special status species. This is largely a feature of the modeling approach, which works well for species for which there is sufficient data (meaning observations of that species) to make robust estimates of proportional mortality. Two features render species of special interest (typically) unfit for evaluation: larvae of species of special interest are almost by definition rare (e.g. giant sea bass) and are sometimes smaller than mesh size used for sampling (e.g. some stages of black abalone). This means that the absence of such species from either the formal evaluation process (i.e. the ETM/APF modeling) or from the list of species sampled in the field studies (as in the Huntington Beach evaluation) should not be taken to indicate that such species will not be entrained or that there will be no impact to these species resulting from entrainment.

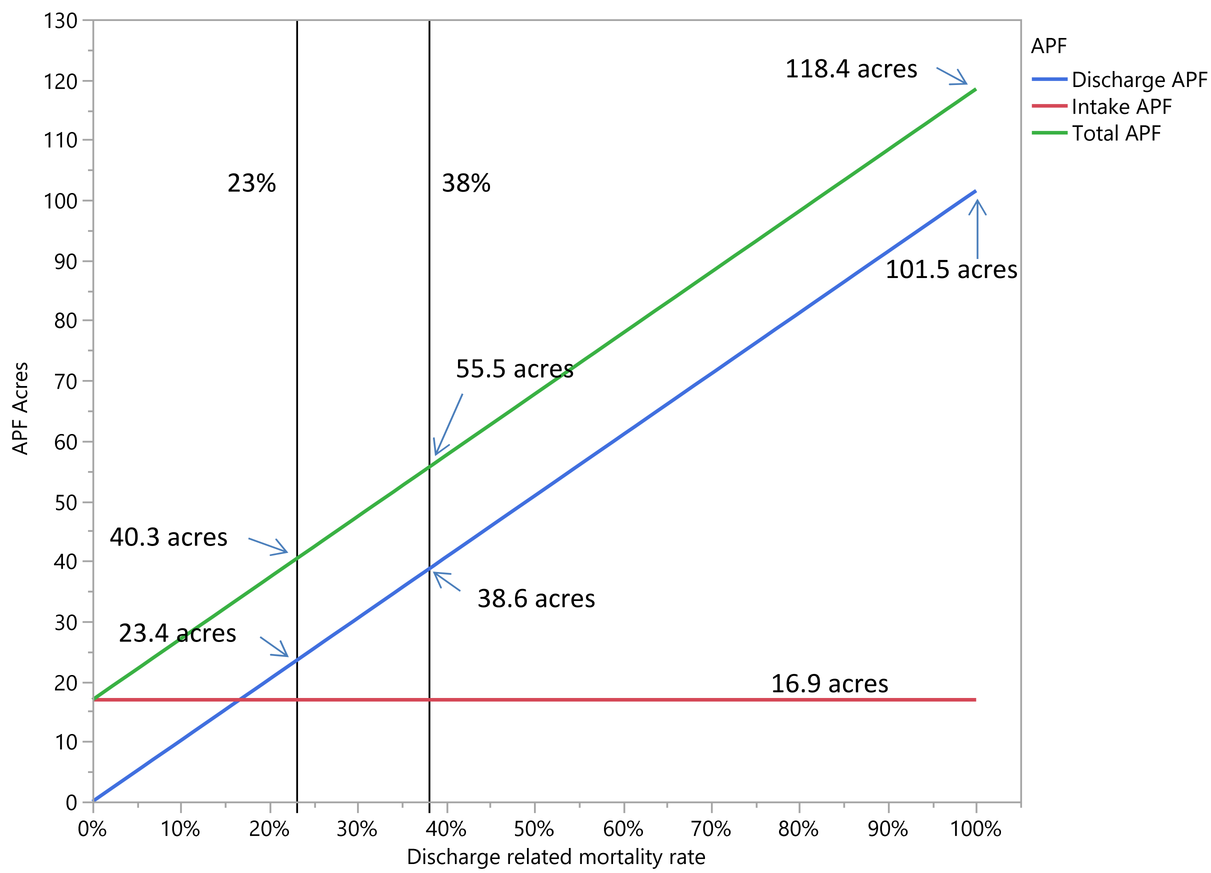

Figure 1: Relationship between estimated APF and discharge related mortality rate (blue line) (proposed diffuser, standalone operation). The two vertical lines at 23% and 38% are the range estimated in Foster et al. (2013). Shown also are the Intake related APF (in red based on 106 MGD) and the total APF (in green)

Table 1: Comparison of Proposed Modifications with 2010 Analysis

Table 1. Impingement and Entrainment – Comparison of 2010 Project and Proposed Modifications

Project Component	2010 Project				Proposed Modifications					
	Volume (MGD)	Impingement	Entrainment	APF[4]	Volume (MGD)	Volume entrained (MGD)	"Lethal" volume entrained (MGD)	Impingement	Entrainment	APF (acres)
Intake										
Co-located	127	0[1]	88,255,368[2]	N/A	127	N/A	N/A	0[6]	~88,255,368[2]	N/A
Stand-alone	152	see SEIR 2010 Table 4.10-11	103,303,290[3]	N/A	106	N/A	N/A	0[6]	~74,000,000[7]	17.003[10]
Discharge										
Co-located	--	N/A	0	N/A	77	762[13]	175[14]	N/A	121,611,727[8] –529 million[15]	22.81[11] - 99[15]
Stand-alone	--	N/A	0	N/A	56[5]	782	180	N/A	125,086,348[9] – 543 million[16]	23.46[12] – 101.5[16]

1 – Since this previously-approved operational scenario would draw from HBGS intake water it would not result in any impingement above that attributed to HBGS

2 - Entrained fish larvae, does not include fish eggs or any other meroplankton propagules or eggs. Estimates based on data collected in 2003-2004. Represents 0.33 percent of total population of fish larvae surrounding intake. Source: 2010 SEIR (p 4.10-62)

3 - Entrained fish larvae, does not include fish eggs or any other meroplankton propagules or eggs. Estimates based on data collected in 2003-2004. Represents 0.02-0.33 percent of total population of fish larvae surrounding intake. Source: 2010 SEIR (p 4.10-65)

4 – Not presented in 2010 EIR materials

5 - Turbulent shearing water volume. Source: MBC, 2016 (Appendix T, page 7)

6 – 1-mm slot wedgewire screens with a through-screen velocity of 0.5 feet per second or less would eliminate impingement

7 – Reduction in entrainment would scale proportionally with the (31%) reduction in intake volume (= (106.7 MGD/127 MGD) x 88255368 larvae); does not include additional reduction in entrainment from installation of 1mm WWS, which does not translate to reduction in impact using ETM/APF.

8 – Entrainment scales with volume (= (175 MGD/127 MGD) x 88255368 larvae). Entrained fish larvae, does not include fish eggs or any other meroplankton propagules or eggs. Estimates based on data collected in 2003-2004. Assumes 23% mortality.

9 – Entrainment scales with volume (= (180 MGD/127 MGD) x 88255368 larvae). Entrained fish larvae, does not include fish eggs or any other meroplankton propagules or eggs. Estimates based on data collected in 2003-2004. Assumes 23% mortality.

10 – 0.103 acres from benthic impacts from installation of intake structures + 16.9 acres from intake entrainment. Source: Dudek, 2016 (Appendix HH, page 19)

11 – Estimated based on 23 % mortality and Stand-alone (23.46 acres x (175 MGD/180 MGD)

12 – 0.034 acres from BMZ + 23.43 acres from shear stress entrainment. Source: MBC, 2016 (Appendix T, page 7)

13 – Based on volume required to reduce salinity to 2 ppt above ambient using mass balance equation (55.3 ppt x 77 MGD +33.5 ppt x C MGD =35.5 ppt x (C MGD+ 77 MGD).

14 – Based on 23% of 762 MGD

15 – Assumes 100% mortality

16 – Assumes 100% mortality

Summary of the Comparison of the Proposed Modifications with the 2010 Project

For both co-located and stand alone operations I was asked to estimate APF values for scenarios where the values were not directly calculated (see footnotes). These estimates were based the relationship between APF values and entrainment volumes that were calculated directly. Because these relationships differed, as noted above with some concerns, between the intake and discharge assessments I used the ones linked to my extrapolations (e.g. discharge extrapolation based on discharge relationship).

Co-located Operation

With regard to intake, the proposed modifications would result in the same amount of larvae entrained per year as the 2010 project.

With regard to discharge, and assuming 23% mortality, the proposed modifications would result in entrainment of 121,611,727 fish larvae per year. This is a result of a lethal discharge entrainment volume of 175 MGD.

This represents an estimated 121,611,727 additional fish larvae entrained per during operation of the project with proposed modifications. This equates to an estimated APF of approximately 22.81 acres (see footnote 11 for Table 1).

Stand alone Operation

With regard to intake, the proposed modifications would result in approximately 29,303,290 fewer fish larvae entrained per year (103,303,290 - ~74,000,000) than the 2010 project. This is a result of the reduction in intake volume from 152 MGD to 106 MGD

With regard to discharge, and assuming 23% mortality, the proposed modifications would result in entrainment of 125,086,348. This is a result of lethal discharge entrainment volume of 180 MGD.

This is a total of 95,783,058 fish larvae entrained per year (125,086,348 - 29,303,290) during operation of the project with proposed modifications. This represents a difference in lethal volume of 134 MGD (180-46 MGD) and equates to an estimated APF of ~21.5 acres[3].

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[3] Based on equation relating APF to entrained volume of water: (17.003 acres APF/106 MGD = X acres APF/2010 MGD). APF of 17 acres related to 106 MGD from Tenera 2015c

References

Highfield, J.M., Eloire, D., Conway, D.V.P., Lindeque, P.K., Attrill, M.J., and Somerfield, P.J. 2010. Seasonal dynamics of meroplankton assemblages at station L4. Journal of Plankton Research, 32 (5), p. 681-691.

Primary Documents Reviewed (many others were also consulted)

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Appendix 1

Fundamentals of the Empirical Transport Model (ETM) coupled with the modeling for Area of Production Foregone (APF) (From Raimondi (2011))

A detailed description of the ETM can be found in Steinbeck et al (2007). The following is derivative of that paper. Results of empirical transport modeling provide an estimate of the conditional probability of mortality (P_M) associated with entrainment. P_M requires an estimate of proportional entrainment (*PE*) as an input, which is an estimate of the daily entrainment mortality on larval populations in that body of water subject to entrainment, called the source water body (SWB). Empirical transport modeling has been used extensively in recent entrainment studies in California (Steinbeck et al. 2007) and elsewhere (e.g. at the Salem Nuclear Generating Station in Delaware Bay, New Jersey and at other power stations along the east coast of the United States (Boreman et al. 1978, 1981; PSE&G 1993). ETM derivations have also been developed (MacCall et al. 1983) and used to assess impacts at the San Onofre Nuclear Generating Station (SONGS; Parker and DeMartini 1989).

The basic form of the *ETM* incorporated many time-, space-, and age-specific estimates of mortality as well as information regarding spawning periodicity and larval duration (Boreman et al. 1978, 1981). Much of this type of information is unknown for species entrained in California, Hence, a variation of ETM has been developed for use for coastal once through cooling (OTC) systems in California. The essence of the approach is the compounding of *PE* over time, which allows estimation of P_M using assumptions about species-specific larval life histories, specifically the length of time in days that the larvae are in the water column and exposed to entrainment.

On any sampling day *i*, PE can be expressed as follows:

$$PE_i = \frac{E_i}{N_i} \qquad (1)$$

where

E_i = total numbers of larvae of species entrained during a day during the i^{th} survey; and

N_i = numbers of larvae at risk of entrainment, i.e., abundance of larvae in the sampled source water during a day during the i^{th} survey.

Survival over one day = 1-PE_i, therefore survival over the number of days (*d*) that the larvae are vulnerable to entrainment = $(1-PE_i)^d$. Here *d* is determined based on a derived age distribution of entrained individuals. The derivation is based on the measured size frequency distribution of entrained individuals. Many values of d could be used, but the most common are average age and the constrained maximum (Steinbeck et al. 2007) age of entrained individuals. The difference between these two estimates can have profound effects on the estimate of impact (see below). Methods for estimating E_i and N_i can be found in Steinbeck et al. (2007).

Regardless of whether the species has a single spawning period per year or multiple overlapping spawnings the estimate of total larval entrainment mortality can be expressed as the following:

$$P_M = 1 - \sum_{i=1}^{n} f_i (1 - P_S PE_i)^d \qquad (2)$$

where

PE_i = estimate of the proportional entrainment for the ith survey

P_S = ratio (sampled source water / SWB)

f_i = proportion of total annual larvae hatched during ith survey

d =estimated number of days larvae vulnerable to entrainment

To establish independent survey estimates, it was assumed that each new survey represented a new, distinct cohort of larvae that was subject to entrainment. Each of the surveys was weighted using the proportion of the total population at risk during the i^{th} survey (f_i) calculated as follows:

$$f_i = \frac{N_i}{N_T} \qquad (3)$$

where

N_i = the source population spawned during the i^{th} survey

N_T = the sum of the N_i s for the entire study period.

As noted above, the number of days that the larvae of a specific taxon were exposed to the mortality estimated by *PE*, can be estimated using length data from a representative number of larvae from the entrainment samples. Typically, a point estimate of larval exposure has been used in the calculations (mean or maximum). These point estimates are constrained by using the values between the 1st and upper 99th percentiles of the length measurements for each entrained larval taxon. The constrained range is used to eliminate potential outlier measurements in the length data. Each measurement can then be divided by a species-specific estimate of the larval growth rate obtained from the scientific literature to produce an age frequency distribution. Maximum larval duration is calculated as the number of days between the 1st and 99th percentile. The second estimate uses an estimate of *d* calculated using the difference in length between the 1st percentile and the 50thth percentile and is used to represent the mean number of days that the larvae were exposed to entrainment.

The term P_S represents the ratio of the area or volume of sampled source water to a larger area or volume containing the population of inference (Parker and DeMartini 1989). This allows for sampling of an area smaller than the likely source water body (SWB). If an estimate of the larval population in the larger area is available, the value of P_S can be computed directly.

There are two extreme versions of estimation of the SWB. These are noted for simplicity – the actual estimation is often more complex (Steinbeck et al. 2007). When an intake is withdrawing water exclusively from a contained water body, such as an estuary, the assumed SWB is often that water body for all species entrained. [Note that even in these cases there is often an addition to the SWB that represents tidal flux]. For intakes withdrawing water from the open ocean, SWB is calculated separately for each assessed species. This calculation is based on the value of *d* and an estimate of net current velocity over the period of larval vulnerability. Hence P_S is then calculated as:

$$P_S = \frac{L_G}{L_P} \quad (4)$$

where

L_G = length of sampling area

L_P = length of alongshore current displacement based on the period (d) of larval vulnerability for a taxon

Estimation of Area of Production Foregone (APF) and consideration of error in its estimation (see Strange et al. 2004 and Steinbeck et al. 2007 for detailed treatment of this topic,)

One problem associated with the use of ETM approaches is in the estimation of impact and potential mitigation opportunities. This is because the currency of ETM is proportional mortality (P_M), which is not an intuitive currency for impact assessment. Calculation of the area of production foregone (APF) is one approach for estimating impact and for giving guidance to compensation strategies because it yields the amount of habitat that would need to be replaced to compensate for the larval production lost due to entrainment.

Area of Production Foregone models can be used to understand the scale of loss resulting from entrainment and the extent of mitigation that could yield compensation for the loss. The basis of APF calculations with respect to entrainment rests on the assumptions that (1) P_M information collected on a group of species having varied life history characteristics can be used to estimate to impact to all entrained species and, (2) the currency of APF (habitat acreage) is useful in understanding both direct and indirect impacts resulting from entrainment, which is essential for understanding the extent of compensation required to offset the loss.

Because APF considers taxa to be simply independent replicates useful for calculating the expected impact, the choice of taxa for analysis may differ from Habitat Replacement Cost (HRC) assessments (Stenbeck et al. 2007). For APF the concern is that each taxon is representative of others that were either unsampled (most species including invertebrates, plants and holoplankton) or not assessed for impact (most fish species, see Figure 1). The core assumption of APF with respect to estimating impact is that the average loss across assessed taxa is the single best point estimator of the loss across all entrained organisms. This fundamental statistical-philosophic assumption of APF addresses one of the most problematic issues in impact estimation: the typical inability to estimate impact for unevaluated taxa.

The calculation of APF is quite simple mathematically and in concept. Conceptually, it is an estimate of the area of habitat that would be required to replace all resources affected by the impact. Hence, for entrainment, it can be considered to be the area of habitat that would have to be added to replace lost larval resources. As an example, assume that for gobies the estimate was that 11% of larvae at risk in a 2000-acre estuary were lost to entrainment. The estimate of APF then would simply be 2,000 acres (the Source Water Body = SWB) x 11% (P_M) or 220 acres. Therefore the creation of 220 acres of new estuarine habitat would compensate for the losses of goby larvae due to entrainment. This does not mean that all biological resources were lost from an area of 220 acres, which is a common misunderstanding. Instead it means that if 220 acres of new habitat were created then losses to gobies would be compensated for.

Mathematically then APF is the product of P_M and SWB. This calculation is done separately for each species i.

$$APF_i = P_{M_i}(SWB_i) \quad (5)$$

Clearly the goal should not be to assess impacts to individual species. Rather it should be to estimate all direct and indirect impacts to the system and to provide guidance as to the mitigation that would be compensatory. Indeed one criticism of many assessment methodologies (e.g. Habitat Equivalency Analysis = HEA) is that there is a focus on only a limited number of taxa (Figure 1) of all that are directly affected by entrainment and that there is also no provision for estimation of indirect impacts (often food web considerations). APF, as discussed, addresses this concern by expressing impact in terms of habitat and assuming that indirect impacts are mitigated for by the complete compensation of all directly lost resources. The idea is that the addition of the right amount of habitat would lead to compensatory production of larvae ***and*** would also compensate for indirect effects resulting from the larval losses. For example, if one indirect consequence of larval losses was the loss of a food resource for seabirds, the replacement of those lost larvae should mitigate the impact to seabirds. Hence the task is to determine the *right* amount of habitat.

The most obvious approach, as noted, and one that is consistent with the underlying assumptions of APF is to use species specific APF values to calculate a point estimate of overall effect. The main assumptions of this approach are:

1) Species specific APF values represent random samples from a population of APF values (the family of all possible species specific APF values)

2) Each species specific APF is the mean value of a series of samples and hence has associated measurement error.

Based on these assumptions, the mean $\overline{\overline{APF}}$ (across species) should represent the single best estimate of the impact due to entrainment.

$$\overline{APF} = \sum_{i=1}^{n} APF_i \quad (6)$$

Because species in APF are simply independent replicates that yield a mean loss rate, habitat restored or created should not be directed by species. Instead the habitat monetized or created should represent the habitat for the populations at risk. That is, if the habitat in the SWB estuary was 60% subtidal eelgrass beds, 15% mudflats and 25% vegetated intertidal marsh, the same percentages should be maintained in the created habitat. Doing so would ensure that impacts on all affected species would be addressed.

Probably the most controversial issue in APF assessment is how measurement error is accommodated, although such accommodation is part of national policy recommendations (EPA 2006). In most assessments, including Habitat Replacement Cost (HRC) (Strange et al. 2002), estimates of loss of taxa are implicitly considered to be without error. In APF, each species specific estimate is considered to be prone to (sometimes) massive error (indeed, estimates of confidence intervals in ETM calculations often cross through zero). Because of the uncertainty as to how error should be calculated and used in the calculation of estimates of compensatory mitigation, the goals of this project were to evaluate the effect of:

(1) Incorporation of statistical uncertainty in estimation of APF – specifically how incorporation of error affects estimates of the likelihood that proposed mitigation acreage will be compensatory.

(2) Sample size (number of species for which APF is assessed) on estimation of APF. Here the idea was to test how sensitive APF estimates are to sample size. The results of this portion of the study inform future sampling design.