Mitigation and Fees for the Intake of Seawater by Desalination and Power Plants

Report submitted to Dominic Gregorio, Senior Environmental Scientist, Ocean Unit, State Water Resources Control Board (SWRCB) in fulfillment of SWRCB Contract No. 09-052-270-1, Work Order SJSURF-10-11-003

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Background

Raw seawater is used for a variety of purposes, including as source water for desalination plants and to cool coastal power plants. Raw seawater is, however, not just cold and salty but an ecosystem that contains diverse and abundant organisms including the young stages of numerous invertebrates and fishes. Whether impinged (large individuals stuck on screens prior to entering the plant or killed during other plant processes such as heat treatment) or entrained (small individuals carried into the plant with the water) the organisms are killed, essentially eliminating the living production in the water used (review in York and Foster 2005). Considerable research has have been done in California to better estimate losses to this ecosystem by coastal power plant intakes (York and Foster 2005, Steinbeck et al. 2007), and to determine how these losses can be mitigated (Strange et al. 2004).

The information from this research has contributed to State of California policy regulating water used by power plants (policy at http://www.waterboards.ca.gov/water_issues/programs/ocean/cwa316/docs/policy100110.pdf). The policy now applies only to power plants but the intent to protect marine organisms is also broadly applicable to desalination plants and other users of large volumes of seawater. The State's Once-through Cooling Policy (Policy) states that plants must implement measures to mitigate interim impacts occurring after October 1, 2015, and until the plant comes into full compliance through conversion to closed cycle cooling or by using operational controls and/or structural control technology that results in comparable reductions in impingement and entrainment (IM&E).

The SWRCB is currently developing a policy for addressing desalination plant intakes and discharges which will be instituted through amendments to the Ocean Plan and Enclosed Bays and Estuaries Plan (statewide water quality standards). The California Water Code currently requires new or expanded industrial facilities (e.g., desalination plants) to use the "best available site, design, technology, and mitigation measures feasible" to minimize the intake and mortality of marine life (see the Ocean Plan Triennial Review 2011-2012 Work-plan at http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2011/rs2011_0013_attach1.pdf). The panel's assumption, based on SWRCB direction, is that the "best site, design and technology" would be employed prior to mitigation measures. Mitigation measures would be applied to compensate for any the residual impacts.

The staff of the SWRCB requested the formation of an expert review panel (chaired by Foster and composed of the authors of this report) to assist in answering questions related to present policy concerning interim mitigation for impacts from power plant intakes and future policy concerning mitigation for impacts caused by the intakes of desalination plants. The issues and questions for the panel to address were:

A. Power Plants: Provide a scientifically defensible basis and unit cost for a fee paid by power plants based on the volume of cooling water used. This fee would be used for mitigation projects to compensate for continued impacts due to IM&E during the interim period after October 1, 1015 and until a plant comes into full compliance with the Policy.

B. Desalination Plants: How should any remaining IM&E be mitigated after the best site, design and technology are determined for a new desalination plant intake?

C. Desalination Plants: Are there desalination intake technologies and designs that can reduce IM&E?

The panel met twice to discuss the questions and possible answers, and panel members Steinbeck and Raimondi prepared three reports as Appendices 1, 2 and 3 to this report. Appendix 1 develops a fee-based approach to questions A. and B. based on the cost of replacing the habitat production lost due to entrainment. Appendix 2 develops a fee-based approach to questions A. and B. based on the loss of adult equivalent fish due to entrainment. Appendix 3 addresses question C. with a review of the efficacy of desalination plant intake technologies and designs in reducing IM&E. The panel recommendations below are based on these reports, discussions and experience from prior assessments and mitigation for power plant intake impacts in California.

Alternatives and Recommendations

A. *Interim Mitigation for Power Plants*

1. Given uncertainties about the length of time for interim impacts and amount of water a particular power plant may use while in interim operation, interim mitigation should be fee-based according to the amount of water used ($/Million Gallons (MG)).

2. One alternative is a fee based on Adult Equivalent Loss (AEL), the number of adult fishes eliminated by the entrainment of larval fishes plus fish losses due to impingement (Appendix 2). This fee was estimated for comparison to the APF-based fee (see 3. below) using data and analyses for the Huntington Beach Generating Station (HBGS). The average fee using this estimate and including indirect economic losses is $0.77/MG. This fee, however, only compensates for economic losses of adult fishes and is, therefore, not recommended.

3. The other alternative is a fee for interim mitigation based on the costs of mitigation already determined for some power plants using Area of Production Foregone (APF; Appendix 1). This fee is based on the cost of creating or restoring habitat that replaces the production of marine organisms killed by entrainment. The APF method is preferred because creation and restoration of coastal habitats compensates for all organisms impacted by entrainment, not just select groups such as fishes. The average fee, based on existing examples of mitigation for power plant entrainment, adjusted for inflation, and assuming a 50 year half- life for the habitat produced, is $2.45/MG (range: $1.66 - $3.28; Appendix 1). The fee is linearly proportional to half-life so, for example, if the half- life of a project was 25 years the fee would double. This fee does not include the cost of management and monitoring after implementation. Management and monitoring costs typically range from 10 - 25% of projects costs (Appendix 1). The fee also does not account for impacts due to impingement. These could be determined using the value (cost/pound) of fishes impinged/MG plus the indirect economic value of the fisheries (see Appendix 2). For example, average annual impingement of fishes from normal operations and heat treatments at HBGS from 2000-2010 was 2,686 lbs. (Appendix 2, Tables 1 and 5). Using the value for fishes estimated from catch totals plus the average indirect economic value (see Appendix 1) yields a total value of ~ $0.80/lb., and an average annual value of fishes impinged of ~ $2,150.00. Divided by the average annual intake flow of 92,345 MG (Appendix 2, Table 5), the average annual mitigation fee for impingement at HBGS during this period would be ~ $0.023/MG.

4. An APF-based fee for entrainment could be determined for each plant but the process could be complex and expensive, especially if a suitable entrainment study is not available. Moreover, while the amount of habitat required to be directly compensatory can be estimated for intakes entraining or impinging mainly estuarine or rocky reef species (examples in Appendix 1), impacts to open coast soft bottom species are more difficult to deal with using habitat restoration or creation. Given the relatively small range of fees based on power plants for which the cost of creating habitat equivalent to APF has been determined (see 3. above) the simplest approach for entrainment mitigation would be to use the average fee and apply it to all intakes. Impingement, however, varies greatly among power plants so one fee for all is inappropriate for this impact. The interim mitigation fee for impingement could be determined from ongoing impingement/heat treatment monitoring at each plant, modified as necessary to insure the weight of fishes impinged is determined.

5. The fees, either from individual power plants or groups of power plants, should be used for habitat creation, restoration, protection or other projects that best compensate for the impacts in the region where they occur. In cases where habitat creation or restoration is not feasible, alternatives could include implementation of marine protected areas with limited or no take; such areas may produce healthy, fecund adult populations which, in turn, can produce and provide more offspring to the greater marine environment. Alternatives could also include potentially in-kind but indirect mitigation such as clean-up or abatement of contaminants, and restoration or creation of habitat critical to other marine species (e.g. rocky reef or estuarine) based on habitat-specific larval productivity; for example, mitigation that

is viewed as critical to the State's resources such as funding for white abalone restoration. One potential advantage of the fee based approach is that funds could more easily be aggregated if more costly projects are likely to provide the highest mitigation value.

6. Costs associated with the planning and management of mitigation projects should be minimized to achieve maximum compensation for impacts.

B. *Mitigation for Desalination Plants*

7. Ocean intakes at desalination plants can cause IM&E impacts like those of a power plant intake. The primary difference is in magnitude; desalination plants generally use less water than power plants. Therefore, a similar, fee-based approach to mitigation for such desalination plants is appropriate and could use the same fee/MG based on APF (3. and 4. above) for any impacts that remain after the best site, design and technology have been used. The fee should be used as for power plants (5. and 6. above).

C**.** *Intake Designs and Technologies for Impact Reduction at Desalination Plants*

8. Subsurface intakes such as sand wells likely have no IM&E since the water filters through the overlying substratum at low velocity. Such intakes, however, may not be feasible at some locations and for large plants (Appendix 3). Large beach galleries or seabed filtration systems may have low IM&E impacts but large construction impacts on benthic organisms. Such construction impacts should be thoroughly evaluated for any projects proposing such intakes.

9. Wedge wire screens and a variety of other passive and active devices have been used or proposed for use on surface intakes to reduce IM&E (Appendix 3). Initial pilot studies of wedge wire screens indicate they have little effect on the number of small fish eggs and larvae entrained, but reductions in entrainment of larger larvae may provide some benefit by protecting older larvae that have a greater likelihood of becoming adults (see analyses in Appendix 3). A more thorough assessment of the effectiveness of wedge wire screens is underway in Redondo Beach for the West Basin Municipal Water District but the results are not yet available. While their effects on entrainment may be small, such screens have potential to eliminate impingement of juvenile and adult fishes if properly designed and located. Other entrainment reduction technologies for surface intakes have not been evaluated in the coastal waters of California.

Literature Cited

Strange, E., Allen, D., Mills, D., and Raimondi, P. 2004. Research on estimating the environmental benefits of restoration to mitigate or avoid environmental impacts caused by California power plant cooling water intake structures. CEC Report 500-04-092. California Energy Commission, Sacramento

Steinbeck, J., Hedgpeth, J., Raimondi, P., Cailliet, G., and Mayer, D. 2007. Assessing power plant cooling water intake system entrainment impacts. CEC Report 700-2007-010. California Energy Commission, Sacramento.

York, R. and Foster, M.S. 2005. Issues and environmental impacts associated with once-through cooling at California's coastal power plants. CEC Report 700-2005-013 + Appendices (CEC 700-2005-013-AP-A). California Energy Commission, Sacramento

Attachments

Appendix 1. What should be the cost per million gallons for power plant once-through cooling interim mitigation, using entrainment weighted flow and examples of existing mitigation projects? By Peter Raimondi. 4 pages.

Appendix 2. Example of Costing IM&E Losses from Huntington Beach Generating Station. By John Steinbeck. 8 pages + Attachments.

Appendix 3. Desalination Plant Intake Technology Review. By John Steinbeck. 12 pages + Attachments

Appendix 1

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What should be the cost per million gallons for power plant once-through cooling interim mitigation, using entrainment weighted flow and examples of existing mitigation projects?

By: Peter Raimondi (University of California, Santa Cruz)

Although, I will discuss entrainment in this document, the logic should apply directly to impingement as well. I reviewed a series of mitigation or proposed mitigation projects that have resulted from estimation of impacts resulting from entrainment (Table 1). In all cases I relied on Empirical Transport Models (ETM), coupled to the use of Area of Production Forgone (APF – sometimes called HPF) to calculate the area of habitat that would need to be created to compensate for resources lost to entrainment. In all cases resource loss was based on larval fish loss (note that a similar approach has been used for adult fish that were impinged). In all cases, I used information that was either in the assessment documents, the findings or the permits.

The key assumption of APF

The key assumptions of APF that makes it useful in estimating the fee that should be applied per million gallons of water are: (1) it should reflect impacts to measured and unmeasured resources (e.g. to invertebrate larvae). This is because its calculation assumes that those species assessed are representative of those not assessed. Practically this means that should the amount of habitat calculated using APF be created or substantially restored, the habitat will support species that were assessed as well as those that were not assessed in the ETM. Importantly that amount of habitat will also compensate for impacts to species only indirectly affected. For example, species feeding on larval fish will be positively affected by the creation of habitat that will produce more larval fish, even if those species are not affected directly by entrainment. (2) The losses are directly compensated in time. This means that should the mitigation take place according to APF estimates there will be no net impact. Importantly (for calculations that occur later), benefits do not need to accrue to be compensatory.

Assessment of cost per million gallons of water

The key components of the calculation were Intake Volume, APF (in acres), and the cost estimate for the creation or restoration of acreage. In addition I made the (very) simplifying assumption that the half- life of the restoration or mitigation project was 50 years. (Note that this assumption, along with discounting rate is adjustable in the model). Half-life is the midpoint in the expected life of the restoration project and is the point where the resource value conveyed is expected to be 50% of as-built, in the absence of further funding. This is an important assumption and one that should be discussed. The main implication of this assumption is that it affects the discounting of the fee.

Appendix 1

As noted, the general goal of APF is to determine the amount of habitat that would immediately compensate for losses due to entrainment (or any other sort of impact). When once through cooling (OTC) was considered to be ongoing and the life of the power plant was considered to be long, there was the expectation that the full cost of mitigation should be borne by the plant operator, *even though the benefits of the mitigation might last longer than the plant operations.* Given that the proposed fee structure is intended to operate for a period much shorter than the life of the plant, there needs to be a way to discount the cost of the mitigation. I modified the approach to one that is simpler and I think more reasonable. Looking at the table below will help with the following explanation.

For each of the Facilities shown in the table I show the intake volume that was used to estimate APF and note the type of mitigation that was used to estimate he compensatory costing (e.g. wetland restoration, rocky reef). Also shown is the cost estimate at the time of the assessment and the year of the assessment. The cost escalator is essentially the average inflationary rate that is applied to produce costs in 2012 dollars. This rate can be adjusted. The estimated half-life of the project is used to discount the cost. The half-life is used to estimate the accrued resource value of the project. For example if the mitigation project is for 200 acres and the half-life is 50 years, the accrued resource value is 10000 acre years (generally the formula is acres*half-life, based on a linear decrease of value with time). This can be used to determine the annual cost to the operator. For 2012 the estimate would simply be 1/50th of the 2012 cost per MG (in the table). That value is called the prorated 2012 cost. If the plant operated in 2013, then the cost would the 2012 cost plus an increase due to cost escalation. This approach allows for easy estimation of cost per MG that is linked to cost of compensation of impacts due to use water.

One key consideration is how to use the results. For specific projects (eg Moss Landing) where APF estimation has occurred, very specific costing can be done. Alternatively, we could use the average cost per MG as the basis for all projects, large and small. Using data from Moss landing, Morro Bay, Poseidon, Huntington Beach and Diablo Canyon, I estimated the cost per Million Gallons (MG) of water used based on the best estimate of the total cost of habitat creation or restoration that would be compensatory based on APF calculations. The table below has these values. Based on this calculation (half-life = 50 years and cost escalator of 3%) the estimate of the annual fee ranged between $1.66 and $3.28 per MG. Two types of restoration were included: estuarine/wetland and rocky reef. The average cost was $2.45 per MG. I included a column of estimated annual fee based on the intake volume for each power plant and the average cost per MG. These ranged from $113,139 to $2,387,994. These values are less than half of earlier estimates.

To provide some context for these values I used all information that was available related to larval entrainment to derive the average concentration of larval fish that are entrained due to power plant operations. That value is ~ 6000/MG. At a cost of $2.45 per MG the

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cost per larval fish is ~ 0.05 cent. Note this is only to provide context as vast numbers of fish eggs ad invertebrate eggs and larvae are also lost due to entrainment.

Another way to provide context is through comparison to the cost of water. One possibly relevant comparison is to well water. Using Pajaro Valley Water Management District as an example, the cost is ~$500 per MG. Such water is delivered through user provided infrastructure and therefore its cost is not tied in any way to delivery. Even water that is massively subsidized for use in agriculture costs on the order of $30 dollars per MG.

The straw method under discussion allows for context dependent adjustment of fee. One example is described above and can be easily seen in the worksheet. The estimated fee per MG is considerably less for construction of artificial reef than for wetland. Other adjustments could be made for region specific cost of land acquisition. One extremely important caveat is that the fee structure shown is based only on the creation/restoration of habitat. No adjustments have been made to cover the cost of assessment of the effectiveness of the projects. Such an adjustment should be incorporated.
On possible approach would be to determine a reasonable percentage of restoration cost that should be used for assessment. I think that the range is somewhere between 10% and 25%. From a base cost of say $2.45 per MG, the cost including funding that would be used for assessment would range from $2.70 (10%) to $3.06 (25%).

Appendix 1

			Annual Cost Escalator	**3.00%**		**average cost per MG**	**$2.45**
			Estimated Half-Life of Project	**50**			
			Cost projection (year)	**5**			

: escalator built in.

APF (acres)	**Mitigation Type**	**Cost estimate**	**cost per annual intake (MG)**	**Notes**	**Years between assessment and 2012**	**Cost escalator**	**total escalator**	**2012 cost per MG**	**estimated half-life fo project (years)**	**Prorated 2012 cost per MG**	**Estimated 2012 Annual cost (based on average cost per MG)**
840	wetland	$15,100,000	$115	based on max larval duration, dollars in year 2000	12	3.00%	$1.43	$163.84	50	**$3.28**	**$321,977**
760	wetland	$13,661,905	$101	based on max larval duration, dollars in year 2001 and cost per acre = Moss Landing)	11	3.00%	$1.38	$139.65	50	**$2.79**	**$331,815**
37	wetland	$11,100,000	$100	based on max larval duration, dollars in year 2009 and cost per acre =300K (SONGS cost)	3	3.00%	$1.09	$109.31	50	**$2.19**	**$271,891**
66	wetland	$4,927,560	$107	based on max larval duration, dollars in year 2009 and cost per acre =74.66K (from Davis et al report and final permit (acres)	3	3.00%	$1.09	$116.62	50	**$2.33**	**$113,139**
543	Rocky reef	$67,875,000	$70	based on125K per acre (SONGS) in 2006	6	3.00%	$1.19	$83.16	50	**$1.66**	**$2,387,994**
				Average		**3.00%**				**$2.45**	**$685,363**

Example Costing of IM&E Losses from Huntington Beach Generating Station

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Introduction

This report provides an example of using impingement mortality and entrainment (IM&E) data to determine an appropriate cost for interim mitigation requirements for the state policy for once-through cooling. This example is presented as an alternative costing approach based on the use of Area of Production Forgone (APF) to calculate the area of habitat that would need to be created to compensate for resources lost to entrainment. The example presented here uses data from the Huntington Beach Generating Station (HBGS) (MBC and Tenera 2005), which was one of the examples used for the previously presented APF calculations. The HBGS is a good choice as it has recent IM&E data, an existing mitigation settlement determined using APF, and an existing cost-benefit analysis submitted as part of the 316(b) Comprehensive Demonstration Study (CDS) to the Santa Ana Water Board (attached).

The example costing for HBGS using APF was based on the cost for a mitigation project to restore 66.8 acres of salt marsh wetland habitat, but this acreage was determined based on an agreement with HBGS to curtail intake flow during certain times of the year (Final CEC Agreement attached). The agreement required flow restrictions of 25, 50, 80, and 45% of maximum per quarter. These flows were used to recalculate the ETM and APF estimates for the HBGS to arrive at the of 66.8 acres at a cost of $5,511,000, which included $523,712 for maintenance over ten years. The cost per acre was estimated at $74,660. The APF based on an unrestricted flow of 253.5 mgd was estimated at 104 acres, which would total $7,764,640. The annual cost of maintenance was estimated at $784 per acre for a total of $81,536.

The cost-benefit analysis for the HBGS CDS was based on annual estimates of IM&E losses provided in MBC and Tenera (2005). The species analyzed in the report only included those that accounted for approximately 90 percent of the total organisms impinged or entrained. HBGS has four units, but the cost-benefit analysis was also only conducted for IM&E impacts associated with Units 1 and 2, so the annual entrainment estimates in the report that were calculated for a total design flow of 507 mgd for all four units were divided by two, resulting in the same flow volume used in the CEC analysis of mitigation. The estimated annualized benefits associated with IM&E reductions of 90% ranged from $4,719 to $12,700 with a mean estimate of $7,928. These estimates would need to be adjusted upwards to determine the total annualized benefits of the IM&E losses. The estimates assume that reducing IM&E leads to increases in local fish populations and corresponding increases in expected commercial and recreational catch. The estimated equilibrium change in recreational catch was estimated at 543 fish per year and the expected change in commercial harvest was 80 pounds per year. The estimates in the report did not account for non-use benefits, which is the approach recommended by EPA (2004, p. 41,648) when effects due to IM&E do not cause “substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function” in the coastal waters.

The estimates in this report provide a third approach toward quantifying the lost value associated with IM&E losses at HBGS. Unlike the other two approaches (APF and cost-benefit), I have attempted to account for interannual variability in the estimates used in the calculations. This was only possible due to the long-term data on impingement available from HBGS. While these data provided an opportunity to use site-specific data in adjusting the annual estimates, other long-term data sets such as the CalCOFI information on interannual changes in larval fish abundance in the southern California bight could also be analyzed to determine if they could also be used to provide similar adjustments.

Methods

The IM&E estimates provided in MBC and Tenera (2005) were first standardized to a daily fixed flow of 253.5 mgd. While this was straightforward for the entrainment estimates, which were calculated using a design flow of 507 mgd in the report and were simply divided by two, the impingement estimates had to be recalculated for each survey, since the daily impingement was calculated using a flow-weighted rate. The recalculated impingement and entrainment estimates were then combined into annual estimates of the total losses at HBGS due to IM&E.

Impingement

The IM&E study period in MBC and Tenera (2005) was September 2003 through August 2004. Although entrainment sampling was only done during this period, impingement sampling at the plant has been conducted on an ongoing basis for many years. Therefore, rather than using the specific impingement estimates from the study period, it was decided that the long-term average from 2000–2010 would provide a better estimate for the calculations (**Table 1**).

The impingement data were also used to calculate an index (multiplication factor) for adjusting the annual entrainment estimates from the 2003–2004 study. The index of 3.7 was calculated as the ratio of the long-term 2000–2010 mean to the mean from 2003–2004, which was used to represent the IM&E study period (**Table 1**). The use of the long-term impingement data as an index of interannual variability was based on recent analyses in Miller et al. (2011) showing that trends in the abundances of sciaenids (croakers) from impingement monitoring tracked trends in abundance from other fishery-independent monitoring and correlated with decadal-level changes in the ocean environment in the southern California bight. A similar approach was used in the 316(b) study at the Diablo Canyon Power Plant (DCPP) where entrainment estimates from a study conducted in 1996 and 1997 were adjusted to a long-term mean using a separate set of data that extended over a nine-year period that encompassed the DCPP entrainment sampling (Tenera 2000).

Table 1. Annual estimates of impingement of fishes during normal operations adjusted for a fixed design flow of 253.5 mgd at Huntington Beach Generating Station (HBGS) with the average for 2003–2004 that encompasses the period of study from MBC and Tenera (2005), as well as averages and statistics for 2000–2010. The Index was calculated as the ratio of the 2000-2010 average to the 2003–2004 average and was used to adjust annual entrainment estimates from MBC and Tenera (2005). Source of impingement data: E. Miller, MBC Applied Environmental Sciences from NPDES required monitoring at HBGS.

Year	Estimated Annual # Impinged Fishes	Annual Estimate of Fish Biomass (kg)	Annual Estimate of Fish Biomass (lb)
2000	8,699	1,274.9	2,811
2001	5,407	340.1	750
2002	415	118.1	260
2003	3,344	136.1	300
2004	9,325	121.9	269
2005	191,631	2,341.9	5,163
2006	39,031	370.2	816
2007	3,191	128.4	283
2008	6,283	76.1	168
2009	2,582	44.1	97
2010	815	335.5	740
Grand Total	270,723	5,287.3	11,657
2003-2004	6,335	129.0	284
Average	24,611	480.7	1,060
Std. Dev.		707.5	1,560
CV		1.5	1.5
Index		3.7	3.7
Upper 95% CI using 2*SE		907.3	2,000

The impingement losses at HBGS in **Table 1** do not include losses that resulted from heat treatment events that occurred periodically. These were estimated from data in Steinbeck (2008) for the period from 2000–2005 when an average of 4.8 heat treatments were done each year with an average impingement biomass of fishes of 153.6 kg (338.7 lb). The average annual losses due to heat treatments were combined with the normal operations estimates to calculate a normalized estimate of the total combined losses due to impingement.

Entrainment

The entrainment estimates from September 2003 through August 2004 provided in MBC and Tenera (2005) were adjusted for a fixed flow of 253.5 mgd (**Table 2**). The results for only the taxa that were used in the adult equivalent (AEL) modeling are present in **Table 2**. These taxa accounted for 89.6% of the total estimated larvae entrained.

Table 2. Annual estimates of entrainment of fishes during normal operations at Huntington Beach Generating Station adjusted for a fixed design flow of 253.5 mgd for the study period of September 2003–August 2004 from MBC and Tenera (2005). Only fishes used in adult equivalent modeling (AEL), which accounted for 89.6% of the total are presented.

Taxon	Common Name	Sample Count	Average Density per m^3	Density per mgd	Entrainment Estimate 253.5 mgd	Proportion
Croakers						
Roncador stearnsi	spotfin croaker	912	0.05307	200.9	34,850,795	0.1978
Seriphus politus	queenfish	306	0.01817	68.8	8,904,932	0.0505
Genyonemus lineatus	white croaker	446	0.02814	106.5	8,812,631	0.0500
Sciaenidae unid.	croaker	244	0.01473	55.8	5,267,401	0.0299
Menticirrhus undulatus	California corbina	43	0.00233	8.8	1,404,708	0.0080
Cheilotrema saturnum	black croaker	96	0.00541	20.5	3,564,064	0.0202
Umbrina roncador	yellowfin croaker	24	0.00163	6.2	481,452	0.0027
Atractoscion nobilis	white seabass	5	0.00029	1.1	173,653	0.0010
All croakers		2076	0.12377	468.5	63,459,637	0.3602
Gobiidae unid.	gobies	2484	0.15156	573.7	56,583,417	0.3212
Engraulidae	anchovies	1209	0.07446	281.9	27,174,509	0.1542
Paralichthys californicus	California halibut	98	0.00640	24.2	2,510,584	0.0142
Hypsoblennius spp.	blennies	166	0.01028	38.9	3,582,757	0.0203
Hypsopsetta guttulata	diamond turbot	87	0.00528	20.0	2,721,559	0.0154
Atherinopsidae	silverside	97	0.00598	22.7	1,827,114	0.0104
39 other taxa + unidentified larvae		682	0.04083	154.5	18,324,667	0.1040
Totals		6899	0.41857	1,584.4	176,184,244	1.0000
Total proportion for fishes with AEL estimates						0.8960

The entrainment estimates in **Table 2** were used to determine the number of equivalent fishes at age-1 using adult equivalent modeling (Goodyear 1978) (**Table 3**). The survival estimates to age-1 were the same values used in modeling for the HBGS and other recent 316(b) studies in the southern California bight. The mean ages at entrainment were determined from the average length of larvae measured during the study and larval growth rates provided in MBC and Tenera (2005). The methods and data used in determining the weight at age-1 are presented in **Table 4**.

Table 3. Results of age-1 equivalent modeling for seven taxa of fishes from HBGS. The mean age at entrainment was determined from the length of the larvae collected from the study and the growth rates used in MBC and Tenera (2005). The data for croakers were combined and the mean age at entrainment determined from the average from four of the species. The survival estimates used to determine the number of age-1 equivalents were also from MBC and Tenera (2005) in addition to more recent studies in the southern California bight.

Taxon	Common Name	Mean Age (d) at Entrainment	AE at age-1	Wt at age-1 (g)	Total Weight (g)	Total Weight (lb)
Croakers						
Roncador stearnsi	spotfin croaker	3.2				
Seriphus politus	queenfish	17.3				
Genyonemus lineatus	white croaker	9.1				
Cheilotrema saturnum	black croaker	3.1				
All croakers		13.2	50	38.94	1,929	4
Gobiidae unid.	gobies	11.6	378,096	0.21	78,165	172
Engraulidae	anchovies	18.3	223,905	14.75	3,302,593	7,281
Paralichthys californicus	California halibut	4.3	7,997	38.50	307,874	679
Hypsoblennius spp.	blennies	3.3	1,496	3.06	4,575	10
Hypsopsetta guttulata	diamond turbot	4.0	8,569	38.50	329,889	727
Atherinopsidae	silversides	6.8	1,687	15.97	26,927	59

Combined Estimates

To combine the estimates from impingement and entrainment, the ages of the fishes collected from the two data sets needed to be adjusted to approximately the same age. The fishes collected during impingement in highest numbers were reported to be young-of-the-year or age-1 (MBC and Tenera 2005) so no AEL adjustments were made to the impingement data. The estimates from the entrainment data for the most abundant fishes were extrapolated to age-1 using AEL (**Table 3**) with weights of these fishes determined from published sources (**Table 4**). These AEL estimates of equivalent age-1 biomass only accounted for 89.6% of the total larvae entrained so the biomass was adjusted to account for the total number of larvae entrained (**Table 5**). This assumes that the remaining taxa include the same proportion of small, forage, and larger fishes as the taxa used in the AEL modeling, but only increased the estimated biomass by approximately 12%. To adjust the entrainment estimate to a value that may be more representative of the long-term average, the adjusted estimate from 2003–2004 was further adjusted using the index value of 3.7 from the long-term impingement data from 2000–2010. The coefficient of variation from the 2000–2010 impingement data was used to calculate an approximate standard deviation for the entrainment estimate and used to calculate an approximate 95% confidence interval for the estimate. The standard deviation for the eleven years of impingement data was also used to calculate a 95% confidence interval for the impingement estimate.

Table 4. Methods and references used in determining weight of age-1 fishes from Table 3.

Common Name	Weight per Age-1 (g)	Method and References
silversides	15.97	Age-1 length = 11 to 12 cm (Clark 1929); W=0.00000886L^3.03574 (L=SL (mm)) (Quast 1968)
CA halibut	38.50	Age 1 = 118.6 male and 146.7252 female TL (Haaker 1975) logW=5.03 - 10 + 3.088 Log SL (Haaker 1975)
northern anchovy	14.75	Methot, R. 1989. Synthetic Estimates of Historical Abundance and Mortality for Northern Anchovy. American Fisheries Society Symposium 6:66-82. mean from Table 2.
goby	0.21	Data for *Clevelandia* age-1 = 28.8 SL W(mg)=.0114*SL^2.918 (Brothers 1975)
blenny	3.06	*H. gilberti* 65-80 mm, *H. gentilis* 45 mm, *H. jenksii* 40 mm. No length-weight relationships used equation for gobies (Stephens et al. 1970)
croakers	39.25	100 mm SL at age-1. Miller et al. 2009. Life history, ecology, and long-term demographics of queenfish.
	38.64	15 cm TL Females = W=0.0109TL^3.0239 Males W=0.0111TL^3.0114. Love et al. 1984.
	38.94	use average from male and female white croaker

Table 5. Combined estimates of annual losses of age-1 fishes due to IM&E at HBGS. Entrainment estimate from 2003–2004 adjusted to long-term average using index of 3.7 from Table 1.

		AE at age-1	Total Biomass (kg)	Total Biomass (lb)	Total Value ($)	Average ($) per lb - 2010 CDF&G Catch Totals
Entrainment	Total age-1 equivalents	621,800	4,052	8,933	3,573	0.41
	Adjusted for proportion to total	697,493	4,545	10,020	4,008	
	Adjusted using impingement index	2,601,648	16,954	37,376	14,951	
	Std. Deviation based on 2000-2010 Impingement CV	3,829,625	24,956	55,018	22,007	
	Approximate upper 95% CI using 2*std.error	4,910,999	32,002	70,553	28,221	
Impingement	Average weight 2000-2010 (lb)			1,060	432	
	Upper 95% CI weight (lb)			2,000	816	
	Average annual heat treatment 2000-2005 weight (lb)			1,626	663	
	Total combined IM&E biomass (lb)			40,062	16,345	
	Upper 95% CI using E+I and average HT (lb)			74,179	30,265	
	Annual Flow @ 253 mgd = 92,345 mg					
	Average $ per mgd				0.18	
	Upper 95% CI $ per mgd				0.33	

The estimated combined IM&E losses totaled 39,876 lbs with an upper estimate of 73,828 lbs. A value of $0.41 per lb from the 2010 CDF&G commercial catch was used to estimate the total value of the losses at $16,269 and $30,122. These estimates are similar to the estimates from the cost-benefit study, after accounting for the differences in the adjustments used in this analysis. The estimate of $0.41 includes landings of both fishes and invertebrates. A recent study on the economic structure of the California commercial fishing industry indicates that every dollar generated from commercial fishing results in an additional $1.8 to $2.1 for the California economy (Hackett et al. 2009). Therefore, a multiplier of 2.8 to 3.1 would need to be used to determine the total economic effects of the IM&E losses.

The range of values for the IM&E losses was then used with the total annual flow of 92,345 mgy to estimate an average lost value of $0.18 to $0.33 per mg. As previously mentioned, these estimates would increase to $0.54 to $1.00 to account for the total economic effects of the losses.

Literature Cited

Goodyear, C.P. 1978. Entrainment impact estimates using the equivalent adult approach. U.S. Fish and Wildlife Ser., FWS/OBS-78/65. Ann Arbor, MI.

Hackett, S. C., D. King, M. D. Hansen, and E. Price. 2009. The economic structure of California's commercial fisheries. A report submitted to California Department of Fish and Game. 87 pp.

MBC Applied Environmental Sciences and Tenera Environmental (MBC and Tenera). 2005. AES Huntington Beach Generating Station entrainment and impingement study final report. Prepared for AES Huntington Beach L.L.C. and California Energy Commission, Sacramento, CA.

Miller, E. F., D. J. Pondella, D. S. Beck, and K. T. Herbinson. 2011. Decadal-scale changes in southern California sciaenids under different levels of harvesting pressure. Journal of Marine Science 68:2123–2133.

Steinbeck, J. R. 2008. Compilation of California coastal power plant entrainment and impingement estimates for California State Water Resources Control Board staff draft issue paper on once-through cooling. Submitted to California State Water Resources Control Board and included as Appendix E in State of California water quality control policy on the use of coastal and estuarine waters for power plant cooling, Final Substitute Environmental Document. May 4, 2010.

Tenera Environmental Services (Tenera). 2000. Diablo Canyon Power Plant 316(b) demonstration report. Tenera Environmental Services, San Francisco.

U.S. Environmental Protection Agency (EPA). 2004. National pollutant discharge elimination system—final regulations to establish requirements for cooling water intake structures at Phase II existing facilities; final rule. Federal Register Vol. 69, No. 131 (Friday, July 9):41,576–41,693.

Attachments

Attachment 1: Cost-Benefit Analysis for Huntington Beach Generating Station.

Attachment 2: Final Agreement for Mitigation for Huntington Beach Generating Station.

Attachment 1: Cost-Benefit Analysis for Huntington Beach Generating Station

Huntington Beach Generating Station Benefit Valuation Study

Final Report, December 2007

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REPORT SUMMARY

The Huntington Beach Generating Station (HBGS) provides reliable generation of electricity in an urban setting. The four generating units produce enough electricity to light nearly one million homes. To help support California's growing energy needs, HBGS recently invested in refurbishing Units 3 and 4 so that they could be returned to service. Thus, the HBGS is a critical component of the southern California power generation strategy and plays an important role in stabilizing the electrical system within Orange County. Moreover, the facility produces 10 percent of the state's peak electricity demand.

HBGS also produces clean power generation through the use of selective catalytic reduction (SCR) technology, which is designed to reduce atmospheric emissions. This technology reduced emission of NO_x by more than 90 percent. AES is also one of the only generators in the state with carbon monoxide reduction catalyst technology in use.

HBGS also contributes to the local economy and the quality of life in Orange County. It provides employment for 50 people and a source of revenue for the City of Huntington Beach.

HBGS is required to comply with 316(b) regulations. This report is a Draft Benefits Valuation Study (BVS) for Huntington Beach Generating Station. The now suspended 316(b) Phase II rule requires a BVS as part of an Alternative 5 Comprehensive Demonstration Study (CDS). The Phase II 316(b) rule addresses impingement mortality and entrainment (I&E) standards for existing power plants that use more than 50 million gallons per day of cooling water. The rule's standards require that facilities reduce impingement mortality by 80 to 95 percent and, if applicable, entrainment by 60 to 90 percent from a calculation baseline. The California State Water Resources Control Board has developed a draft 316(b) policy that is more stringent, requiring a reduction of 90 percent for entrainment and 95 percent for impingement. Under Alternative 5, a determination that the costs of meeting the standards are significantly greater than the benefits indicates that site-specific standards are appropriate. Although the rule has been suspended, the permit under which HBGS operates requires compliance with the Phase II rule.

The BVS quantifies the economic benefits of reducing I&E at HBGS. The annualized (net present value/20) benefits associated with I&E reductions range from $4,719 to $12,700 with a mean estimate of $7,928. The 20-year discounted value of that benefit stream ranges from $94,000 to $254,000 with a mean estimate of $158,600. This distribution of expected benefits is conditional upon the presumption that reducing I&E leads to increases in local fish populations and corresponding increases in expected commercial and recreational catch. The equilibrium expected change in recreational catch is 543 fish per year. The equilibrium expected change in commercial harvest is 80 pounds per year. The remainder of the document describes the specific methodology, analysis, and data used to estimate the benefits of reducing I&E.

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1 INTRODUCTION

The Huntington Beach Generating Station (HBGS) provides reliable generation of electricity in an urban setting. The four generating units produce enough electricity to light nearly one million homes. To help support California's growing energy needs, HBGS recently invested in refurbishing Units 3 and 4 so that they could be returned to service. Thus, the HBGS is a critical component of the southern California power generation strategy and plays an important role in stabilizing the electrical system within Orange County. Moreover, the facility produces 10 percent of the state's peak electricity demand. HBGS also contributes to the local economy and the quality of life in Orange County. It provides employment for 50 people and a source of revenue for the City of Huntington Beach.

HBGS also produces clean power generation through the use of selective catalytic reduction (SCR) technology, which is designed to reduce atmospheric emissions. This technology reduced emission of NO_x by more than 90 percent. AES is also one of the only generators in the state with carbon monoxide reduction catalyst technology in use.

In the course of its normal operation, HBGS withdraws ocean water through a cooling water intake structure (CWIS). CWISs are regulated under Section 316(b) of the Clean Water Act (CWA). This statute directs the EPA to ensure that the location, design, construction and capacity of CWIS reflect the best technology available (BTA) for minimizing adverse environmental impacts (AEI). EPA developed national technology standards in three phases. The Phase II Rule generally applies to existing electric generating plants with significant cooling water intake capacity. It requires that these plants reduce impingement mortality and entrainment (I&E) of aquatic organisms according to national standards.[1] The rule's standards require that facilities reduce impingement mortality by 80 to 95 percent and, if applicable, entrainment by 60 to 90 percent from a calculation baseline. The California State Water Resources Control Board has developed a draft 316(b) policy that is more stringent, requiring a reduction of 90 percent for entrainment and 95 percent for impingement.

On January 25, 2007 the Second Circuit Court of Appeals released a ruling that disallowed many significant components of the EPA's Phase II § 316(b) rule for cooling water intake structures (*Riverkeeper et al. v. U.S. Environmental Protection Agency*). In response to the Second Circuit Court ruling, EPA has suspended the Phase II Rule and directed that all permits for Phase II facilities be considered on a Best Professional Judgment basis as described at 40 *CFR* § 401.14 (Grumbles 2007; 72 *Federal Register* 37107).

[1] Impingement occurs when fish and aquatic species become trapped on equipment at the entrance of the cooling system. Entrainment occurs when aquatic organisms, eggs, and larvae are taken into the cooling system, through the heat exchangers, and discharged back into the waterbody.

Introduction

Because the permit for HBGS requires that it comply with the Phase II rule, this assessment reflects the Phase II rule with California reduction requirements. The rule provides five specific compliance alternatives to achieve these standards. Alternative 5, a demonstration that a site-specific determination of BTA is appropriate (EPA 2004a, p. 41,593), allows site-specific standards based on cost and benefit analyses (e.g., the cost-cost test and the cost-benefit test [EPA 2004a, p.41, 503–41,604]). Specifically, if the costs of meeting the performance standards are significantly greater than the corresponding benefits, then the plant can qualify for alternative performance standards. Making and supporting such a determination requires conducting a sound benefit-cost analysis.[2] It also entails identifying what constitutes costs of I&E reductions being significantly greater than the corresponding benefits. This report contains a benefit-cost analysis for the Huntington Beach Generating Station (HBGS) and serves as the plant's Benefit Valuation Study (BVS)—one of the regulatory submittals required as part of an Alternative 5 Comprehensive Demonstration Study (CDS).

Overview of Results

The benefit estimates in this assessment reflect the current I&E estimates provided by Applied Environmental Sciences and Tenera Environmental (2007). The organisms analyzed by MBC and Tenera are limited to those that were sufficiently abundant to provide a reasonable assessment of impacts. Specifically, the I&E estimates reflect the most abundant fish taxa that together comprised 90 percent of all larvae entrained and/or juveniles and adults impinged at HBGS. Moreover, the benefit estimates reflect the benefits of complying with the performance standards. Based on the existing technology at HBGS, compliance with the impingement mortality standard requires a 13 percent reduction in impingement for all units at HBGS. Compliance with the entrainment standard requires a 90 percent reduction in entrainment for Units 1 and 2 at HBGS.

The annualized (NPV/20) benefits associated with I&E reductions range from $4,719 to $12,700 with a mean estimate of $7,928. The 20-year discounted value of that benefit stream ranges from $94,000 to $254,000 with a mean estimate of $158,600. This distribution of expected benefits is conditional upon the presumption that reducing I&E leads to increases in local fish populations and corresponding increases in expected commercial and recreational catch. The equilibrium expected change in recreational catch is 543 fish per year. The equilibrium expected change in commercial harvest is 80 pounds per year. In addition, this distribution of expected benefits recognizes that nonuse benefits do not need to be quantified because HBGS's I&E does not cause "substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function" in the coastal waters near HBGS (EPA 2004a, p. 41,648).

Organization of the Report

Section 2 presents an overview of the methodology used for the analysis. Section 3 discusses the recreational and commercial fisheries. Section 4 describes the I&E data on which the benefit estimates are based and the approaches used to estimate the fishery impacts and the forgone

[2] Appendix A contains a discussion of benefit-cost analysis.

fishery harvests. Section 5 provides a conceptual overview of valuing use and nonuse benefits. Section 6 details the calculation of economic benefits from reducing I&E at the Huntington Beach Generating Station.

2
OVERVIEW OF METHODOLOGY FOR BENEFIT VALUATION

This section presents an overview of the methodology for estimating the economic benefits associated with reducing I&E at HBGS. The benefit-estimation methodology uses a *site-calibrated benefits transfer* based on dynamic population modeling, site-specific application of an existing random utility model (RUM) of recreational angling demand, species-specific consideration of the relevant commercial fisheries, and qualitative evaluation of the potential nonuse benefits associated with I&E reductions.[3] With respect to quantifying uncertainty, the methodology uses a scientific analysis of uncertainty, where uncertainty in catch changes is based on equilibrium concepts of dynamic modeling and uncertainty in the value of those catch changes is determined based on coefficients from transferred methods.[4]

Figure 2-1 provides an overview of the methodology for evaluating the economic benefits of reducing I&E. Each step depicted in the figure is summarized below.

[3] By calibrated benefits transfer, we mean that an already estimated equation is transferred to the policy context and then tailored to the affected population and resource.
[4] By "scientific analysis of uncertainty" we mean that the degree of uncertainty can be quantified in a manner that allows formulation and testing of statistical hypotheses.

Overview of Methodology for Benefit Valuation

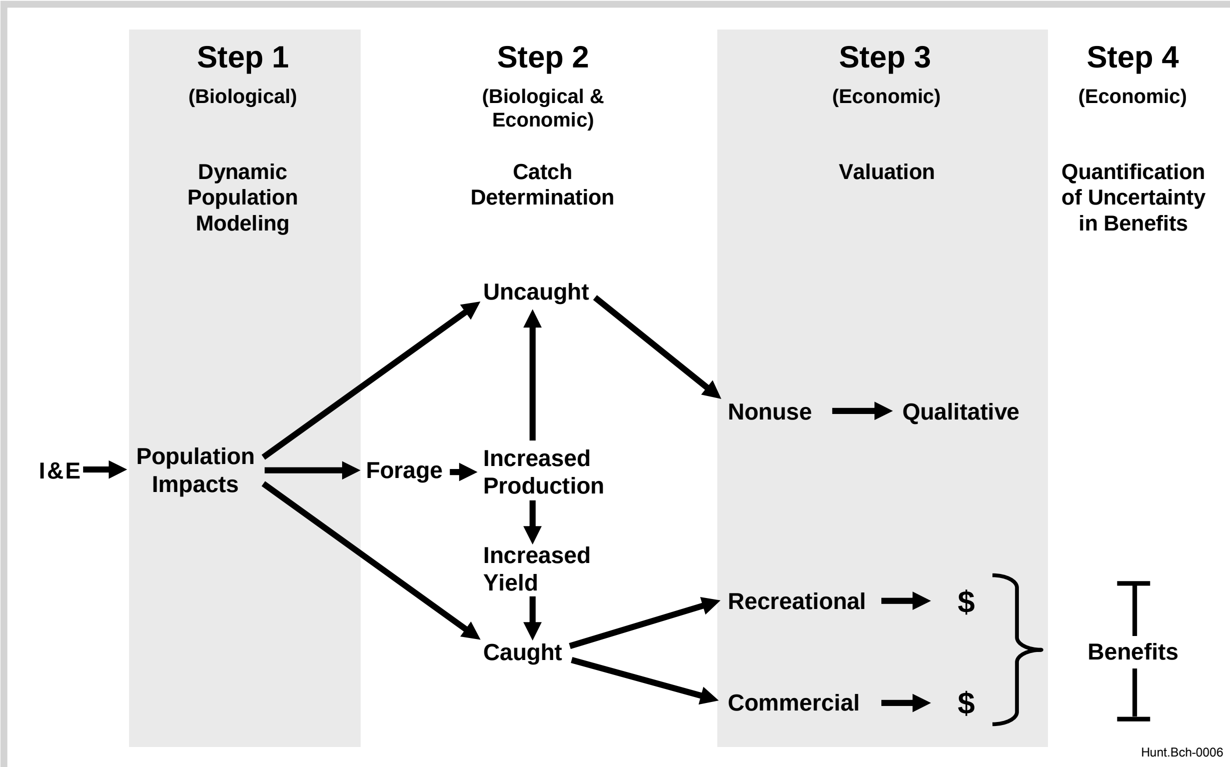


Figure 2-1
Overview of Methodology for Estimating the Benefits of I&E Reductions

Step 1: Develop Dynamic Population Models

Step 1 involves developing dynamic population models from the HBGS impingement and entrainment data. The methodology uses the best available information on life stages, natural and fishing mortality rates, and fecundity to develop population increases for the I&E species. The methodology follows Leslie (1945) and is widely used by fishery managers. Section 4 presents a detailed description of this methodology as well as the results of applying it to HBGS's I&E data.

Step 2: Catch Determination

In this step, the methodology entails determining forgone yield, production, and species categorization (i.e., the percentage of impinged and entrained organisms that would have been caught, uncaught, or are forage). The determination of harvested versus forage species is based on the best available information, including consultation with local fishery experts, EPA's regional case study for California (2004b), and local catch data. Step 2 uses calibrated natural and fishing mortality parameters to determine the forgone yield and forgone production for each species.

As Step 2 shows, the methodology relates reductions in forage species to the increased production of uncaught fish as well as the increased production and yield of caught fish. Section 4 contains a detailed description of the methodology along with the results of its application.

Step 3: Determine the Value of Fish Produced as a Result of I&E Reductions

After completing Steps 1 and 2, the methodology values the additional fish production that would be achieved through I&E reductions. There are three categories of benefits that result from reducing a plant's I&E: recreational, commercial, and potential nonuse benefits.

As part of this step, the methodology determines which species are recreational versus commercial. This determination is based on the best available information, including consultation with local fishery experts, recreational breakdowns employed in EPA's Regional Study, and local creel/harvest data. The methods for assessing each benefit category are summarized below. Section 5 describes the economic concepts that underlie estimating each benefit category, and Section 6 presents the specific methodology and estimates for each benefit category.

Step 3a: Recreational Benefits

Correctly calculating recreational benefits requires a significant amount of information and calculations. The calculations are based on a simulation of angler behavior and changes in social welfare resulting from reductions in I&E and the associated increases in expected catch. Important factors that should be accounted for include the number and quality of substitute fishing sites, the geographic range of impacted species, the number of trips with improved catch rates, and the number of anglers associated with those trips.

Random utility analysis is the best method for valuing I&E reductions on recreational fishing.[5] However, conducting an original random utility model (RUM) study can require extensive primary data collection. A site-calibrated transfer of an existing RUM study can capture important behavioral responses (i.e., changes in trip-taking behavior as a result of changes to a fishery) without requiring survey-data collection. The accuracy of this methodology is limited only by the analyst's ability to calibrate an already estimated preference function to a different population using appropriate economic methodologies (Smith, van Houtven, and Pattanayak 2002). Section 5 describes the economic concepts underlying the relationship between I&E reductions and estimating the recreational benefits associated with those reductions. Section 6 describes the site-calibrated RUM used to estimate the recreational benefits associated with HBGS's I&E reductions.

Step 3b: Commercial Benefits

Commercial benefits from I&E reductions accrue to commercial fishermen as increased profit attributable to the higher catch per unit effort (CPUE) associated with increases in fish populations and/or to fish consumers in the form of lower prices. The ability of commercial fishermen to realize *sustained* increased profits depends on the responsiveness of market prices to higher CPUE. Market extremes determine the upper and lower bounds on commercial

[5] RUMs are recognized in the Department of the Interior (DOI) regulations (43 *CFR* §11.83) as an appropriate method for quantifying recreation service losses in natural resource damage claims. Currently, the RUM is the most widely used model for quantifying and valuing natural resource services. RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985), as well as more recently in environmental and resource economics.

benefits. In competitive markets, prices adjust instantly and benefits accrue to consumers. In restricted markets, prices do not change and commercial benefits are maximized in the form of producer surplus at price times quantity (P * Q). Estimating the commercial benefits of I&E reductions involves consideration of the fishery's relevant market conditions. Section 5 describes the economic concepts underlying the relationship between I&E reductions and changes in commercial fishing benefits for alternative market conditions. Section 6 describes the market conditions for the species associated with the HBGS I&E impacts and presents the methods and results associated with evaluating changes to the fishery resulting from I&E reductions at the HBGS.

Step 3c: Nonuse Benefits

Uncaught recreational fish and forage fish do not have a traditional use value and are therefore categorized as having potential nonuse value. Nonuse values are the values that people may hold for a resource independent of their use of the resource. That is, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist.

The 316(b) rule requires that the benefits assessment consider the nonuse benefits associated with reductions in I&E (§ 125.95(b)(6)(ii)). Currently, the only methods available for estimating nonuse values are survey-based techniques that ask respondents to value, choose, rate, or rank natural resource services in a hypothetical context. The reliability of this approach for evaluating nonuse impacts is questionable. For example, because of conceptual and empirical challenges associated with measuring nonuse values, which are further described in Appendix B, the EPA decided in the final rule that "…none of the available methods for estimating either use or nonuse values of ecological resources is perfectly accurate; all have shortcomings" (EPA 2004a, p. 41,624). More importantly, EPA determined that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004a, p. 41,624).

Therefore, for assessing the nonuse benefits of I&E reduction at an individual facility, the rule states the following:

> When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information (EPA 2004a, p. 41,648).

Specifically, the rule directs that nonuse benefits should be monetized "in cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function in a facility's waterbody or watershed" (EPA 2004a, p. 41,648). Otherwise, monetization is unnecessary and the analysis should contain a qualitative assessment of nonuse benefits.

Section 5 contains a detailed description of the economic concepts underlying the relationship between reductions in I&E and assessing the nonuse benefits associated with those reductions.

Section 6 then presents the rationale for conducting a qualitative evaluation of HBGS's nonuse benefits and presents the results of that evaluation.

Step 4: Quantify Uncertainty in Benefits

As part of conducting a cost-benefit analysis, the rule requires that a benefits assessment include uncertainty analysis but does not specify methods (see EPA 2004a, p. 41,647). In statistical analysis, the term *uncertainty* refers to the quantifiable imprecision in estimates. Benefit estimates are most useful when uncertainty is quantified and its causes are clearly identified.

As recommended by EPA, Step 4 uses a Monte Carlo analysis to quantify the effects of uncertainty on benefits. The Monte Carlo analysis combines uncertainty in input parameters with the benefits-estimation model to quantify uncertainty in 316(b) compliance benefits. The approach takes specified distributions for each variable input, randomly selects a value from each distribution, and then combines the estimates. The resulting combination of the various inputs creates an estimate of compliance benefits. Section 6 contains a detailed explanation of Step 4 and presents its analysis and results.

3

RECREATIONAL AND COMMERCIAL FISHERIES

AES Huntington Beach L.L.C. Generating Station (HBGS) lies within the southeastern portion of the City of Huntington Beach at 21730 Newland Street (Figure 3-1) in the coastal part of Orange County, California. HBGS draws cooling water from the Pacific Ocean through an intake structure located about 1,500 feet offshore (MBC and Tenera 2007).

Figure 3-1
Location of the Huntington Beach Generating Station

Recreational and Commercial Fisheries

More than 3 million people live in Orange County: of those, more than 195,000 live in Huntington Beach. Cities located within 20 miles of Huntington Beach include Anaheim (population 332,000), Long Beach (population 475,000), Newport Beach (population 78,000), and Santa Ana (population 343,000) (City of Huntington Beach 2006; U.S. Census Bureau 2007a).

The Huntington Beach Generating Station is located just across Pacific Coast Highway (inland) from the Huntington State Beach, and the intake and discharge structures for the generating station are just offshore the state beach. The state beach is a little over two miles in length, extending north from the Santa Ana River mouth past the generating station to Beach Boulevard. At Beach Boulevard, the state beach borders the Huntington City Beach. Over 11 million people visit the beaches of Huntington Beach annually.

The Orange County Health Care Agency and its Ocean Water Protection Program test bacteriological samples and review the results daily for the presence of disease-causing organisms. Ocean and bay water closures, postings, and health advisories are issued as conditions warrant. Portions of Huntington Harbour, Huntington City Beach, and Huntington State Beach have been closed to body-contact recreation when sewage spills and leaks occur (Orange County Health Care Agency 2007; California Regional Water Quality Control Board, Santa Ana Region 2002).

Fishery research has demonstrated that some fishery stocks can fluctuate independently of the generating station operations. One recent case is that of white seabass (*Atractoscion nobilis*) a highly prized gamefish that once supported a large recreational and commercial fishery (Allen et al. 2007). White seabass is the largest resident sciaenid (croaker/drum) within the Southern California Bight, and as such, it functions as a higher trophic level predator within the nearshore ecosystem. Much of its diet consists of queenfish, white croaker, anchovies, Pacific sardines, and California market squid (Cailliet et al. 2000). I&E at HBGS have the potential to constrain white seabass populations directly through entrainment (impingement), or indirectly through entrainment (impingement) of common prey species. Both instances have been documented at HBGS. MBC and Tenera (2007) reported that an estimated 347,306 white seabass larvae were entrained and an additional 60 individuals were impinged.

Allen et al. (2007) observed that both recreational and commercial landings had declined precipitously since the 1970s. Commercial catch generally fluctuated between 100 and 400 metric tons (mt) for most of the 20^{th} century, but declined to 10 percent or less of the historic catch from 1980 on. Similar patterns were seen in recreational landings, which declined from a peak of 0.13 fish per angler in 1949 to 0.001 fish per angler in 1978. In 1994, the California Department of Fish and Game enacted a nearshore commercial gillnet ban, effectively removing the majority of commercial fishing pressure from the adult spawning aggregation sites. This, in conjunction with strong recruitment classes in 1994 and 1998, sparked resurgence in the white seabass population levels. Despite the increased commercial restrictions, both commercial and recreational landings returned to near historic levels. In 2002, the commercial fishery landed approximately 219 mt. More importantly, the recreational fishery landed an estimated 360 mt in 2001. It should be noted that the recreational fishery, unlike the commercial fishery, is still permitted to fish adult spawning aggregation sites.

Mean daily cooling water flow at HBGS declined from a peak of more than 90 percent in 1982 to less than 40 percent from 1987–2001, coinciding with much of the period of depressed white seabass stocks. From 2002–2005, mean daily cooling water flow at HBGS has been greater than 50 percent. In this analysis, it is assumed that I&E were proportional to cooling water flow throughout this period. Based on these data, if I&E acted as a constraining factor on white seabass populations, a reciprocal increase in the white seabass population parameters would be expected in relation to flow levels. No evidence exists to support this. The data show, however, that white seabass populations fluctuated relatively independently of HBGS operations. Commercial landings have fluctuated between approximately 150 and 250 mt annually from 2001–2005, a period of increased operation at HBGS (Allen et al. 2007). Recreational landings have declined since their peak in 2001, although this may relate to overfishing. Allen et al. (2007) reported that while landings for commercial and recreational fisheries in 2002 were both approximately 220 mt, the mean length for commercially landed white seabass was substantially larger than that of recreational catches. This indicates that the recreational fishery harvested substantially more individuals, potentially from spawning aggregation sites.

The empirical data concerning the white seabass fishery suggest that while they were subject to I&E, as were their prey species, their populations fluctuated independently of plant operations. The resource, and its associated economic products, would largely feel no effect of modifications to the HBGS cooling water system. The following text provides detailed information on the recreational and commercial fisheries.

Recreational Fishery

The California Fish and Game Commission (1998) notes the richness and diversity of California's marine life, stating that "[t]housands of species of marine plants, crustaceans, mollusks, other invertebrates, fish, seabirds, and marine mammals use an astonishing diversity of habitats." At least 30 public fishing piers in southern California provide opportunities for anglers to land popular game fish from ocean waters. Additionally, shore-based fishing is popular from public access points, and boat ramps provide opportunities for boat anglers.

About 300 varieties of fish and shellfish are native to California (California Seafood Council 1997). Table 3-1 lists many of the fish and invertebrates inhabiting the Pacific Ocean off the coast of Huntington Beach. None of these species are included on the U.S. Fish and Wildlife Service's (USFWS's) or California's listings of endangered and threatened species (USFWS 2007; California Department of Fish and Game (DFG) 2006a).

Recreational and Commercial Fisheries

Table 3-1
Fish and Invertebrates Inhabiting the Pacific Ocean off Huntington Beach

Fish of the Pacific Ocean at Huntington Beach			
Arrow goby	Combfishes	Pacific butterfish	Shield-backed kelp crab
Barred sand bass	Deepbody anchovy	Pacific electric ray	Shiner perch
Barred surfperch	Diamond turbot	Pacific hake	Shovelnose guitarfish
Basketweave cusk-eel	English sole	Pacific littleneck	Smoothhead sculpin
Bat ray	Fantail sole	Pacific mackerel	Spanish shawl
Bay ghost shrimp	Garibaldi	Pacific rock crab	Speckled sanddab
Bay goby	Giant kelpfish	Pacific sanddab	Specklefin midshipman
Bay pipefish	Giant sea bass	Pacific sardine	Spiny brittlestar
Bigmouth sole	Graceful rock crab	Pacific staghorn sculpin	Spotfin croaker
Black croaker	Grass rockfish	Painted greenling	Spotted cusk-eel
Black perch	Halfmoon	Pile perch	Spotted sand bass
Black surfperch	Horn shark	Plainfin midshipman	Spotted turbot
Blackeye goby	Hornyhead turbot	Pubescent porcelain crab	Striped shore crab
Blacksmith	Jack mackerel	Purple-striped jelly	Stubby dendronotus
Blackspotted bay shrimp	Jacksmelt	Pygmy poacher	Thick-clawed porcelain crab
Blind goby	Jellyfish	Queenfish	Thornback
Blue rockfish	Innkeeper worm	Red rock crab	Topsmelt
Bocaccio	Intertidal coastal shrimp	Red rock shrimp	Tube blennies
Brown rockfish	Kelp bass	Ribbon worm	Tuberculate pear crab
Cabezon	Kelp blennies	Ridgeback rock shrimp	Tubesnout
California aglaja	Kelp greenling	Rock wrasse	Turbot
California barracuda	Kelp pipefish	Rockpool blenny	Two-spotted octopus
California clingfish	Labrisomid blennies	Roughcheek sculpin	Vermillion rockfish
California corbina	Leopard shark	Round herring	Walleye surfperch
California grunion	Longjaw mudsucker	Round stingray	Warty sea cucumber
California halibut	Market squid	Rubberlip seaperch	White croaker
California headlightfish	Masking crab	Sanddab	White seabass
California lizardfish	Mexican lampfish	Salema	White seaperch
California needlefish	Mussel blenny	Salp	Xantus swimming crab
California petricola	Northern anchovy	Sand crab	Yellow rock crab
California sheephead	Northern lampfish	Sargo	Yellow shore crab
California scorpionfish	Nudibranch	Sea star	Yellow snake eel
California spiny lobster	Ochre starfish	Senorita	Yellowfin croaker
California tonguefish	Olive rockfish	Shadow goby	Yellowfin goby
Cheekspot goby	Opaleye	Sheep crab	Yellowleg shrimp
Chub mackerel	Pacific barracuda		

Source: MBC Applied Environmental Sciences and Tenera Environmental (2007)

California offers angler recognition programs for ocean fishing, as described below. The angler recognition programs for ocean fishing records comprise both angling and diving categories.

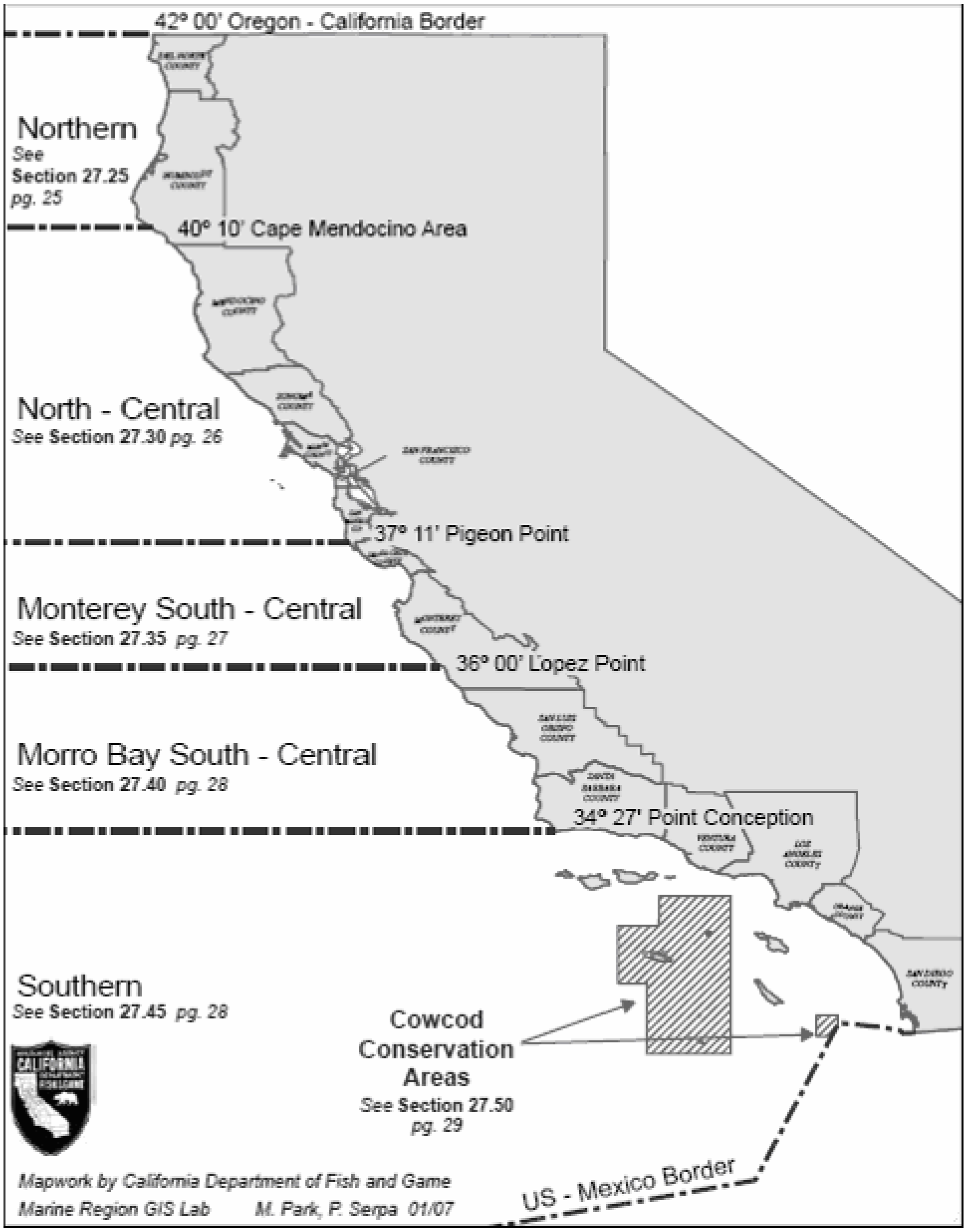
- Ocean Fishing Record Program—A diver or angler catching a state-record fish must land the fish/shellfish unaided. The fish must be weighed on a scale certified by a government agency and in the presence of two witnesses unknown to the angler or diver. A biologist must identify the catch (California DFG, Marine Region 2007a).
- California Fishing Passport Program—The passport lists 150 different species of freshwater and saltwater finfish and shellfish that inhabit waters throughout California. Participating anglers catch and document all of the different species listed, receiving a stamp for each one (California DFG 2007a).

Huntington Beach offers an attractive venue for fishing tournaments. For example, the largest surf fishing tournament ever held on the Pacific Coast—Albackore's Gulp! Only West Coast Fall Surf Slam—took place on Saturday, October 7, 2006 at Huntington Beach. More than 300 anglers participated. On April 14, 2007, the Albackore Sportfishing Gear Spring Surf Slam fishing tournament was held at Huntington Beach. That tournament featured catch-and-release fishing for surfperch, croaker, and halibut. On August 25, 2007, the Huck Finn Fishing Derby for children was held at Huntington Beach (Jackson 2006; Huntington Beach Events.com 2007).

California grunion provides a unique recreational fishery near Huntington Beach and other California beaches from Point Conception south. For two to six nights after the full and new moons during the spring and summer months, grunion leave the water at night to spawn on the beach. Spawning begins after high tide and continues for several hours. Grunion may be taken by sport fishers (with a valid fishing license) using their hands only (Stockteam.com 2007).

The California Fish and Game Commission and the Pacific Fishery Management Council have established six groundfish management areas in California's ocean waters, each with a different set of regulations tailored to meet regional needs. Groundfish include all species of rockfish, cabezon, and greenlings; lingcod; leopard shark; Pacific sanddab; ocean whitefish; California sheephead; California scorpionfish; and federal groundfish: rock sole, sand sole, butter sole, curlfin sole, rex sole, and flathead sole, dover sole, English sole, petrale sole, arrowtooth flounder, starry flounder, spiny dogfish, soupfin shark, big skate, California skate, longnose skate, ratfish, rattail, codling, Pacific cod, Pacific whiting, sablefish, and thornyheads. The Southern Management Area includes Huntington Beach and substitute fishing sites in California' ocean waters (Figure 3-2). See Appendix C for a summary of the recreational groundfish regulations for 2007 in the Southern Management Area (California DFG, Marine Region 2007b).

Recreational and Commercial Fisheries



Source: California DFG, Marine Region (2007b)

Figure 3-2
Groundfish Management Areas in the Pacific Ocean off the California Coast

This figure shows that the ocean waters near Huntington Beach and substitute saltwater fishing sites are located in the Southern Management Area.

Substitute Fishing Sites

The value of any particular fishery impact is related to both the level of the impact and the quality of available substitute sites. Anglers can choose from many other sites near Huntington Beach when they want to fish in saltwater. Attractive substitute sites provide opportunities for saltwater fishing and other recreation, such as:

- Dana Point, where anglers can fish from a pier, launch a boat, or take a fishing charter. Anglers can catch California halibut, corbina, diamond turbot, jacksmelt, opaleye, croaker; spotted sand bass, and many other fish. State-record corbina and yellowfin croaker have been landed from Dana Point Harbor (Jones undated).
- Long Beach, where anglers can fish from a pier, launch a boat, or take a fishing charter, whale watching tour, or harbor tour. Anglers can catch barracuda, bocaccio, bonito, calico and sand bass, queenfish, rockfish, sculpin, yellowtail, and many other fish. An angler caught a state-record pile perch on February 26, 2007 at Long Beach (Sportfishingreport.com 2007; California DFG, Marine Region 2007a).
- Marina del Rey, where anglers can participate in fishing derbies; take a fishing charter, cruise, or whale-watching tour; or enjoy one of the many special events. Marina del Rey has the largest marina on the West Coast. Anglers can catch barracuda, calico and sand bass, dorado, halibut, marlin, rockfish, and many other fish at Marina del Rey (Los Angeles County Department of Beaches and Harbors undated).
- San Diego Bay, where anglers can enjoy fishing, boating, charters, and adjacent parks. Anglers can catch albacore; bluefin, big-eyed, and skipjack tuna; barracuda; bat ray; bonito; calico bass; California corbina; flounder; halibut; shark; and many other fish. Anglers caught state-record thresher shark and skipjack tuna from San Diego Bay (California DFG, Marine Region 2007a; San Diego Sportfishing Council undated).

Table 3-2 compares Huntington Beach and other saltwater fishing sites. See Appendix C for a list of additional saltwater fishing sites near Huntington Beach. Appendix C also lists site characteristics for Huntington Beach and the additional sites.

Table 3-2
Comparison of Huntington Beach and Other Fishing Sites

Water Bodies	Saltwater Bass	Bonito	Corbina	Halibut	Shark	Tuna	Boat Ramp(s)	Noteworthy Facts
Saltwater								
Huntington Beach	•	•	•	•	•	•	•	Adjoins Huntington Beach State Park and Bolsa Chica Ecological Reserve. Anglers caught state-record jack mackerel and bat ray at Huntington Beach.
Dana Point	•	•	•	•	•		•	Anglers caught state-record corbina and yellowfin croaker at Dana Point Harbor.
Long Beach	•	•	•	•			•	Angler caught state-record pile perch on February 26, 2007.
Marina del Rey	•			•		•	•	Largest marina on the West Coast; WaterBus during the summer; near Aubrey Austin, Chace, and Admiralty Parks and North Jetty Walkway.
San Diego Bay	•	•	•	•	•	•	•	Anglers caught state-record thresher shark and skipjack tuna from San Diego Bay.

Sources: DeLorme (2005); Jones (undated); Sportfishingreport.com (2007); California DFG, Marine Region (2007a); Los Angeles County Department of Beaches and Harbors (undated); San Diego Sportfishing Council (undated)

Recreational and Commercial Fisheries

No fish consumption advisories based on chemicals have been issued for Huntington Beach or for substitute fishing sites at Santa Monica Pier, Venice Pier, Venice Beach, Marina del Rey, Redondo Beach, Emma/Eva oil platforms, Laguna Beach, Fourteen Mile Bank, Catalina (Twin Harbor), and Dana Point. Consumption advisories for some species of sport fish have been issued for substitute fishing sites in ocean waters because of elevated DDT and PCB levels, as listed in Table 3-3 (California DFG 2007b).

Table 3-3
Fish-Consumption Advisories for Southern California Coastal Waters

Site	Fish	One Meal[a] Every Two Weeks	One Meal a Month	Do Not Consume
Point Dume/Malibu offshore	White croaker			•
Malibu Pier	Queenfish		•	
Short Bank	White croaker	•		
Redondo Pier	Corbina	•		
Point Vicente Palos Verdes—Northwest	White croaker			•
White's Point	Kelp bass	•[b]		
	Rockfishes	•[b]		
	Sculpin	•[b]		
	White croaker			•
Los Angeles/Long Beach harbors, especially Cabrillo Pier	Black croaker	•[b]		
	Queenfish	•[b]		
	Surfperches	•[b]		
	White croaker			•
Los Angeles/Long Beach breakwater (ocean side)	Black croaker		•[b]	
	Queenfish		•[b]	
	Surfperches		•[b]	
	White croaker		•[b]	
Belmont Pier Pier J	Surfperches	•		
Horseshoe Kelp	Sculpin		•[b]	
	White croaker		•[b]	
Newport Pier	Corbina	•		

[a] A meal for a 150-pound adult is about 6 ounces. Calculate 1 ounce of consumption for each 20 pounds of body weight (Office of Environmental Health Hazard Assessment 2003).

[b] Consumption recommendation applies to all listed species combined at the site (Office of Environmental Health Hazard Assessment 2003).

Additionally, the Office of Environmental Health Hazard Assessment (OEHHA) provides general guidance for fish consumption (2003). The general advisories caution consumers to eat smaller fish of legal size rather than large fish, which are likely to have higher levels of contaminants. Mussels are quarantined from May 1 through October 30 in California and should not be eaten.

OEHHA also refers consumers to the U.S. EPA (2007) advisory for women who are pregnant or might become pregnant, nursing mothers, and young children. The EPA advisory cautions them not to eat shark, swordfish, king mackerel, or tilefish because those fish contain high levels of mercury.

Angler Characteristics

Recreational fishing values are related to the number and characteristics of anglers in the recreational market. Recreational anglers need no license to fish from California piers or during the two free fishing days offered annually, when all other fishing regulations still apply. During 2007, California's free fishing days were June 9 and September 22 (California DFG 2007c; California DFG, Marine Region 2007b).

Otherwise, recreational anglers aged 16 or older must have a basic fishing license to take any kind of fish, mollusk, invertebrate, amphibian, or crustacean from California waters. The license is valid for the calendar year. A basic fishing license also entitles an angler to fish in the ocean north of Point Arguello, Santa Barbara County. Besides the basic fishing license, anglers fishing in the Huntington Beach area or at substitute sites may also need:

- An Ocean Enhancement Stamp for ocean fishing south of Point Arguello, except when fishing under the authority of a one- or two-day sport fishing license
- A Steelhead Fishing Report and Restoration Card when fishing for steelhead in anadromous waters
- A Sturgeon Fishing Report Card when fishing for sturgeon (California DFG 2007c; California DFG, Marine Region 2007b).

The USFWS conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation every five years. Among other information, the survey collects data on anglers and the types of fish that they catch. We use data from the 2001 survey (updated during 2003) because it is the most recent survey with complete data. Table 3-4 estimates the number of anglers who fished during 2001 as summarized in the report for California (USFWS 2003).[6]

Table 3-4
Estimates of Fishing in California during 2001

Category	California
Number of residents who fished during 2001	2.389 million
Percentage of residents who fished during 2001	7.05%[a]

[a]Anglers may fish from public fishing piers in California without a license.

Source: USFWS (2003)

[6] During 2001, 6.51 percent of Californians bought a fishing license (2,206,382 of 33,871,648 residents) (American Sportfishing Association 2007; U.S. Census Bureau 2007b).

Recreational and Commercial Fisheries

The USFWS reports statistics on fishing in saltwater separately from fishing in freshwater bodies.[7] Table 3-5 summarizes the number of anglers and days spent fishing in California water bodies during 2001. Table 3-6 lists the estimated days that anglers fished for selected species in California water bodies during 2001 (USFWS 2003).

Table 3-5
Fishing Reported in California during 2001

Category	Saltwater	Freshwater
Number of anglers	0.932 million	1.877 million
Days spent fishing	8.371 million	19.685 million
Average number of fishing days per angler	9 days	11 days

Source: USFWS (2003)

Table 3-6
Estimated Days that Anglers Fished for Selected Species in California Water Bodies during 2001

Species	Number of Days Spent Fishing in Saltwater Bodies (in thousands)	Number of Days Spent Fishing in Freshwater Bodies (in thousands)
Trout	—	9,901
Black bass	—	4,121
Salmon	833	3,735
Striped bass	3,552	—
Other saltwater fish	2,964	—
White bass, striped bass, striped bass hybrids	—	2,945
Catfish, bullheads	—	2,918
Any kind of fish	2,138	1,909
Crappie	—	1,076
Flatfish (flounder, halibut)	1,013	—
Panfish	—	998
Other freshwater fish	—	714
Mackerel	434	—
Shellfish	379	—

Source: USFWS (2003). Note that anglers could list more than one species.

[7] See Appendix D for regulations and opportunities related to freshwater fishing near Huntington Beach.

Commercial Fishery

The California Fish and Game Code, Division 6, Part 3, Sections 7600–14105 and Title 14, California Code of Regulations govern commercial fishing in California waters. Federal regulations affect coastal pelagic species (jack mackerel, market squid, northern anchovy, Pacific mackerel, and Pacific sardine), groundfish, highly migratory species, and salmon. Tribal fishing does not affect the coastal waters near Huntington Beach (National Marine Fisheries Service [NMFS] Northwest Regional Office 2007a, 2007b; NMFS Southwest Regional Office 2007a, 2007b).

The California DFG requires licenses for all commercial fishermen and fishing vessels. In 2007, there were nearly 5,000 licensed commercial fishermen in the state and over 3,000 registered commercial vessels (California DFG 2007d). California DFG also issues permits to take certain species of fish or use certain gear types for commercial purposes. For example, the Department issues ocean enhancement stamps (required for landing white seabass south of Point Arguello) and commercial fishing salmon stamps (required when taking salmon commercially).

A commercial fishing license issued in California may contain provisions that

- establish the amount and size of species that may be taken
- designate the areas where the licensee is permitted to fish
- specify the season and the depths where the licensee may fish commercially
- specify the methods and gear that the licensee may use
- specify other terms, conditions, and restrictions.

Additionally the California DFG designates several fisheries as limited entry/restricted access fisheries. These determinations are based on extant fish populations as well as the pressure they receive. Those that are dwindling are restricted, with some permits being transferable and others non-transferable. Table 3-7 lists California's limited entry/restricted access fisheries.

California's coastal waters are divided into commercial fishing districts 6–20 (Figure 3-3). The coastal waters near Huntington Beach are part of District 19B (California DFG 2007a, 2007f). However, I&E impacts from HBGS may also affect commercial species in the other portions of the larger District 19.

Recreational and Commercial Fisheries

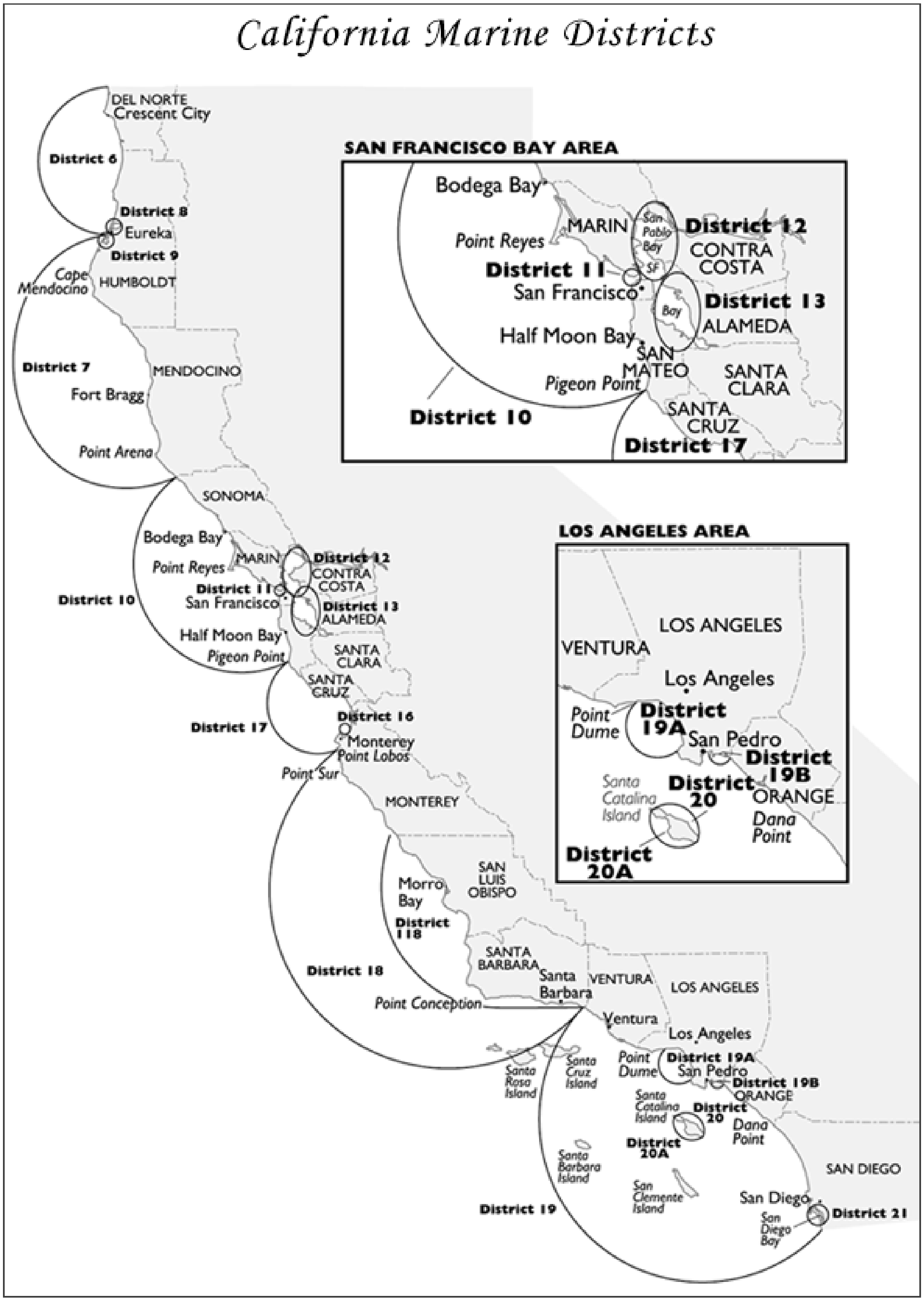
Table 3-7
Limited Entry/Restricted Access Fisheries of California

Type of Limited Entry/Restricted Access	Transferable	Non-Transferable
Herring Stamp		
Lobster Operator		
Market Squid Vessel	•	
Market Squid Vessel		•
Market Squid Brail	•	
Market Squid Brail		•
Market Squid Light Boat	•	
Market Squid Light Boat		•
Nearshore Fishery Permits		
North Coast Region	•	•
North-Central Coast Region	•	•
South-Central Coast Region	•	•
South Coast Region	•	•
Nearshore Fishery Trap Endorsements		
North-Central Coast Region	•	•
South-Central Coast Region	•	•
South Coast Region	•	•
Nearshore Fishery Bycatch Permit		
Northern Pink Shrimp Trawl Vessel	•	
Northern Pink Shrimp Trawl Vessel		•
Salmon Vessel		
Sea Cucumber Diving		
Sea Cucumber Trawl		
Sea Urchin Diving		
Southern Rock Crab Trap		
Spot Prawn Trap Vessel—Tier 1		
Spot Prawn Trap Vessel—Tier 2		
Spot Prawn Trap Vessel—Tier 3		

Source: California DFG (2007f)

Both the California DFG and the federal government regulate catch limits and fishery closures to help reduce overfishing in the California waters of the Pacific Ocean (72 *Fed. Reg*. 85 24543; California DFG 2007f, 2007g; International Pacific Halibut Commission 2007; NMFS Northwest Regional Office 2007c; National Oceanic and Atmospheric Administration 2006, 2007; Pacific Fishery Management Council 2006). Table 3-8 lists catch limits and closure dates by species and district for 2007–2008.

Table 3-9 lists the weight and dollar value of the commercial catch landed at ports in the Los Angeles area during 2006. The weight and dollar value of the commercial catch from ports near Los Angeles fluctuated from 2000 through 2006, as Figure 3-4 shows, reaching low points in 2003 (landings) and 2004 (value).



Source: California Fish and Game Commission (1998)

Figure 3-3
Commercial Fishing Districts of Coastal California

Recreational and Commercial Fisheries

Table 3-8
Catch Limits and Closure Dates for Commercial Fisheries in District 19: 2007–2008

Species	District	Catch Limit	Closure Dates
Bigeye tuna	All		August 1–September 11, 2007
Cabezon	All	59,300	March 1–April 30, 2007
California halibut	Halibut trawl grounds		March 15–June 15, 2007
Chinook salmon	6, 7, 10, 17, 18, 19		October 1, 2007–April 30, 2008
Coho salmon	6, 7, 10, 17, 18, 19		All year
Coonstripe shrimp (trapping)	All		November 1, 2007–April 30, 2008
Dungeness crab	All districts except 6, 7, 8, 9		July 1–November 14, 2007
Greenling	All	3,400	March 1–April 30 and August 1–December 31, 2007
Nearshore fishery[a]	South of 40°10′		March 1–April 30, 2007
Pacific halibut	6, 7, 10, 11, 16, 17, 18, 19	31.7% X (1,340,000 lb. – 25,000 lb.) California and Oregon	November 1–December 31, 2007
Pacific sardine	All	152,564 metric tons Pacific coast	
Pink shrimp (trawling)	6, 7, 10, 17, 18, 19		November 1, 2007–March 31, 2008
Red sea urchin	All		April 1, 6–8, 13–15, 20–22, 27–29; May 4–6, 11–13, 18–20, 25–27; June 1–3, 7–10, 14–17, 21–24, 28–30; July 1, 4–8, 11–15, 18–22, 25–29; August 2–5, 9–12, 16–19, 23–26, 30–31; September 1–2, 7–9, 14–16, 21–23, 28–30; October 5–7, 12–14, 19–21, 26–28, 2007
Ridgeback prawn (trawling)	6, 7, 10, 17, 18, 19		June 1–September 30, 2007
Sea cucumber	Halibut trawl grounds		March 15–June 15, 2007
Sheephead	All	75,200	March 1–April 30, 2007
Skipjack tuna	All		August 1–September 11, 2007
Spiny lobster	18, 19, 20A, and part of 20		March 20–October 2, 2007
Spot prawn (trapping)	18, south of Point Arguello, 19, 19A, 20, 20A, 21		November 1, 2007–January 31, 2008
Surfperch	All		May 1–July 31, 2007
White seabass	All districts south of Point Conception		March 15–June 15, 2007
Yellowfin tuna	All		August 1–September 11, 2007

[a]The nearshore fishery consists of black rockfish, black-and-yellow rockfish, blue rockfish, brown rockfish, cabezon, calico rockfish, California scorpionfish, California sheephead, China rockfish, copper rockfish, gopher rockfish, grass rockfish, greenlings of the genus Hexagrammos, kelp rockfish, monkeyface eel, olive rockfish, quillback rockfish, and treefish.

Sources: California DFG (2007f, 2007g); California DFG, Marine Region (2007c, 2007d); 72 *Fed. Reg*. 85 24543; International Pacific Halibut Commission (2007); NMFS Northwest Regional Office (2007c); National Oceanic and Atmospheric Administration (2006, 2007); Pacific Fishery Management Council (2006)

Table 3-9
Commercial Catch Landed at Ports near Los Angeles: 2006

Fish/Shellfish	Dollar Value	Weight in Pounds
Market squid	$20,392,649	81,806,330
Pacific sardine	$3,244,992	59,043,970
California spiny lobster	$2,465,904	266,140
Pacific bonito	$1,359,972	4,885,920
Spot prawn	$906,099	83,035
Pacific mackerel	$800,619	12,594,563
Swordfish	$769,060	201,730
All other species	$3,041,551	6,512,958
Totals	**$32,980,846**	**165,394,646**

Source: California DFG (2006b)

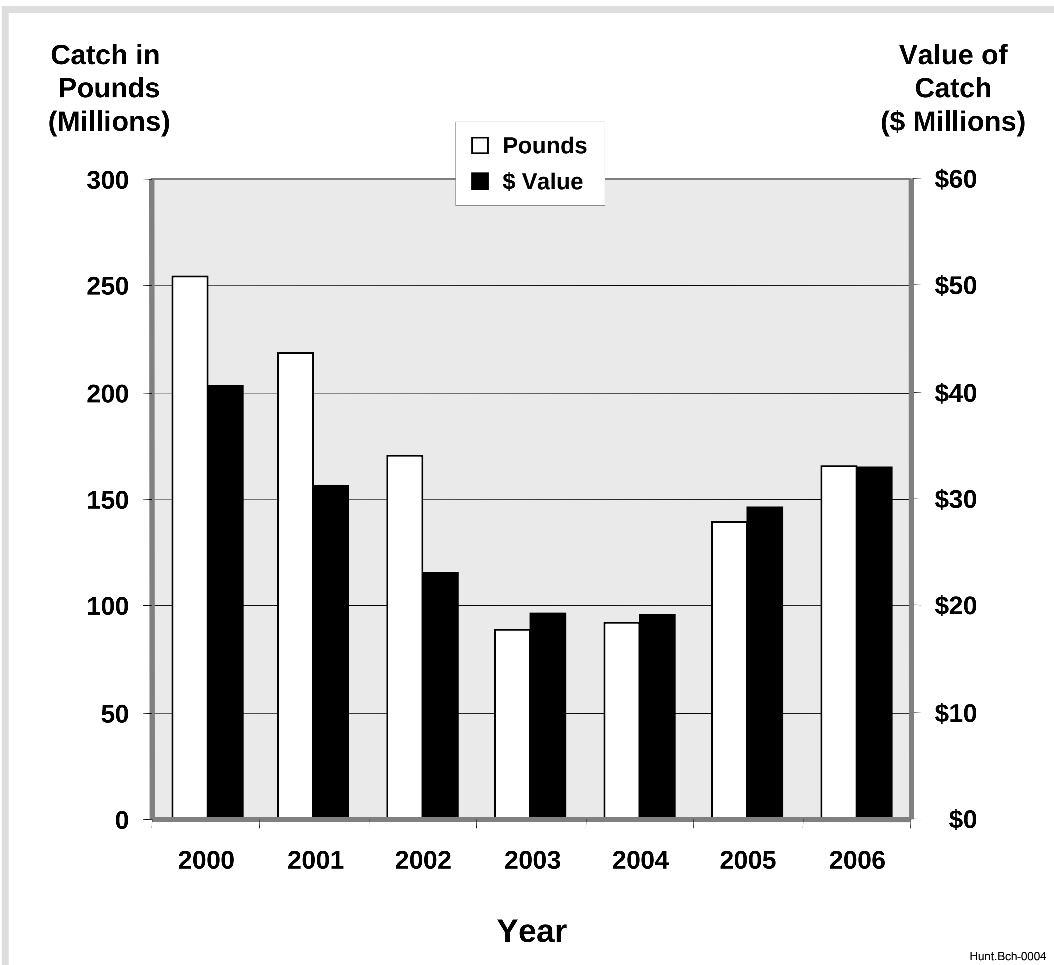


Figure 3-4
Pounds and Values of Commercial Catch Landed at Ports near Los Angeles, 2000–2006
This figure shows the weight and dollar value of commercial fish landings at ports near Los Angeles.

4
CHANGES IN CATCH

Age-structured population models are the best-recognized quantitative framework for the representation and evaluation of populations. Such models are often used for analysis of human demographics (Pollard 1973) and renewable resources (Getz and Haight 1989). Leslie (1945) developed the representation of a linear discrete population model as a matrix equation, now commonly referred to as the Leslie matrix population model. This model is frequently used in fisheries management and has long been an important component of professional judgment (PJ) 316(b) assessments under 1977 draft guidance (Akçakaya, Burgman, and Ginzburg 2002; Public Service Electric and Gas Company [PSEG] 1999; U.S. Environmental Protection Agency [EPA] 2002).[8]

In the assessment of I&E impacts, the advantages of population models include acceptability, correctness, and the ability to refine with improved information. However, these advantages are somewhat offset by significant data requirements. Development of a statistical model that estimates population effects requires I&E data, as well as population data over time. Approaches that employ the age-structure formulation in a dynamic simulation are less data intensive.[9] For example, life history and I&E estimates are sufficient when using simulations that represent part of the population. In situations where there is limited information about species life history, transfers using life history parameters, such as survival and fecundity, of similar species are sometimes employed. Because these approaches rely on dynamic simulation, specification errors can compound. This can lead to dramatic errors when minor differences between species are extrapolated through time.

[8] Fishery managers use the Leslie matrix in various applications. For example, the Shark Population Assessment Group of the National Oceanic and Atmospheric Administration (2006) uses the Leslie matrix to represent the population dynamics of sharks through demographic methods and to assess the status of shark stocks through stock assessment methodology. Sabaton et al. (1997) use a mathematical model to represent long-term change in a trout population under different river management scenarios. Their model describes the structure of a population divided into age classes based on the Leslie matrix. Hein et al. (2006) use an age-structured Leslie matrix model to determine which removal method most effectively reduced the population of invasive rusty crayfish in an isolated lake in Wisconsin. Carlson, Cortés, and Bethea (2003) simulated Leslie matrices to study the life history and population dynamics of the finetooth shark in the northeastern Gulf of Mexico.

[9] We use the term dynamic simulation to refer to a mathematical simulation that models changes over time using the difference equations of population dynamics.

Changes in Catch

Unfortunately, life history and population information for impinged and entrained species at HBGS is scarce. Despite this drawback, the conversion of impingement and entrainment impacts to fishery impacts in this assessment employs a dynamic population assessment approach. When life history information is unavailable, transferred parameters are employed.[10] Potential problems with compounding errors are addressed with adjustments based on mathematical simulation techniques. Here a distinct advantage of using models with known properties and fishery implications is that adjusted and transferred parameters can be combined with species specific information in a manner that has specific implications for observable population-level outcomes. This allows calibration based on bounds selected through empirical or even anecdotal information. This approach also supports the identification of cost-effective data sources to improve model accuracy.

Without population data, estimated annual impacts can be projected through these models to identify numeric (not percentage) impacts. With population information, percentage impacts can be identified. In either case, fishery impacts can be evaluated through specification of recreational and commercial mortality rates. With limited information, the reasonable specification of relative mortality rates (recreational, commercial, natural) is sufficient to identify timing and amount for recreational and poundage for commercial fishery impacts. With more information, the I&E assessment methodology could be synchronized with existing fishery models.

Under certain conditions, reductions in early life stage survival are reflected in equivalent changes in populations (Newbold and Iovanna 2007a, 2007b). The associated mathematics, as well as some preliminary simulations, identify the conditions under which reductions in early life-stage mortality lead to equivalent changes in expected catch (i.e., a 2-percent reduction in early life stage survival is associated with a 2-percent reduction in steady-state recreational catch rates and a 2-percent reduction in steady-state commercial catch rates). The direct extrapolation of changes in survival rates to equivalent changes in catch rates over a sampled impact area is an approach that has been supported by California regulatory agencies.

The approach taken here is to calibrate fishing mortality rates from life-history tables such that numeric changes estimated from population dynamic models are equivalent to percentage changes in catch rates implied by reductions in early life-stage survival rates.[11] For example, if biological sampling indicates a 1-percent reduction in early life-stage survival over an area with an annual recreational harvest of 1,000 fish the life-history table is calibrated so that it forecasts a steady-state reduction of 10 fish. This approach has the advantage of consistency with existing methodologies and mathematical rigor. The details and mathematical assumptions of this approach are detailed further in this text.

[10] Using transferred parameters has been generally characterized as benefits transfer, the use of existing information designed for one context to address policy questions in another. This approach is commonly used in practical policy analysis when it is generally prohibitively expensive or impossible to implement original studies (see Desvousges, Johnson, and Banzhaf 1998).

[11] In two cases (commercial anchovies and commercial rock crab), severe violations of underlying assumptions invalidate this approach and it is not applied.

The Leslie Matrix

The mathematical representation of the Leslie matrix is:

$$\underbrace{\begin{pmatrix} N_{1,t+1} \\ N_{2,t+1} \\ N_{3,t+1} \\ \vdots \\ N_{A,t+1} \end{pmatrix}}_{\text{Estimated Population at Time } t+1} = \underbrace{\begin{pmatrix} \overbrace{S_0 f_1 \quad S_0 f_2 \quad \cdots \quad S_0 f_A}^{\text{Fecundity}} \\ \begin{matrix} S_1 & 0 & \cdots & 0 \\ 0 & S_2 & 0\ldots & 0 \\ \vdots & 0 & \vdots & \vdots \\ 0 & \cdots & S_{A-1} & 0 \end{matrix} \end{pmatrix}}_{\text{Transition Matrix}} \underbrace{\begin{pmatrix} N_{1,t} \\ N_{2,t} \\ N_{3,t} \\ \vdots \\ N_{A,t} \end{pmatrix}}_{\text{Initial Population at Time } t} \quad \textbf{(4-1)}$$

This representation consists of a population vector and a transition matrix. $N_1 \ldots N_A$ is the population vector (on the far right of Equation 4-1). The population vector represents the age-structured population of a single stock at time t. Using a population of queenfish as an example, $N_{1,t}$ would be the number of age one queenfish in the population at time t, $N_{2,t}$ would be the number of age twos in the population at time t, through all the life stages for queenfish.

The transition matrix (in the middle of Equation 4-1) contains two types of information. The first type of information is survival rates, represented by the S_ns. Survival rates include both natural mortality (M) estimates and fishing mortality (F) estimates. The survival rate can be calculated for each life-stage transition by applying Baranov's catch equation (C=FN(average) or $C = \frac{F}{Z} AN_0$) to standard mortality tables (Ricker 1975). In this development, survival is an exponential relationship of M and F:

$$\text{Survival (S)} = e^{-(M+F)} \quad \textbf{(4-2)}$$

Survival rates in the transition matrix represent the probabilities that a fish in a population will survive to the next life stage. Applied at the population level, these survival probabilities are the percentage of one life stage that survives to the next.

The second type of information contained is the transition matrix is fecundity, represented by f_ns. Fecundity is the average number of eggs laid annually by each female of a particular age-class. For example, the f_1 in the matrix above represents the average number of eggs laid by an age one female.

As the equality condition indicates, multiplying the age-structured population vector at time t by the transition matrix returns the age-structured population vector at time t + 1. Thus, with knowledge of a population's structure and the transition matrix, it is possible to predict the population's structure in the next time period. Proceeding in an iterative way allows simulation of populations for future periods.

Changes in Catch

Process for Determining Fishery Impacts at HBGS

This section presents the methodology employed to determine the fishery impacts associated with I&E at HBGS. Our process began by reviewing the annual estimates of I&E provided by MBC and Tenera (2007). This report contains annual estimates of impinged and entrained species that represent about 90 percent of the total organisms impinged or entrained. To account for I&E impacts associated only with Units 1 and 2, we divide the annual entrainment estimates by 2. Table 4-1 below contains the annual I&E estimates used in the benefits assessment.

Table 4-1
Annual I&E Impacts at HBGS for Units 1 and 2

Species	Annual Impingement	Annual Entrainment (Larvae)
CIQ gobies	0	56,593,417
northern anchovy	2,193	27,174,509
spotfin croaker	49	34,850,795
queenfish	35,847	8,904,932
white croaker	4,903	8,812,632
black croaker	65	3,564,064
salema	46	5,848,480
blennies	3	3,582,757
diamond turbot	0	2,721,559
California halibut	21	2,510,584
shiner perch	4,045	0
sand crab megalops[a]	N/A	34,897
California spiny lobster[b]	32	0
market squid[b]	7	0
rock crab	5,820	3,205,586
nudibranch[a]	65,150	0
two spotted octopus[b]	61	0
purple-striped jelly[b]	53	0

Source: MBC and Tenera (2007)

[a] See the discussion of forage species below.

[b] Due to the low frequency of impingement, and the paucity of life history parameters for invertebrates, these species are not considered further.

For each species in Table 4-1, our review included a determination of whether species-specific life history parameter information was available. When precise information was not available, a transfer and calibration process was applied. Table 4-2 identifies the sources of the life history parameters used in this assessment. Transfer species are selected on the basis of biological similarity (i.e., lifespan, size) with consultation of fishery experts.

Table 4-2
Source of Life History Parameters by Species

Impinged and Entrained Species at HBGS	Fecundity			Mortality	
	Species	Eggs per Year	Source	Species	Source
CIQ gobies	goby	1,538	MBC and Tenera (2007)	gobies	EPA (2004b), Table B1-17
northern anchovy	anchovy	20,000 to 320,000	MBC and Tenera (2007)	anchovy	EPA (2004b), Table B1-2
spotfin croaker	white croaker	800 to 37,200	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
queenfish	queenfish	5,000 to 90,000	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
white croaker	white croaker	800 to 37,200	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
black croaker	white croaker	800 to 37,200	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
salema	salema	21,600	Muncy (1984)	other forage	EPA (2004b), Table B1-39
blennies	blennies	1,265	MBC and Tenera (2007)	blennies	EPA (2004b), Table B1-5
diamond turbot	Atlantic winter flounder	600,000	EPRI (2005)	flounder	EPA (2004b), Table B1-15
California halibut	California halibut	5.5 million	MBC and Tenera (2007)	California halibut	EPA (2004b), Table B1-7
shiner perch	shiner perch	5 to 20 young	MBC and Tenera (2007)	surfperch	EPA (2004b), Table B1-35
sand crab	sand crab	100,000	MBC and Tenera (2007)	other commercial crab	EPA (2004b), Table B1-23
graceful rock crab	graceful (slender) crab	681,000	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-23
yellow rock crab	yellow crab	3.3 million	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-23
Pacific rock crab	Pacific (brown) crab	1.8 million	MBC and Tenera (2007)	other commercial crab	EPA (2004b), Table B1-23

The remainder of this section describes the process used to generate estimates of fishery impacts using queenfish as a specific example. This species is both impinged and entrained at HBGS, and the species-specific life history parameters are limited. Although species-specific fecundity information is available, mortality information is not. We considered several sources of information to determine the survival rates of queenfish: EPA's Section 316(b) Phase II Final Rule Regional Analysis for California (EPA 2004b) and MBC and Tenera (2007). Neither report contains a specific life history table for queenfish. However, EPA includes queenfish in the drum/croaker group. Based on this information, and with support from fishery experts from MBC and Tenera, this assessment employed croaker life history parameters for queenfish.

Changes in Catch

EPRI's life history table for croaker includes daily mortality rates by life stage, but does not differentiate between natural and fishing mortality. EPA, on the other hand, includes both natural and fishing mortality rates for each life stage. For this assessment fishing mortality rates are calibrated based on reported local catch rates.

Figure 4-1 describes the approach for assessing harvest impacts associated with I&E in a data-poor environment. As indicated in the figure, the first step integrates transfer information from other species and species-specific information with professional judgment to identify the survival and fecundity components of the transition matrix. In the second step, the specified life history information is evaluated for empirical validity, using implications for long run growth rates. If the long run population growth rate is not consistent with empirical and anecdotal information, professional judgment and calibration are used to adjust the specification of survival parameters. In the third step, specified survival rates are replaced with fishing mortality rates to calculate fishing deaths. In the fourth step, the harvest changes are developed based on calibration to local fishery harvest information. For recreational species, the results are expressed as a number of fish. For commercial species, the results reflect additional pounds of fish harvested. These four steps are illustrated in the following sections.

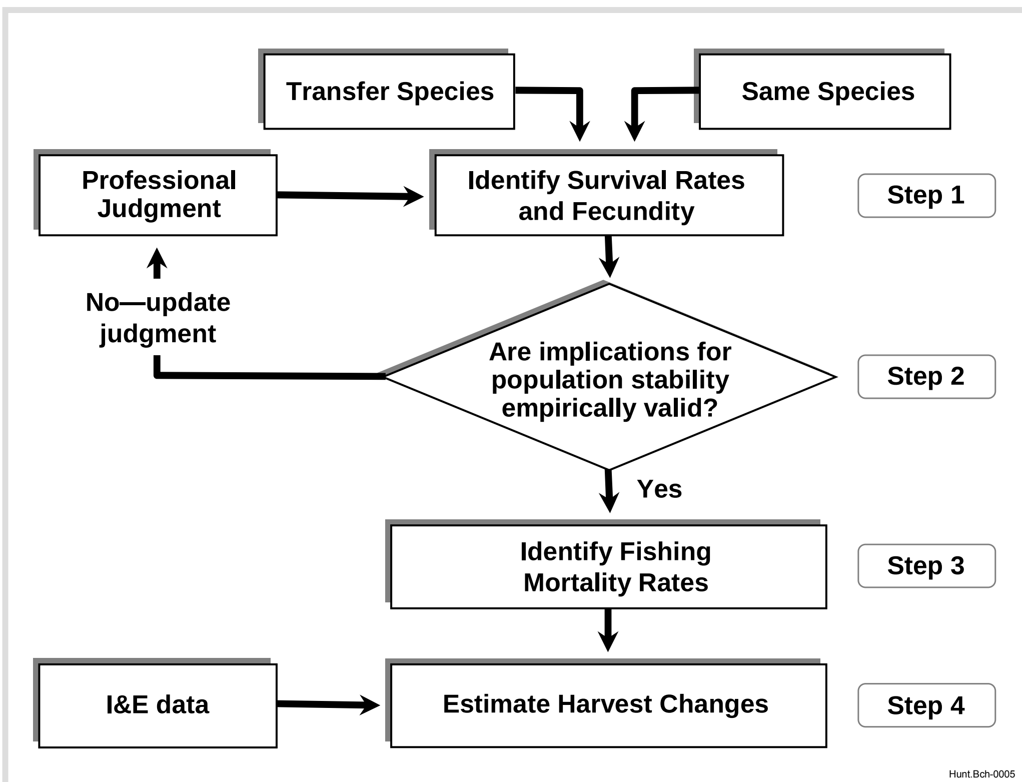


Figure 4-1
Population Dynamic Framework to Support Fishery Harvest Assessment in Data-Poor Environment

When no population or life-history estimates are available, the approach depicted in this figure demonstrates the application of a population dynamic framework to support the assessment of impacts to fishery harvest.

Step 1—Develop Transition Matrix

In a data-poor situation, the survival and regeneration components of a population dynamic model are developed using the best available information and professional judgment. The transition matrix is constructed so that the number in a specific cell is the probability an age-class member will survive to the next age-class. In Figure 4-2 below, age one fishes will have a 0.657 probability of surviving to become age two fishes. Applied at the population level, these survival probabilities are the percentage of one life stage that survives to the next.

	Eggs	Larvae	Juvenile	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Larvae	0.6065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juvenile	0	9.952m	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 1+	0	0	0.03405	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 2+	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0

Figure 4-2
A Basic Leslie Transition Matrix with Survival Probabilities

When a population at time t is multiplied by the above transition matrix (Equation 4-1), a proportion of the age ones will survive the year and transition to age twos at time t+1. The following example demonstrates how to calculate the survival rate (S) for the transition from an age three queenfish to an age four queenfish using mortality values from EPA mortality tables. The age three-to-age-four transition is used as an example because this is the earliest life stage of queenfish that includes fishing mortality. For this species, the natural and fishing mortality parameters are the same when applying equation 4-2.

$$\text{Survival (S)} = e^{-(0.21 + 0.21)} = 0.657 \qquad \textbf{(4-3)}$$

A population regenerates by spawning. Regeneration can be represented in the transition matrix by including stage-specific fecundity in the top row of the transition matrix. The top row of the transition matrix represents the number of eggs expected from the spawn of mature females.

The *AES Huntington Beach L.L.C. Generating Station Entrainment and Impingement Study Report* (MBC and Tenera 2007) includes reproduction information specific to queenfish. The fecundity information in this section is drawn from MBC and Tenera's report. The fecundity of queenfish for each mature adult (age two fishes and above) is expected to lay between 5,000 and 90,000 eggs. This information is incorporated by specifying annual egg laying for each female as demonstrated in Figure 4-3.

Changes in Catch

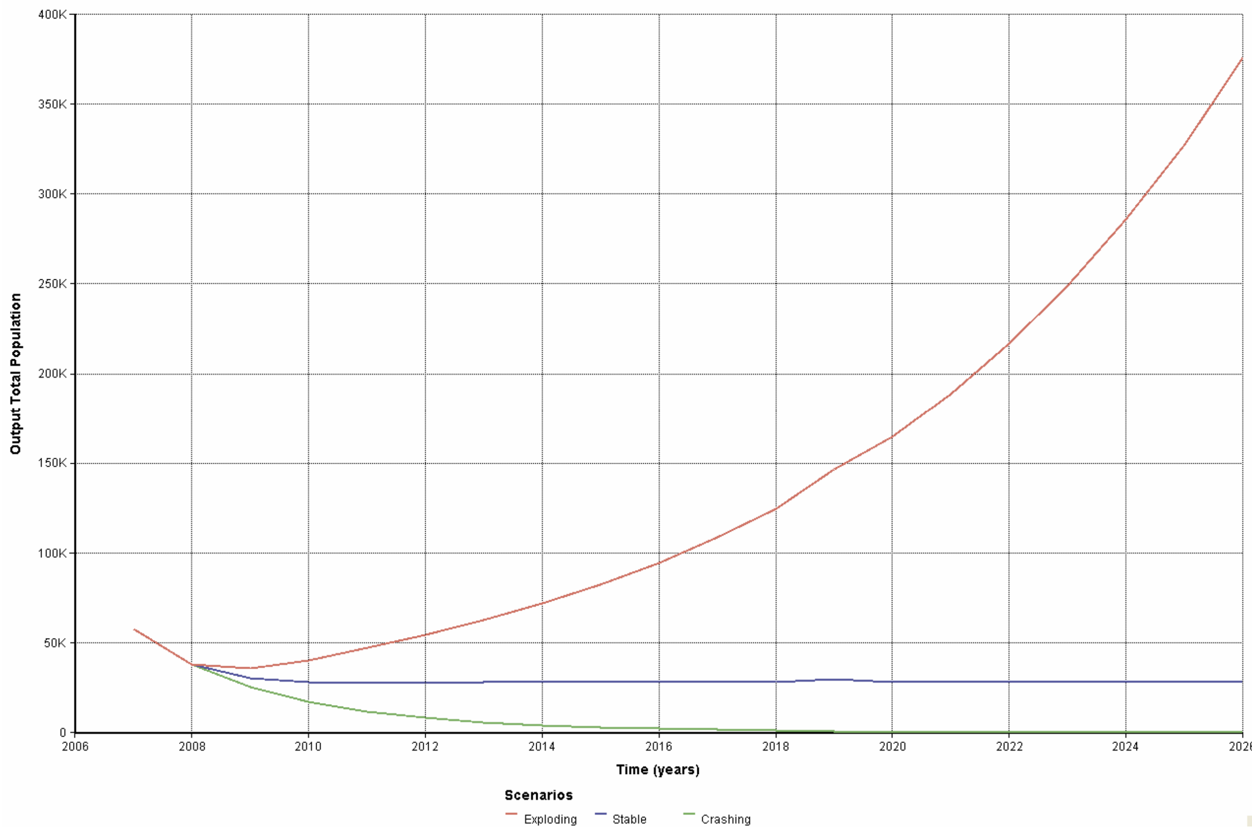
	Eggs	Larvae	Juvenile	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Eggs	0	0	0	0	5000	13K	21K	29K	37K	45K	53K	61K	69K	77K	90K	0
Larvae	0.6065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juvenile	0	9.952m	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 1+	0	0	0.03405	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 2+	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0

Figure 4-3
Transferred Queenfish Transition Matrix with Regeneration[12]

Step 2—Calibrate Transition Matrix

After specifying the transfer-based transition matrix, it is calibrated based upon information available about the population. Once the classification of the population's growth behavior is determined, it can be used to calibrate the simulation model. For this assessment we consider that transfer-based simulations of population growth will indicate that populations are crashing, decreasing, stable, increasing, or exploding. Figure 4-4 below depicts simulations of populations that are exploding, stable, and crashing.

[12] The model is based on females. Changes estimated for females are adjusted to reflect males.



Example 1: An Exploding Population
Example 2: A Steady-State Population
Example 3: A Crashing Population

Figure 4-4
Simulations of Steady-State Population Changes Based on Transferred Information

After the initial Leslie transition matrix is configured with mortality rates, survival rates, and fecundity, simulated population growth behaviors are used to calibrate the life history specification to fine-tune the population's modeled growth or contraction. For example, a population that is assumed stable is calibrated to a long-run population growth of 1.[13] This means that each member of the population is replaced so that the size of the population remains constant over time.

Because most survival uncertainty is associated with early life stages (Quinlan and Crowder 1999), the calibration is applied prior to age one fishes. For example, if the actual population is a steady-state population but the simulation based on the transferred life history table is exploding, then a calibration modification is implemented to decrease the probability of survival to age one. By increasing the mortality of the pre-age one life stages, the calibration limits the growth of the population. This calibration can be tuned until the projected simulation behavior or growth rate

[13] The population growth rate is identified by examining the dominant eigenvalue of the transition matrix. An eigenvalue is the sum of squared values in the column of a factor matrix. The dominant eigenvalue (E_d) for the transition matrix is equivalent to the population growth rate, where: $E_d > 1$ increasing, $E_d = 1$ stable, and $E_d < 1$ decreasing.

Changes in Catch

match the expected behavior for the population. Doing so minimizes the likelihood of compounding error problems associated with dynamic simulations using uncalibrated transfer parameters.

Figure 4-5 depicts the growth rate of queenfish population based on the croaker transfer parameters. Initially it indicates an exploding population (green). Based on professional judgment, we determined that a more appropriate specification is a stable population, depicted in red. A growing population is depicted for illustrative purposes in blue.

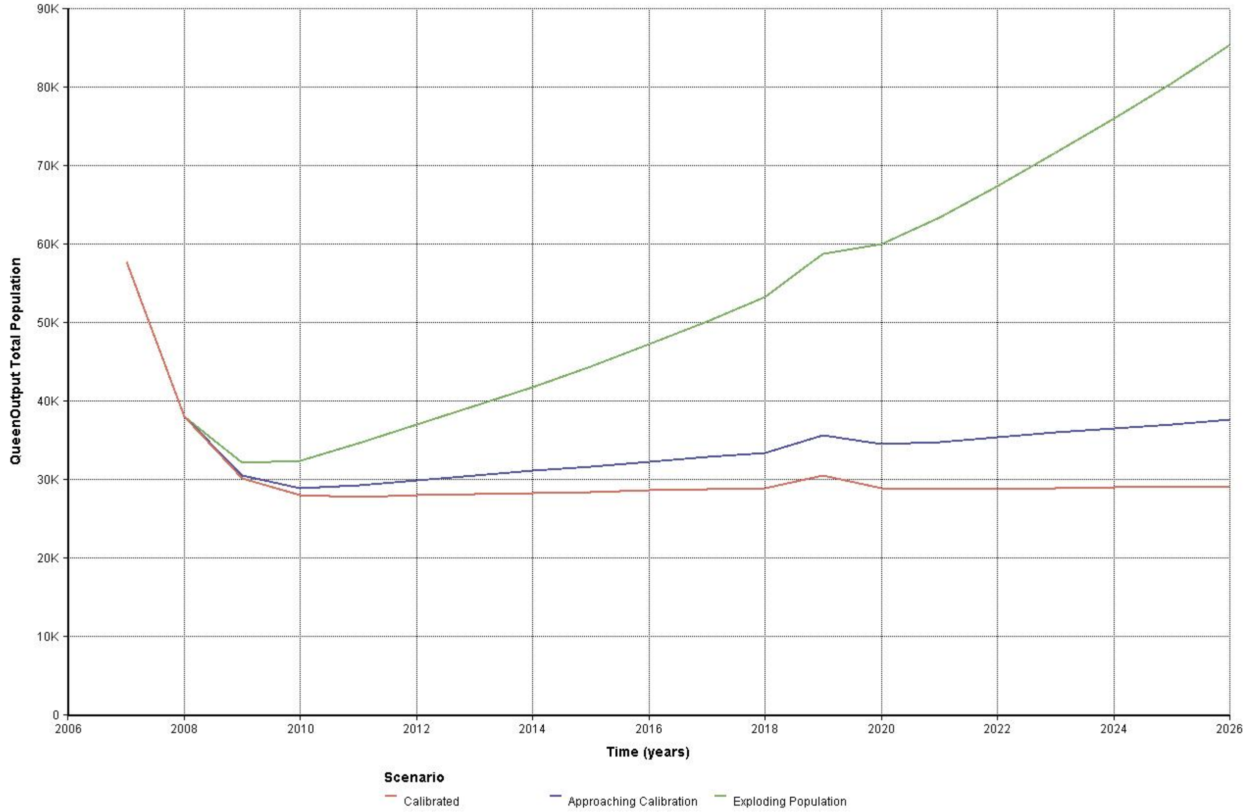


Figure 4-5
Calibration of Transferred Life History Specification for Queenfish

Step 3—Determine Recreational and Commercial Harvest Rates

An important advantage of age-structured population modeling for estimating I&E impacts is the information that survival rates imply for recreational and commercial catch. It is possible to structure the transition matrix to decompose death outcomes into commercial, recreational and natural. A dynamic simulation with specified fishing mortality rates by age can be used to identify numeric changes in catch for each age class and future year. The equations below demonstrate how the components of survival are represented in a typical life history table, where "rate" can be interpreted as the probability of advancing to another stage in the next year.

$$\text{Total Death Rate} = 1 - \text{Total Survival Rate} \quad \textbf{(4-4)}$$

Natural Death Rate	=	M/(M+F) * Total Death Rate	**(4-5)**
Fishing Death Rate	=	F/(M+F) * Total Death Rate	**(4-6)**
*Commercial Death Rate	=	% of Commercial Fishing Mortality * Fishing Death rate	**(4-7)**
*Recreational Death Rate	=	(1 – % of Commercial Fishing Mortality) * Fishing Death rate	**(4-8)**

Deconstructed in this manner, the age-structured population modeling approach can provide a great deal of information about commercial and recreational impacts. For example, a species like anchovies that is commercially fished but not recreationally fished could have an upper bound impact identified by specifying all deaths as commercial catch. Representing all mortality as fishing mortality provides an upper bound for catch changes. For species that are fished commercially and recreationally, all death can be specified as fishing death and the distribution of commercial versus recreational catch can be used in sensitivity analysis. If empirical, anecdotal, or professional judgment indicates that the species is not overfished, the percentage of death that is commercial catch would be adjusted downward. Species that are fished recreationally are considered in a similar fashion. Expected value estimates for species that are fished recreationally and commercially can be identified by applying ratios from aggregated creel and harvest information to harvest rates. With respect to the approach employed in this assessment, proportional changes in expected catch over a geographic area are calibrated to equal sub-adult entrainment rates as identified in the I&E report (MBC and Tenera 2007).

Returning to the queenfish (age three fishes) as an example, the fishing death rates originally specified are:

Total Survival Rate	=	$e^{-(0.21 + 0.21)}$	=	0.657	**(4-9)**
Total Death Rate	=	1 – 0.657	=	0.343	**(4-10)**
Natural Death Rate	=	0.21/0.42 * 0.343	=	0.1715	**(4-11)**
Fishing Death Rate	=	0.21/0.42 * 0.343	=	0.1715	**(4-12)**
Comm. Death Rate	=	0.309 * Fishing Death rate	=	0.05299	**(4-13)**
Recr. Death Rate	=	0.691 * Fishing Death rate	=	0.1185	**(4-14)**

Figure 4-6 below is the calibrated queenfish transition matrix developed earlier with additional rows that accommodate the decomposition of mortality rates. Note that age three fishing mortality rates are highlighted.

Changes in Catch

	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Age 1+	0	0.3199	0.3536	0.3872	0.4209	0.4546	0.4882	0.5219	0.5556	0.5893	0.6229	0.6566	0
Age 2+	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0.657	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0.657	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0.657	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0.657	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0.657	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0.657	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0.657	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0.657	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0.657	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0.657	0
Count Caught Rec	0	0	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0
Count Caught Comm	0	0	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0
Count Died Naturally	0.343	0.343	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0

Figure 4-6
Queenfish Transition Matrix with Commercial and Recreational Fishing Mortality

A review of local recreational and commercial harvest is used to calibrate the life history table. Local commercial fishing data indicates that queenfish is not commercially fished. Accordingly, the commercial mortality rate is calibrated to zero.

Under certain conditions, equilibrium catch impacts from population dynamic models are roughly equivalent to fishery impacts (Newbold and Iovanna (2007a). These include high early life stage mortality rates, high fecundity, and evenly distributed fishing and I&E pressure.[14] Figure 4-7 depicts the final calibrated Leslie transition matrix.

	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Age 1+	0	0.3199	0.3536	0.3872	0.4209	0.4546	0.4882	0.5219	0.5556	0.5893	0.6229	0.6566	0
Age 2+	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0.7298	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0.7298	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0.7298	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0.7298	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0.7298	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0.7298	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0.7298	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0.7298	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0.7298	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0.7298	0
Count Caught Rec	0	0	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0
Count Caught Comm	0	0	0	0	0	0	0	0	0	0	0	0	0
Count Died Naturally	0.343	0.343	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0

Figure 4-7
Queenfish Transition Matrix with Calibration

[14] By evenly distributed fishing and I&E pressure, we mean that the area of I&E impacts and fishing impacts are similar. For brown rock crab and anchovy, this assumption is violated and the calibration is made virtually impossible. Uncalibrated fishing mortality parameters are employed for these species.

Step 4—Estimate Changes in Harvests

Under these assumptions and following geographic areas and entrainment rates as listed in the I&E report, the equilibrium change in recreational catch of queenfish is approximately 270[15] fish annually. Employing these assumptions, and consistent with methodologies previously approved by California regulators, recreational harvest rates are calibrated such that the number of queenfish lost to the recreational harvest is equal to the number implied by percentage impacts.

Identifying numeric changes in catch for each species and year is accomplished by summing recreational catch for each year over age-classes. Figure 4-8 depicts the estimated change in recreational catch of queenfish associated with a 90-percent reduction in I&E at HBGS that began in 2006.

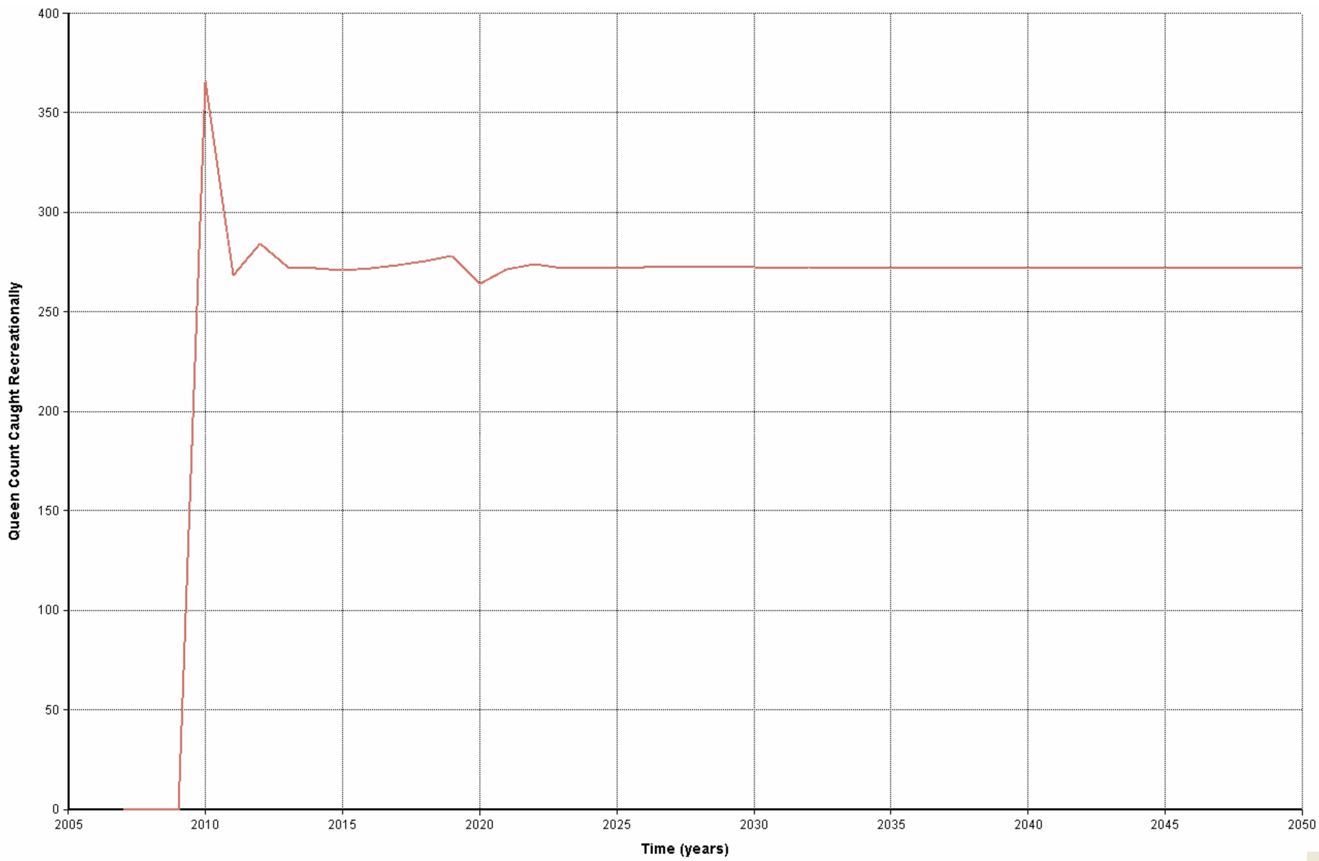


Figure 4-8
Change in Recreational Catch of Queenfish by Year

[15] The calibration is done for entrainment only. Impingement rates are added to the dynamic model after calibration occurs.

Changes in Catch

Incorporating Forage Species

Because commercial and recreational anglers do not target them, forage fish such as gobies are considered to have indirect economic benefits. In this context, indirect-use benefits arise from the role forage species play in supporting game fish populations. Indirect-use benefits can be calculated by evaluating the degree of energy transfer that occurs through the consumption of gobies and other forage fish by game fish. However, this approach requires knowing whether and to what degree limited availability of forage species constrains the populations of commercial and recreational species. There are two general situations:

1. Lack of forage fish does not constrain populations of commercially and recreationally valuable species.
2. Lack of forage fish does constrain populations of commercially and recreationally valuable species.

Valuation in the first instance is straightforward. When forage fish availability does not constrain commercial and recreational populations, impingement and entrainment of forage fish does not impact game fish populations and indirect use values are zero. When the lack of forage species availability does constrain commercial and recreational populations, forage losses are greater than zero, but can potentially be valued using trophic transfer. For purposes of this assessment, we have assumed that populations of harvested species are constrained and incorporate them through a trophic transfer methodology.

Incorporating forage species into this assessment begins with the same process outlined above in Figure 4-1. We first evaluate the available information on survival and fecundity for the forage species. When species-specific information is not available, we use the transfer data identified above in Table 4-2. However, the process departs from the figure at Step 3. Rather than focusing on fishing mortality rates, we evaluate natural mortality rates, which include consumption by other species.

Literature on trophic transfer rates suggests that a trophic transfer efficiency of 10 percent across all species is reasonable. For example, Pauly and Christensen (1995) compiled 140 estimates of trophic transfer efficiency from 48 trophic models of aquatic ecosystems. Pauly and Christensen found that although the range of values was very wide, the mean value was 10 percent and only a few of the values were 20 percent or higher. This finding also is bolstered by more recent work with bioenergetics models that support a value of 10 percent (PSEG 1999). Similarly, the EPA used a 10 percent transfer rate in its final rule (EPA 2004b). However, this approach apparently assumes that all the lost forage production would have been consumed by harvested species. In fact, it is likely that a large portion of the forgone production is consumed by intermediate predators and *then* by harvested species. In addition, it is also likely that a much lower proportion of forage fish are actually consumed by predators. Thus, the assumption that harvested species *directly* consume *all* forage biomass likely leads to an overestimate of the harvested gains.

Forage species evaluated for Huntington Beach include nudibranchs, sand crabs, blennies, gobies, and salema. However, no sportfish consume nudibranchs. Cephalaspidea (also known as headshield slugs and bubble shells) and navanax, a brightly colored sea slug, prey on nudibranchs. Other potential predators avoid attacking nudibranchs because of their color (Wägele and Klussmann-Kolb 2005; Sheckler 1999; Judd 1998). Accordingly, we estimate no impacts to recreational or commercial fisheries associated with the impingement of nudibranchs.

For the other affected forage species, their predators include sportfish:

- Sportfish prey on gobies, particularly arrow goby. Lane and Hill (1975) note that California halibut is probably the major predator of arrow goby. Other predators of arrow goby include cabezon, California corbina, diamond turbot, leopard shark, queenfish, staghorn sculpin, walleye surfperch, and white croaker. Sharks and rays prey on yellowfin goby. California halibut and other finfish prey on longjaw mudsucker, another goby.
- The California Energy Commission (undated) note that California halibut and other large predators may prey on salema.
- Octopus, kelp bass, and cabezon prey on blennies (Feder, Turner, and Limbaugh 1974; Cephbase 2003).
- The barred surfperch preys on sand crabs, which makes up 90 percent of the barred surfperch's diet (LIMPETS undated).

For purposes of this assessment, we assume that all gobies, blennies, salema, black croaker, and shiner perch are converted to California halibut through a 10 percent trophic transfer. Similarly, we convert biomass of sand crabs to surfperches.

Results

This section contains the results of the dynamic population impacts for the impinged and entrained species at HBGS. Based on the discussion of forage fish above, these results reflect the population impacts only for harvested species. For recreational species, the impacts are expressed in numbers of fish. For commercial species, the impacts are expressed in pounds of fish.

The following tables contain the results for the forgone recreational harvests of impinged species, recreational harvests of entrained species, commercial harvests of impinged species, and commercial harvests of entrained species. The time of benefits is specified as though technology is installed during 2008 and operated for 20 years.

Changes in Catch

Table 4-3
Forgone Harvest of Recreational Species Impinged and Entrained at HBGS
(Number of Fish)

Year	White Croaker	Queenfish	California Halibut	Spotfin Croaker	Diamond Turbot
2008	0.0	0.0	0.0	0.0	5.3
2009	0.0	0.0	0.0	0.0	8.2
2010	115.1	538.3	0.0	2.5	8.7
2011	86.7	395.0	0.0	2.0	8.7
2012	95.5	418.9	0.0	2.2	8.4
2013	92.5	401.0	48.0	2.2	8.6
2014	93.6	400.5	40.8	2.2	8.6
2015	93.8	398.9	34.8	2.2	8.6
2016	94.5	400.1	36.8	2.3	8.6
2017	95.2	402.3	37.5	2.3	8.6
2018	96.1	405.4	37.1	2.3	8.6
2019	97.0	409.1	37.1	2.4	8.6
2020	91.2	388.9	37.3	2.1	8.6
2021	93.9	400.0	37.3	2.2	8.6
2022	94.4	403.1	37.3	2.2	8.6
2023	94.1	400.4	37.4	2.2	8.6
2024	94.2	401.1	37.4	2.2	8.6
2025	94.1	400.6	37.5	2.2	8.6
2026	94.2	400.7	37.5	2.2	8.6
2027	94.2	400.7	37.6	2.2	8.6

Table 4-4
Forgone Harvest of Commercial Species Impinged and Entrained at HBGS
(Pounds of Fish)

Year	White Croaker	California Halibut	Northern Anchovy	Rock Crab
2008	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0
2010	33.7	0.0	7.0	0.0
2011	31.1	0.0	7.2	0.6
2012	36.9	0.0	7.4	0.6
2013	39.3	13.2	7.6	0.6
2014	42.1	15.4	7.3	0.6
2015	44.0	16.5	7.4	0.6
2016	45.8	19.3	7.4	0.6
2017	47.2	20.6	7.4	0.6
2018	48.4	21.7	7.4	0.6
2019	49.6	22.9	7.4	0.6
2020	42.5	23.6	7.4	0.6
2021	44.8	24.2	7.4	0.6
2022	44.7	24.9	7.4	0.6
2023	45.0	25.4	7.4	0.6
2024	45.1	25.9	7.4	0.6
2025	45.2	26.3	7.4	0.6
2026	45.3	26.7	7.4	0.6
2027	45.3	27.0	7.4	0.6

5
FISHERY VALUATION OVERVIEW

The California coastal waters near Huntington Beach support a range of commercial and recreational fishing. Considering the impacts of reduced I&E on species abundance and composition, we expect human welfare to improve. Increases in the abundance and changes in the composition of fish species proximate to the HBGS may be expected to change the levels of commercial and recreational fishing in the area as fishers take advantage of the improved fishing opportunities. Individuals who stand to gain from these changes include consumers and producers of commercially important fish species harvested in the ecosystem and recreational fishers. These relationships are depicted in Figure 5-1 below.

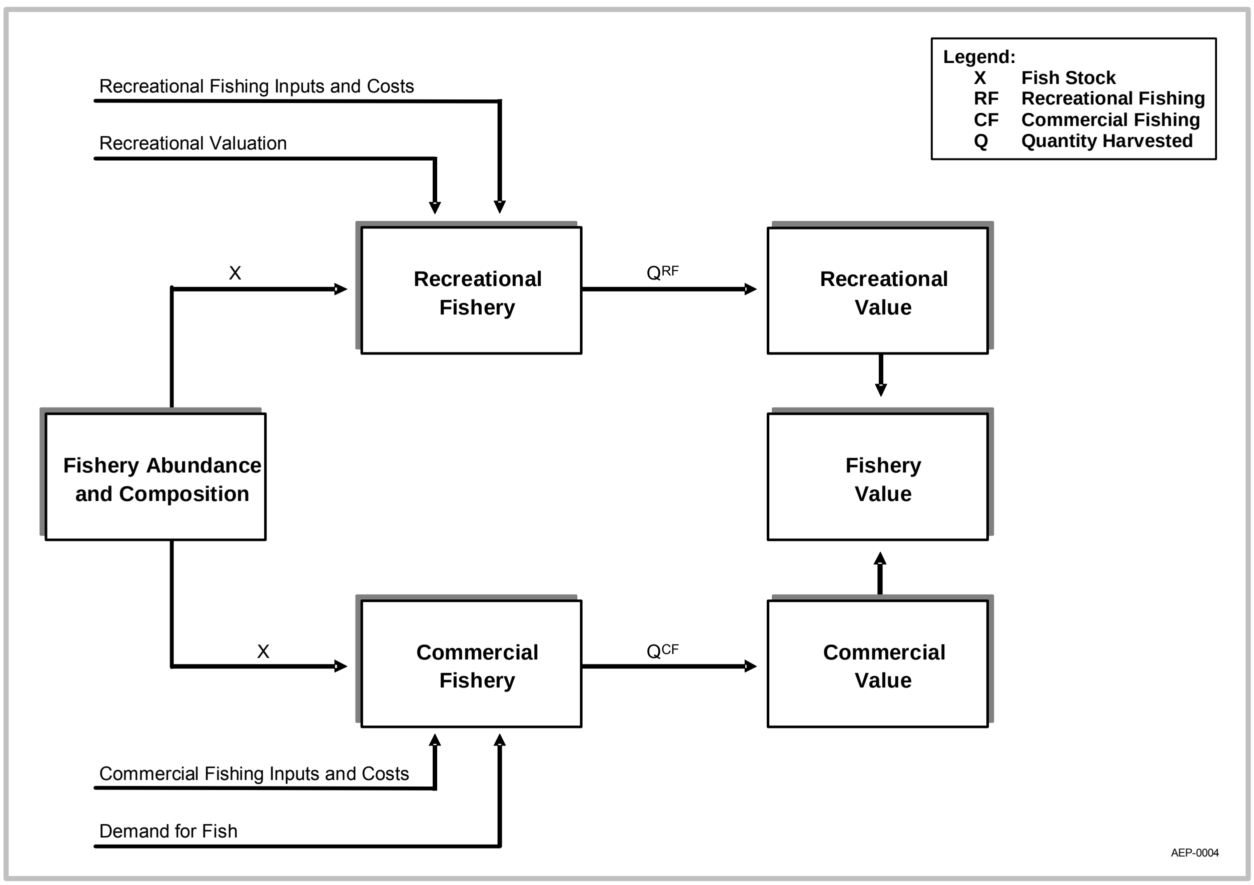


Figure 5-1
Relationship between Fishery Abundance and Value

Fishery Valuation Overview

Fisheries are dynamic environments where organisms are borne, reproduce, and die. Some of these fish will die as a result of harvesting by commercial and recreational fishers. The implications of I&E on this process can be illustrated in a simple biomass growth and population model developed by Schaefer (1954, 1957). This model recognizes that most fish stocks follow a population-dependent growth pattern, as illustrated in Figure 5-2. The growth in fish stock is on the vertical axis, and the size of the fish population on the horizontal axis.

In Schaefer's model, over some population range, the biomass size will grow at an increasing rate. However, beyond some point the carrying capacity of the ecosystem becomes compromised, reducing the species growth rate. With this growth, the population size eventually reaches the carrying capacity of the ecosystem. This is illustrated in Figure 5-2 by the inverted U-shaped function. Without harvesting, the population size will be X which is a natural or stable equilibrium.[16]

I&E and fishing add an outside influence on the population size. Point B represents the results of overharvesting and I&E impacts on the fish population. With reduced I&E, commercial and recreational fishing is the only source of harvesting so the population grows to A_s.

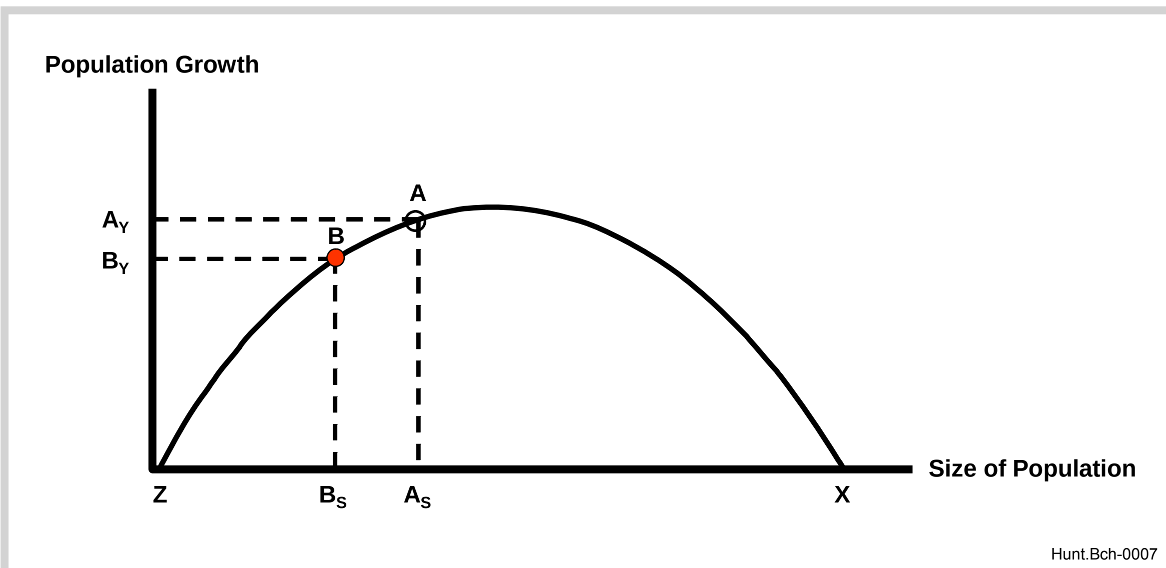


Figure 5-2
I&E and Fishing Impacts on Fish Population and Growth

This section of the report describes the fishery valuation methodologies used to measure the economic benefits of reducing losses. Economic benefits are the monetized values of the improvements in human welfare. In the national benefits valuation for the 316(b) rule, EPA introduced several relevant classifications of economic benefits, including:

[16] X represents a stable equilibrium because if the fish population exceeds X, natural mortality rates increase such that the fish population returns to the natural equilibrium. If the population is less than X growth will push it back to X. Z is the minimum viable population or the point of extinction.

- Market-based benefits
- Nonmarket, direct-use benefits
- Nonmarket, indirect-use benefits
- Nonmarket, nonuse benefits.

Market-based benefits are those that can be measured through markets. An increase in the commercial harvest of fish is the most relevant example of a market-based benefit in the 316(b) context. Nonmarket, direct-use benefits reflect improvements in ecosystem services that are directly used by humans but not traded in a traditional market. An increase in recreational catch associated with reductions in I&E is the primary example of the direct-use benefits applicable to 316(b). Indirect-use benefits are those benefits that accrue to users of a resource indirectly. For example, forage fish provide a food source to harvested fish. Thus, when game fish populations are constrained by lack of forage, an increase in forage fish populations can indirectly provide an economic benefit to anglers. This occurs because the increased food source supports larger sport fish populations, increasing recreational catch. Finally, nonuse benefits are those that are completely independent of any past, present, or future use of the resource, encompassing the concepts of altruism, bequest or existence motives.

Both the commercial and recreational fisheries depend on the determinants of supply and demand to establish price and quantity. The abundance of fish within the fishery is an important factor for the value of the fisheries. For example, in the commercial fishery, a decline in abundance means commercial fishermen will expect to catch fewer fish with the same amount of effort (i.e., commercial fishing inputs and costs). The higher cost of catching fish will result in smaller harvests for commercial fishermen. The reduction in harvested fish will reduce the value of the commercial fishery.

In the recreational fishery, decreased catch rates at some sites leads to less satisfaction with trips to those sites. In addition, some recreational anglers choose to fish elsewhere and take trips of lower value. Others substitute lower-valued activities.

In economic theory, changes in society’s well-being result from changes in the value of environmental services. Consumer and producer surplus are the primary methods for measuring changes in well-being. However, the appropriate method depends on the type of change measured. For example, when the catch rates for fish increase, it would be reasonable to assume that both recreational and commercial fishermen will catch more fish. However, these two effects are measured differently. For recreational fishing, the angler consumes leisure time, or recreation, and he or she may consume the fish that are caught. Changes in consumption flows are measured using consumer surplus. On the other hand, commercial fishermen supply labor that is used to produce a good, or in this case, fish. Commercial fishermen catch fish with the intention of selling them to make money. When production flows are affected by a change in environmental services, producer surplus measures the welfare change.

Fishery Valuation Overview

Recreational Fishery—Consumer Surplus

The concept of individual demand for a good or service is the basis for economic valuation for the recreational fishery. The demand function for any good describes the maximum quantity a person would be willing to purchase at each price for a given time period. Alternatively, the demand function also shows the person's maximum willingness to pay (WTP) for each quantity supplied.

Figure 5-3 shows a demand curve for recreational fishing trips. V_1 is the marginal value people attach to trip T_1, that is, the additional value people experience from taking one more trip (T_1). The downward slope of the curve indicates that individuals are willing to pay less for each additional trip. Thus, the first trip has a higher value than the fifth.

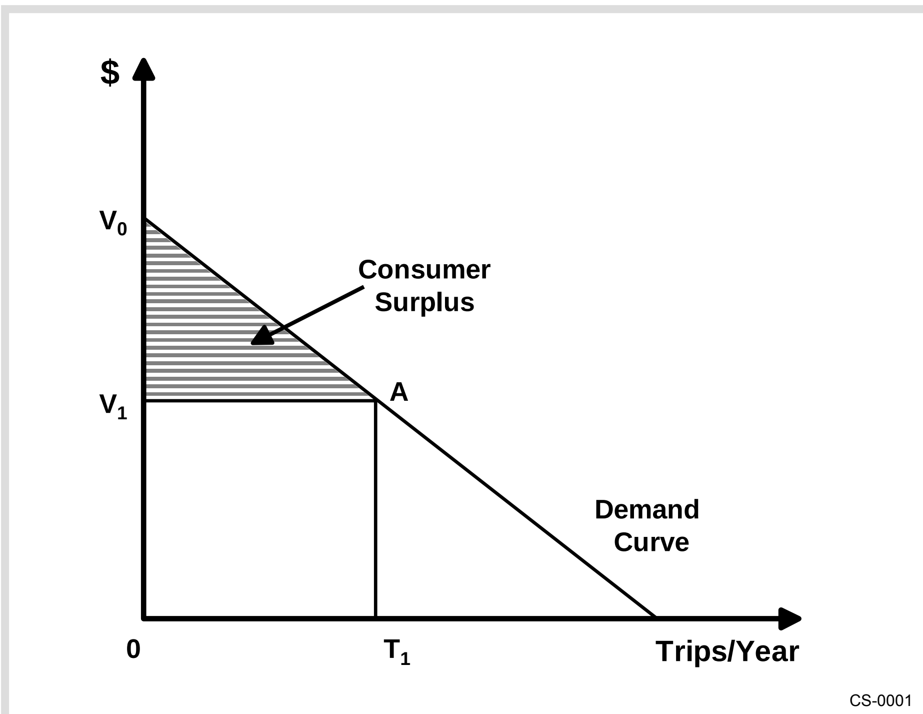


Figure 5-3
The Demand Curve and Consumer Surplus

The area V_1AT_10 shows the individual expenditure on recreational fishing trips. Because the height of the demand curve measures a person's maximum WTP for each fishing trip, the total WTP for all fishing trips between zero and T_1 is the entire area under the demand curve: total expenditures plus the triangle V_1V_0A. The triangle V_1V_oA is the difference between what people actually pay for a recreational fishing trip and the amount they are willing to pay for each trip individually. The value of this triangle is called consumer surplus, and it is the dollar measure of the satisfaction, or utility, people receive from consuming a good or service, beyond what they pay for it.

For a nonmarket service like recreational fishing, the price represents the cost of taking the trip. This price may include transportation costs, the opportunity cost of time, entrance fees, and other trip-related costs. The price of a good itself does not represent consumer welfare. Rather, the surplus value a consumer retains, the difference between what a consumer is willing to pay and what a consumer has to pay (cost) must be measured to determine the consumer's welfare. Consumer surplus is widely accepted as the appropriate measure of the social value of environmental goods (Zerbe and Dively 1994).

For a recreational fishery, the benefit measure appropriate for benefit-cost analysis is the increase in consumer surplus provided by additional trips to the site that occur as a result of a reduction in I&E losses. A reduction in I&E at a facility will lead to an improvement in fish catch at a site, which increases people's enjoyment of (and hence value for) the site, increasing the value of the site's services at each visitation level. This increase in value causes the outward shift in the demand curve shown in Figure 5-4. Thus, the benefit of the improvement in fish catch is measured as an increase in consumer surplus represented by the shaded area in Figure 5-4. Summed over all individuals, it is a measure of the aggregate gain in social well-being.

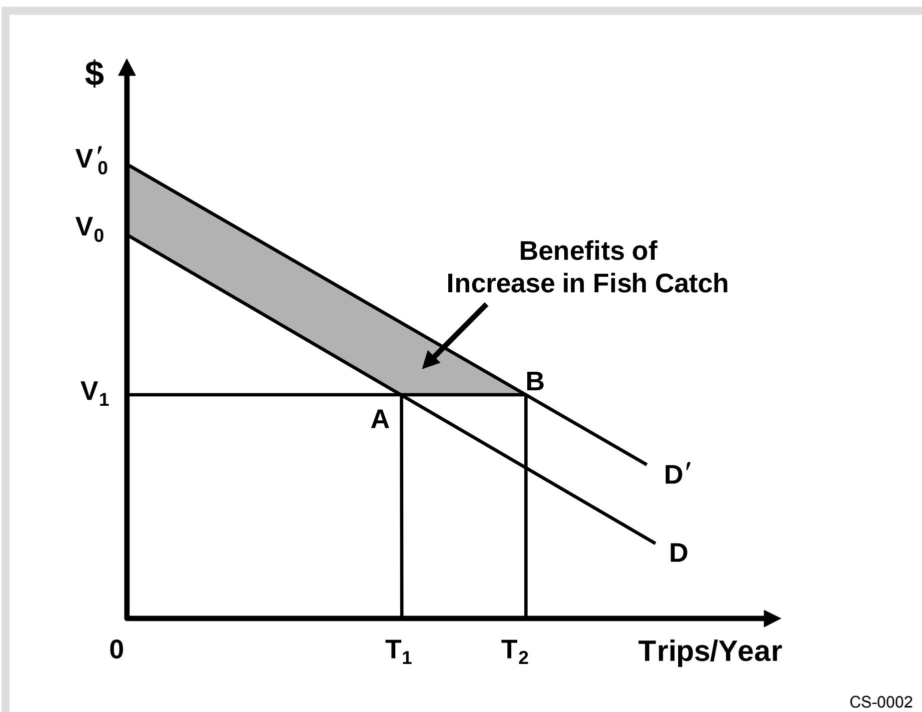


Figure 5-4
Increase in Consumer Surplus from Reduction in I&E

The RUM is the best available tool for measuring changes in consumer surplus for recreation services. Resource economists have long used RUMs in policy applications (Bockstael, Hanemann, and Strand 1986; Bockstael, McConnell, and Strand 1991; Feenberg and Mills 1980; Caulkins, Bishop, and Bouwes 1986; Bockstael, Hanemann, and Kling 1987; Morey, Shaw, and Rowe 1991), and the EPA endorses the use of RUMs for 316(b) applications (69 [131] *Fed. Reg.*

41658 July 9, 2004).[17] The RUM is based on welfare theory and posits that individuals make choices that maximize their utility, subject to constraints. It uses anglers' actual choices to model the factors that influence the site an angler chooses to visit. To the extent that the angler trades off factors such as distance to the site against the quality of the fishing opportunity, we can model the relative influence of these variables as revealed by anglers' decisions. Incorporating the relevant substitute sites, the RUM can then evaluate the importance of site characteristics at each of these sites to determine the site's value to anglers.

Fishing sites are made up of different characteristics. The characteristics of each fishing site, such as fish catch rate, presence of facilities like a boat ramp or lighted fishing pier, and distance to the site from the angler's home, distinguish one site from another. Fishing sites are similar to other goods and services in this respect. For example, different cars have characteristics that distinguish them from one another. Likewise, banking services differ in minimum balance requirements, interest rates, and fees.

Anglers choose the "best" site and fish at the site with the combination of characteristics that gives them the most satisfaction. The "best" site may differ for each angler, depending on the distance to the site. The decision to travel to a site is also affected by time and angler income. Again, choosing a fishing site is similar to choosing among other goods. When choosing a bank, for example, Joe wants to open an account at the bank closest to his house. Mary is willing to travel farther to a bank that offers free checking. Anglers have preferences for fishing sites as well. Joe does not want to travel far from home to fish. Mary prefers to visit a site where she can launch her boat, even if it is farther from home.

The focus on site characteristics, such as catch rates, permits us to isolate the benefits of I&E reductions on recreational fishing. All other site characteristics are held constant. The better the characteristics of a site are, the higher the probability that an angler will choose that site, which is reflected in a higher value for the site. RUMs can be used to estimate both the distribution of trips among various sites and the total satisfaction received from a given set of fishing opportunities.

To determine how much total angler satisfaction would increase from reducing I&E at HBGS, we measure the attractiveness of coastal fishing sites based on current catch rates (based on the current level of I&E). We then recalculate the model to reflect the higher catch rates that anglers would experience at coastal fishing sites with reduced I&E. The difference in angler satisfaction between the two scenarios corresponds to the benefits from reducing I&E at HBGS.

In addition to the direct-use benefits that are measured through the RUM, our assessment also includes indirect-use benefits associated with increases in forage fish. As described earlier, an increase in numbers of forage fish can indirectly benefit anglers and commercial fishermen through an increase in the numbers of harvested species that feed on the forage fish. Our methodology explicitly accounts for this effects. Thus, the increase in catch rate described in our

[17] RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985).

RUM reflects both the direct-use benefits and the indirect-use benefits. Section 6.1 describes the RUM results.

Commercial Fishery—Producer and Consumer Surplus

For many markets, producer surplus is used to measure changes in welfare when it is production, and not consumption, that is affected by the change in environmental services. To determine producer surplus, we must look at the supply curve instead of the demand curve. A supply curve, as shown in Figure 5-5, illustrates how much of a good a producer will supply at each market price.[18] In this case, the supply curve shows the amount of fish a commercial fisherman will supply at each market price. To maximize profits, producers choose to produce to a point where the marginal cost of producing the last unit is equal to the price received for that unit in the marketplace. Thus, the supply curve represents the marginal cost of producing each unit.

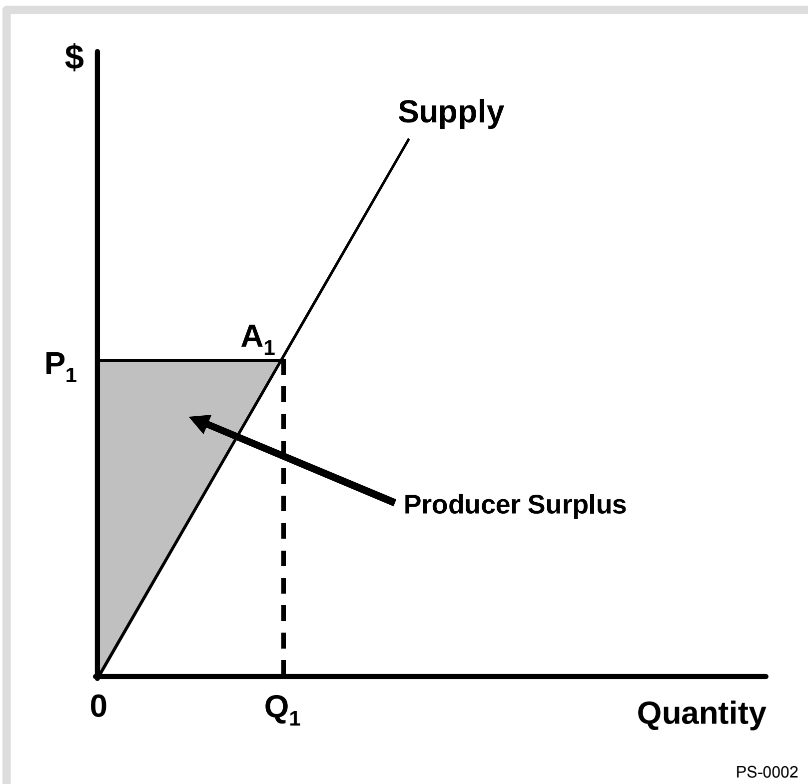


Figure 5-5
The Supply Curve and Producer Surplus

In a competitive market, no individual producer can affect the market price, making producers "price-takers." Thus, the price is determined exogenously and shown in the figure as P_1. At price P_1, the producer is willing to produce Q_1 units. Selling the Q_1 units at price P_1 generates

[18] In this simplified discussion, we assume that producers know what the market price is when they make their supply decisions. Of course, the actual situation is more complex.

revenue represented by the rectangle of $0Q_1A_1P_1$. Because the supply curve represents the marginal cost of production for each unit, the area under the supply curve up to Q_1 represents the costs of production for Q_1 units. The remaining triangle, $0A_1P_1$, is the producer surplus, which represents the amount of revenue received that exceeds the marginal cost of production.

A decrease in the cost of production causes the supply curve to shift to the right. The marginal cost of producing each unit is now lower. Figure 5-6 illustrates this shift: S_1 shows the original supply curve and S_2 shows the curve after the decrease in production costs. Because individual producers are price-takers and cannot change the market price, it remains at P_1. However, with the new supply curve S_2, a producer can choose to supply more units, shown by Q_2. The resulting increase in producer surplus is the area bounded by $0A_1A_2Q_1$.

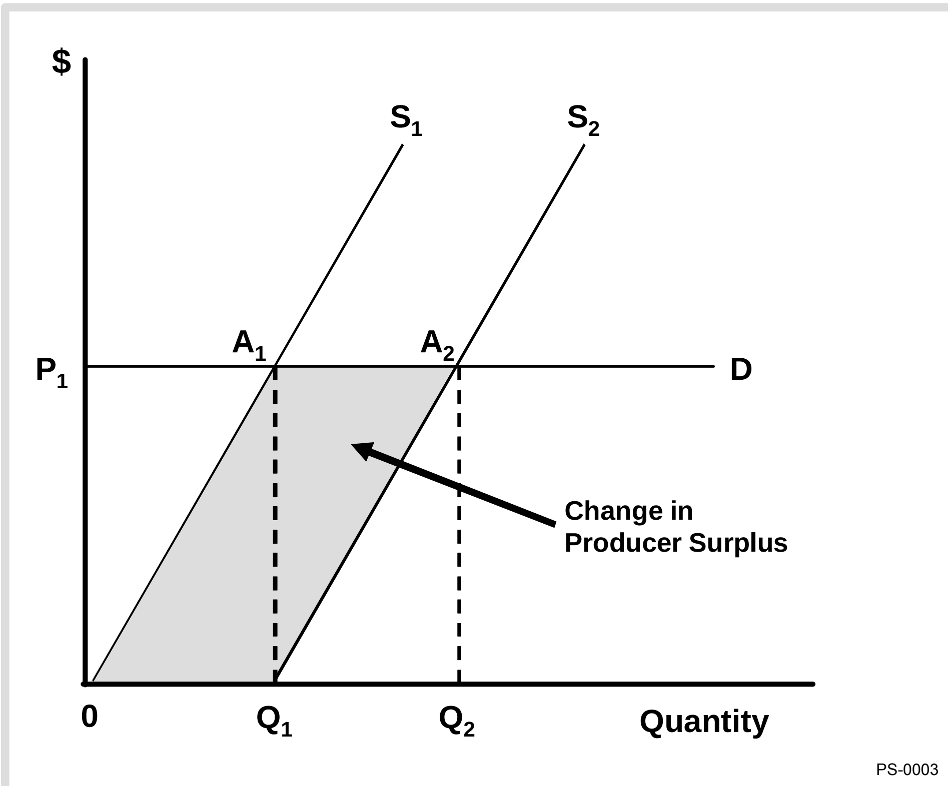


Figure 5-6
Change in Producer Surplus from a Supply Shift

Commercial fishing differs from the typical markets presented in Figures 5-5 and 5-6. Specifically, fisheries belong to a class of resources termed *common property*. By tradition and because of the high cost of rationing their use, these resources are not privatized but are either overseen by government (e.g., nearshore fisheries) or left unregulated (e.g., ocean fisheries). Like some other common property resources (e.g., forests, pastures), fisheries are also, as characterized by Tietenberg (2006), an interactive resource because their species population is jointly determined by both the biological conditions and by the actions taken by society. Thus, a potential problem these resources face is overuse.

When access to a common property fishery is open to anyone, individuals and organizations will enter the business of harvesting fish as long as their expected profits are positive. The result is that many open access fisheries and other resources are exploited beyond economically sustainable harvest levels. Governments world-wide have addressed what Garrett Hardin (1968) labeled as "The Tragedy of the Commons" through a variety of rules and regulations designed to curb overfishing in the resources under their aegis.

Many states and other governmental agencies may require a license or permit to fish commercially. Although the permitting process may not be onerous, it can present a minor and temporary barrier to entry. For some species, harvest quotas may also be established by the relevant regulatory agency to protect certain species from overfishing. For all of these reasons, a particular fishing market may not react in the way that Figures 5-5 and 5-6 describe.

Commercial benefits from I&E reductions accrue primarily to commercial fishermen as increased profit due to the higher catch per unit effort (CPUE) associated with increases in fish populations. The ability of commercial fishermen to realize *sustained* increased profits depends on the responsiveness of market prices to higher CPUE. The tendency for producer surplus to reach zero in the long-run is a well-known foundation of microeconomic theory (Mansfield 1988). However, producer surplus elimination through competition depends upon price changes. It may be possible to have some long-run producer surplus if there are market restrictions such as quotas or regulations.

Market extremes determine the upper and lower bounds on commercial benefits. In competitive markets, prices adjust instantly and there are no benefits. In restricted markets, prices may not change.

Consider first the case where the fishery is an open access fishery. In an open access fishery, new entrants are expected as long as the price of anticipated catch exceeds the cost of entry. The entry of new suppliers (or increased effort of existing suppliers) tends to reduce the stock of fish, raising the cost of catching fish for all participants. Suppliers will continue to enter as long as expected profits are above the normal rate of return for this class of investment. Entry ceases when the price and average cost of harvesting fish are equated at the industry level. At this point, producer surplus is eliminated. Thus, once all adjustments are made, markets reach equilibrium and there is no producer surplus.

This situation is shown in Figure 5-7. Here, the original long-run supply curve is horizontal and producer surplus (represented by the area between the price line and supply curve) is zero. As the stock of fish increases because I&E is reduced, the cost of catching fish drops. Because a supply curve represents costs, permanent lower per fish harvest costs can be depicted by a downward shift in the long-run supply curve (LRS_1 to LRS_2). When all anglers face lower harvest costs, they compete to sell additional fish by lowering prices. This leads to a decrease in long-run equilibrium price (P_1 to P_2). Once competition has caused prices to adjust, there is no producer surplus. Thus, in a competitive situation, benefits do not accrue to commercial anglers. The advantage this sector gains due to lower costs is completely offset by lower prices.

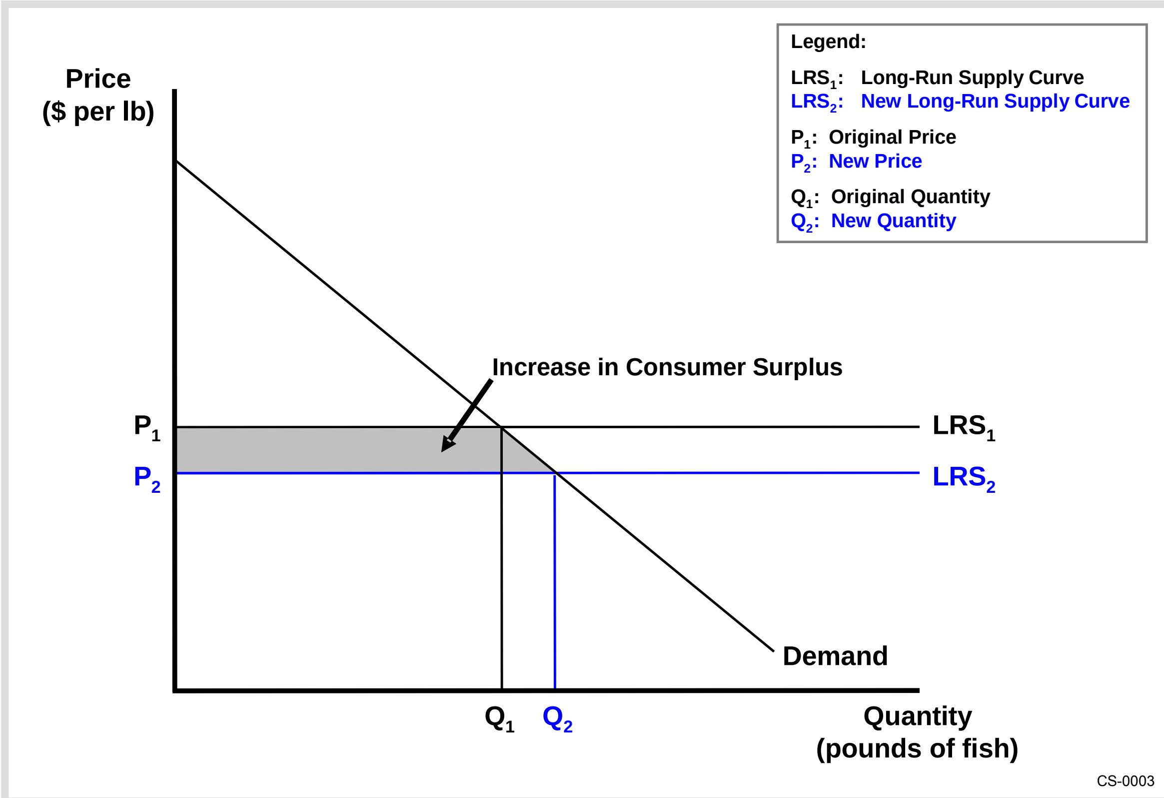


Figure 5-7
Commercial Fish Market with Open Access

However, there is a societal benefit to lower harvest costs, which accrues to fish consumers. Consumers benefit through lower market prices. This benefit can be estimated by calculating the increase in *consumer* surplus that is associated with lower harvest costs. Consumer surplus is the difference between what consumers are willing to pay (as represented by the demand curve) and market price. The change in consumer surplus associated with lower costs in a competitive market is the shaded area depicted in Figure 5-7.

The increase in consumer surplus CS can be calculated mathematically by:

$$\Delta CS = [(P_1 - P_2) * Q_2] - [0.5(P_1 - P_2) * (Q_2 - Q_1)] \qquad \textbf{(5-1)}$$

Inputs to this calculation are existing price and quantity, expected change in quantity, and expected change in price. The change in quantity is already developed through expected reductions in I&E and resultant catch improvements. In order to estimate the change in the long-run equilibrium price, we use the price elasticity of demand for fish. Price elasticity of demand is also called simply elasticity or own price elasticity. It refers to the percent change in quantity associated with a percent change in price. For example, if the price elasticity of demand is –1.5 and the percentage change in quantity is 1%, then the estimated percentage change in price would be:

$$e = \frac{\%DQ}{\%DP} \quad \textbf{(5-2)}$$

$$\%DP = \frac{\%DQ}{e} = \frac{1}{(-\ 1.5)} = -\ 0.67\%$$

This information can be used to calculate the new price level and estimate the change in consumer surplus.

Now consider a model of fish stock improvement under a fishery regime that restricts output. In this model, the government sets a quota on the quantity of commercial stock sold and the quota is the equilibrium quantity (Q_1). As shown in Figure 5-8, there is no initial long-run producer surplus. As the reduction in I&E leads to an increase in the commercial stock, the long-run supply curve shifts down from LRS_1 to LRS_2. However, the quantity supplied remains at Q_1 (the quota level) and the corresponding equilibrium price remains at P_1. In this situation, there would be an increase in producer surplus because the equilibrium price exceeds average costs. The producer surplus is the difference between production costs and price (the shaded area of Figure 5-8) or $(P_1 - P_2) * Q_1$. In this manner, existing price and quantity information can be combined with price elasticity of demand estimates to anticipate changes in producer surplus when there are market restrictions.

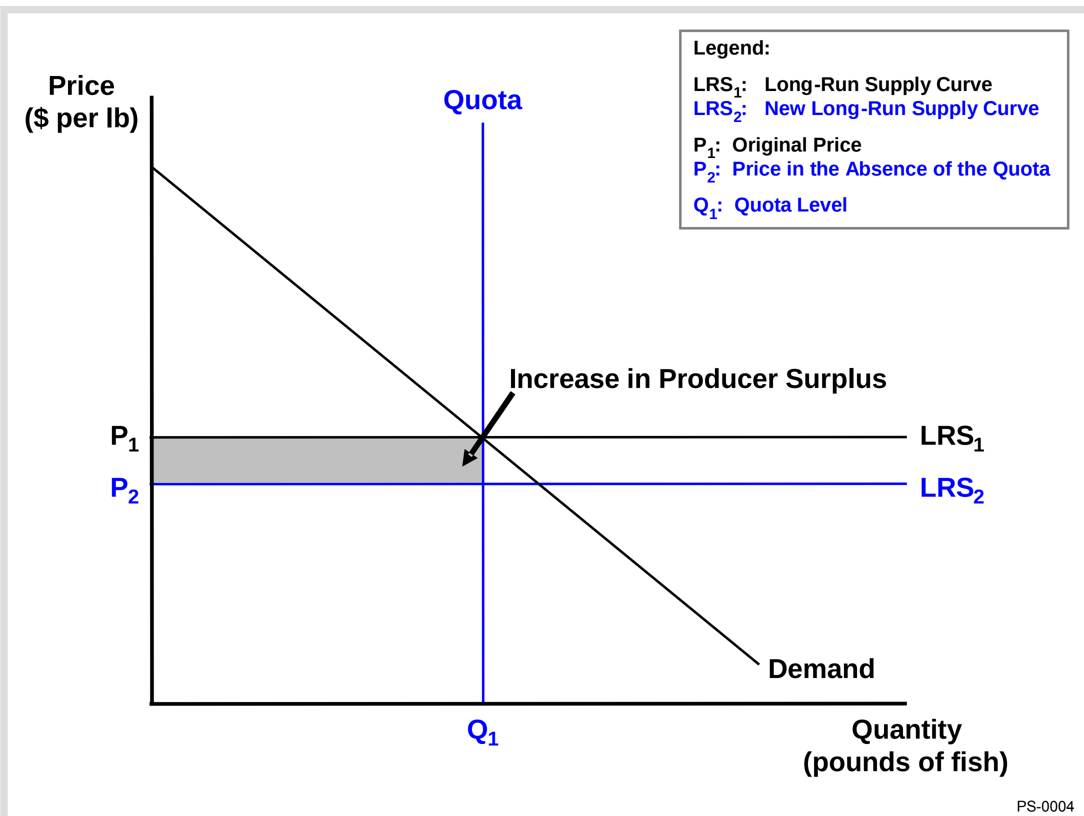


Figure 5-8
Commercial Fish Market (with a Quota)

In terms of the commercial species impinged and entrained at HBGS, none of them is subject to harvest quotas (see Sections 3 and 4 above). However, the California DFG limits access to several of the affected fisheries. Therefore, these fisheries near HBGS reflect neither of the market extremes presented in Figures 5-7 and 5-8.

For purposes of this assessment, we assume that all commercial fishing benefits accrue to consumers. We contend that this position is more conceptually correct than either of the extremes presented. The primary reason for this is that producer surplus is a transitory state that will be eroded through entry and eventually transferred to consumers in the form of lower prices. Moreover, the data necessary to accurately measure producer surplus are not publicly available.

Accordingly, we estimate potential benefits to commercial fisheries near HBGS by computing consumer surplus changes in light of likely demand elasticities. The gain in consumer welfare will depend on original consumption rate, Q_1, the size of the harvest cost decrease, and the responsiveness of consumer demand to the lower price.[19] For markets that are more national or global in nature, we expect a more elastic response to price changes. This occurs because comparable fish are available from more substitute sources. For local markets, we would expect to see less response to a price change because there are fewer alternative sources for comparable fish, compared to larger markets.

Unitary elasticity indicates that price and quantity change by equal proportions but in opposite directions. A review indicates that assuming unitary elasticity (–1) is appropriate for many commercial fish species (Wessells and Anderson 1992; Wessells and Wilen 1994; DeVoretz and Salvanes 1997). Our analysis, the details of which are described in Section 6 below, considers a range of demand elasticities from –0.01 to -–3.00 and varies by the nature of the market for each affected species.

Nonuse Values

Nonuse values are the values that people may hold for a resource independent of their use of the resource. That is, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist. As the EPA rule points out, the economic literature commonly refers to these two components of nonuse values as “bequest” (or “altruistic”) values and “existence” values, respectively (EPA 2004b, p. A9-3).

The EPA provides the following list of nonuse values in its final rule guidance (EPA 2004b, p. A9-3):

- Intergenerational equity
- Stewardship
- Altruism

[19] Since demand curves slope downward this will be a negative number. For example, if the elasticity of demand (ή) is -2, a 10 percent reduction in price will occasion a 20 percent increase in quantity demanded. The elasticity of demand is thus bounded 0< ή < -∞.

- Option value
- Historical/cultural value
- Philanthropy
- Existence
- Bequest
- Vicarious consumption.

Thus, when considering nonuse values, we must discern how a potential increase in the numbers of fish improves human welfare, in the specific ways that EPA identifies with the list above. These improvements in human welfare must be beyond the direct-use and indirect-use benefits associated with recreational and commercial fishing and avoid double-counting.

Moreover, the conceptual framework and challenges associated with properly valuing the potential nonuse benefits can be illustrated through the economic concept of rivalry (Tietenberg 2006).[20] Many goods can only be consumed once by a single person. These goods are termed rival goods. Food is an example of a rival good. An apple eaten by one individual cannot be eaten by another person. Therefore the consumption of food by one person eliminates the possibility that the food can be consumed by another. Goods whose consumption does not imply depletion are called nonrival. A typical example might be a public waterbody. For nonrival goods like public waterbodies, at reasonable levels of use, one person's use of the resource does not diminish the ability of other people to use it.

The importance of differentiating between rival and non-rival goods in assessing the potential nonuse benefits becomes apparent when evaluating the potential societal benefits associated with protecting an additional fish. The nonrenewable nature of use benefits realized by recreational anglers significantly diminishes the likelihood of both existence and bequest motivations for nonuse values. Use of the resource reduces the stock of fish, which is purportedly increased through reduced I&E impacts. Once these benefits have been realized, they are no longer available to others. In this instance, nonuse valuation predicated upon existence or bequest motivations seems at odds with the presence of recreation use values. Thus, the nonuse benefits outlined by EPA (see the bullet list above) can be applied only to the uncaught fish that are harvested recreationally or commercially. Additional fish harvests, and the forage biomass, have been accounted for in the use values. Their rival nature makes nonuse benefits for these fish unavailable to nonusers.

The 316(b) rule requires that the benefits assessment consider the nonuse benefits associated with reductions in I&E (EPA 2004a, p. 41,647). However, because of conceptual and empirical challenges associated with measuring nonuse values, which are further described in Appendix B, the Agency decided in the final rule that "…none of the available methods for estimating either use or nonuse values of ecological resources is perfectly accurate; all have shortcomings" (EPA 2004a, p. 41624). More importantly, EPA determined that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule,

[20] See Desvousges et al (2005) for additional details on this topic.

and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004a, p. 41624).

Therefore, in the final Phase II Rule, EPA provides the following guidance on how to assess the nonuse benefits associated with reductions in I&E:

> Nonuse benefits may arise from reduced impacts to ecological resources that the public considers important, such as threatened and endangered species. Nonuse benefits can generally only be monetized through the use of stated preference (SP) methods. When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information.
>
> In cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, nonuse benefits should be monetized. (EPA 2004a, p. 41,647–41,648).

Thus, in cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not required.

6
ECONOMIC BENEFIT ESTIMATES

Economic benefit categories considered include commercial, recreational, and nonuse. This portion of the report provides details on the quantification of recreational fishery benefits and a qualitative discussion of potential nonuse benefits.

Recreational Fishing Benefits

As described in the previous section, random utility models (RUMs) provide the best method for valuing I&E reduction impacts on recreational fishing. However, conducting an original RUM study can require extensive primary data collection.

In this analysis, we use the results of an existing recreational fishing model to develop estimates of the recreational fishing benefits associated with I&E reductions at the HBGS. Using the valuation results of one study and applying them to another scenario is called "benefits transfer." The economics literature has established criteria to be fulfilled for benefits transfer studies (EPA 2000; Brookshire and Neill 1992; Smith 1992; Desvousges, Naughton, and Parsons 1992; McConnell 1992; Boyle and Bergstrom 1992; Desvousges, Johnson, and Banzhaf 1998). These criteria are termed similarity and soundness.

For use in valuation, the first criterion, similarity, or "fit," recognizes that transferred values from existing studies can be relevant only if these values measure the quantity of interest in the current study. For example, the value of a brand-new luxury SUV should not be identified by the blue book value of a ten-year-old compact car. For this analysis, a transfer study should include a similar fishing experience to that offered by the coastal waters near Huntington Beach. To maximize similarity, this analysis employs a site-calibrated transfer of an existing RUM model. This approach allows capturing important site-specific compensating behavioral responses without requiring survey data collection. The accuracy of this methodology is limited only by the analyst's ability to calibrate a previously estimated preference function to a different population using appropriate economic methodologies (Smith, van Houtven, and Pattanayak 2002).

The second criterion, scientific soundness, refers to the overall quality of a study and is widely recognized as a primary criterion for applying the results from one study to another situation. The quality encompasses all aspects of a study, such as the data, the methodology, the survey protocols, and the analysis technique. This criterion effectively asks whether the original study is sufficiently sound to pass scientific muster. If the results were not based on reliable data, rigorous protocols, and valid analyses, then the results are not reliable and should not be used.

Economic Benefit Estimates

For this assessment, we have conducted a site-calibrated benefits transfer with the California region RUM (CRR) developed by the EPA for its California Regional case study (EPA 2004b). These models rely upon data from the 2000 Marine Recreational Fisheries Statistics Survey (National Marine Fisheries Service [NMFS]). These data were collected on-site by interviewing anglers at the conclusion of their fishing trips, and via telephone. The California case study contains separate models for shore anglers and boat anglers. The models acknowledge that anglers who fish south of Point Conception may have different preferences for target species and catch rate improvements than those who choose fishing sites farther north. Thus, we believe that the CRR models are sufficiently similar for use as a site-calibrated benefits transfer.

The CRR also satisfies the soundness criterion. The underlying data reflect more than 11,000 fishing trips in California coastal waters. The data are collected using rigorous protocols consistent with survey research guidelines. These recreational fishing models are consistent with the RUM framework described in Section 5. The models are rigorous, perform well, and reflect results that are consistent with expectations.

The CRR, however, is not without some limitations as a transfer study. Because it is not a published study, it has not been through an independent, peer-review process. While unpublished studies are not necessarily unsound, published studies have been scrutinized by peers who raise potential quality problems in their initial reviews, which often results in a strengthening of the technical merits of published studies. An evaluation of published studies does not identify a more suitable study. For example, Kling and Herriges (1995) develop a basic RUM for southern California marine anglers that includes travel cost, an aggregate catch rate (for all species combined) and a variable for fishing mode (beach, pier, private boat, or charter boat). Kling and Thomson (1996) describe multiple RUMs for marine fishing in southern California. However, they do not provide the coefficients of the site characteristics, which is critical for the site-calibrated transfer. Moreover, both published studies are also based on data from the 1980s and may not reflect current angler preferences accurately.

Another possible limitation of the CRR as a transfer study is that the separate models for shore fishing and boat fishing would not address cross-mode substitution possibilities. For example, if catch rate improvements were such that shore anglers would prefer to become boat anglers, then these models would not capture that switch. However, given the specifics of this assessment, we do not believe this phenomenon would result from I&E reductions, particularly those of the type and magnitude here. Pier angling, which accounts for the vast majority of shore-based angling in southern California (California DFG 2006c), does not require a fishing license while all forms of boat angling do. Moreover, owning or renting a boat from which to fish requires additional expenditures. Thus, switching from pier/shore fishing to boat fishing would require additional expenditures. Given the small percentage increases in catch rates that are predicted to result from reducing I&E at HBGS, we do not believe the inability to account for mode-switching introduces bias in our results.

Similarly, the design of the models would not predict whether anglers would change their target species in response to increased catch rates. Again, given the specifics of this assessment, we do not believe that this limitation is significant in our assessment. Based on the 2000 NMFS data that the EPA summarizes in its California case study, only 21 percent of the southern California anglers target the species impacted by I&E at HBGS (queenfish, croakers, shiner perch, California halibut and diamond turbot). Thus, it seems unlikely that reducing I&E at HBGS would result in large numbers of anglers changing their target species.

As a related matter, the EPA model does not explicitly model the anglers who take trips on charter or "party" boats. According to California DFG (2006c), in 2005, charter boat trips accounted for 44 percent of boat-based trips and 19 percent of all fishing trips in Southern California. However, in this analysis we, with the authors of the EPA analysis, intend to apply the results of the boat model to these charter boat trips. Kling and Thomson (1996) evaluated welfare estimates for various fishing modes and generally found that per-trip gains for private boat trips were usually larger than were comparable gains for party boat trips. Thus, our strategy is more likely to lead to an overestimate of benefits rather than an underestimate.

In addition, the EPA models do not include a participation component. That is, the models would not predict a change (presumably an increase) in the number of anglers or in the number of trips taken by current anglers as a result of the reduction in I&E. Again, we do not find this limitation particularly meaningful for this particular assessment. Given that catch rates are predicted to increase only a small percentage (see below), we do not believe that this limitation unduly biases our results.

Similarly, the EPA models are based only on single-day trips and do not explicitly model multiple-day trips. Multiple-day trips present a challenging issue in recreational modeling because multiple-day trips are often multi-purpose trips, potentially overstating the assignment of travel costs to the fishing activities. We intend to value multi-day trips by treating them as multiple single day trips. That is, a two-day fishing trip would be counted as two single-day fishing trips. EPA cites unpublished studies that reveal that multi-day anglers have higher trip values than do single-day anglers for east coast and Midwestern sites. If this result holds for marine fishing in southern California, then it is possible that our results may underestimate benefits associated with reduced I&E at HBGS. The extent of that underestimate depends on the relative proportion of multiple days trips and the marginal difference in per trip values associated with catch rate improvements for the bottom and flat fish species that are affected by I&E at HBGS.

Moreover, the on-site data collection likely introduces avidity bias into the results because anglers who fish more often are more likely to be interviewed. Although analysts typically adjust for avidity bias by weighting their models, the EPA models have not made these adjustments. In terms of the potential effect of avidity bias in our assessment, the results may be unrepresentative only if the more avid anglers have different preferences for trading off increased travel distance for increased catch. If the relative trade-offs for avid anglers and less frequent anglers are similar, then the avidity bias in the data is not likely to unduly affect this assessment.

A 50-mile radius from Huntington Beach was used in the calibration to reflect local angling activity near the Huntington Beach Generating Station. The 50-mile radius reflects a reasonable distance for a single-day trip to the site and is likely to include the majority of coastal marine anglers who fish near Huntington Beach. In fact, EPA (2004b) reveals that the average, one-way travel distance for southern California marine anglers is 24 miles. Because we include anglers who may travel more than twice that distance, we believe our approach captures the majority of the anglers potentially impacted by I&E reductions at HBGS.

The valuation approach employed by multiple-site travel cost models is based on predictions of changes in recreational activities and valuation of those changes. In this case, we evaluate how augmenting the annual harvest at coastal fishing sites near Huntington Beach (across all relevant anglers) would affect the consumer surplus for the potentially affected anglers. The simulation captures substitution among sites. This adds a critical level of realism that tends to mitigate loss estimates and increase estimates of gains relative to models that ignore substitution possibilities. Important factors unique to a site that influence the amount of substitution include site location and population distributions.

In this assessment, calibration to reflect the availability of substitute sites considers substitute angling opportunities within a 200-mile coastal range. If the typical angler travels up to 50 miles to his fishing site, that means anglers at the outer edge of the 50-mile radius from Huntington Beach may choose to fish at another site 50 miles in the opposite direction. Thus, to identify the geographic area that contains the relevant substitute sites, we include coastal fishing sites within 100 miles north and 100 miles south from Huntington Beach. The geographic range corresponds roughly to the Santa Barbara-Ventura County line and the southern edge of San Diego County (the U.S.-Mexican border). Figure 6-1 depicts the geographic range of potentially affected anglers and the most relevant substitute sites.

Figure 6-1
Affected Population and Substitute Sites

This figure shows the 50-mile radius where potentially affected anglers live and the 200-mile range of potential substitute sites for those angers.

The 100-mile range is generally consistent with, but somewhat more conservative, than the 140-mile range that the EPA uses in the California Regional study (EPA 2004b). However, in that study, the EPA wanted to capture potential substitution between marine sites in central and northern California and marine sites in central and southern California as the study was a state-wide study. Because our focus here is specifically on substitution opportunities for trips taken near Huntington Beach, we believe that this slightly smaller geographic is appropriate. Moreover, a larger area introduces more substitution possibilities, which can dilute the benefit estimates.

We compiled a list of coastal fishing sites from the *Southern and Central California Atlas and Gazetteer* (DeLorme 2005). This source indicates the location (including latitude and longitude) of fishing piers, public beaches, and boat ramps along the coast. Our research revealed 31 fishing piers, 57 public beaches from which shore fishing is possible, and 36 boat ramps within the 100-mile range. Appendix E provides a detailed listing of the relevant coastal fishing sites.

California DFG conducts annual on-site assessments of angling pressure along the California coast (California DFG 2006c), by county groupings. The "Southern" Coast includes marine sites in Los Angeles, Orange, and San Diego Counties, all of which are within the relevant geographic range identified in Figure 6-1 above. The "Channel" County grouping includes Santa Barbara and Ventura Counties. Although Ventura County is within the relevant area, Santa Barbara County is not. To estimate the portion of these trips that occur within Ventura County, we use the site characteristics of sites within the county to estimate visitation probability. In the CRR study, the number of trips is divided by target species and mode of fishing. These trips are multiplied by the probability that an angler will visit a particular site to determine the number of trips to each site.

The distance traveled to a site is one of the most important site characteristics in a RUM. It directly influences the travel cost to each site for each angler. A critical factor for the site-calibrated benefits transfer is distance from each anglers' residence (Zip code) to each of the relevant coastal fishing sites.[21] These distances are calculated using the most recent version of a popular transportation routing software called PC*Miler. The EPA California models use the estimated travel cost, rather than distance. For the calibrated RUM, travel costs from each of the zip codes to each of the relevant sites are calculated to be consistent with the EPA models. Specifically, travel costs reflect both direct costs and travel time costs. Direct costs are calculated by multiplying the round-trip miles by the standard per mile reimbursement (GSA 2006). The costs of travel time were also calculated to be consistent with the EPA models. The average hourly wage of each zip code within the 50-mile radius was calculated by dividing household income from the U.S. Census by 2000 work hours per year and escalated to 2006 dollars. Travel speed was assumed to average 50 miles per hour. The round-trip time estimate (round trip distance divided by speed of travel) was multiplied by one-third of the average hourly wage rate to reflect the opportunity cost of time. The travel cost included in the model is sum of the direct travel cost and the travel time costs.

[21] The 50-mile radius from Huntington Beach is "as the crow files." The distances calculated for the site-calibrated benefits transfer are the road distances that anglers would actually drive, based on PC*Miler estimates.

Economic Benefit Estimates

For purposes of this assessment, the expected catch rate at each site is an important site characteristic because it is the site characteristic that may be enhanced by a reduction in I&E at the HBGS. In this case, we evaluate how augmenting the annual catch (including fish subsequently released) at coastal fishing sites would affect the consumer surplus for the affected anglers. We determine existing catch rates for the relevant fishing sites based on the same species groups evaluated in the EPA California models, allowing for differences in boat and shore modes (EPA 2004b). Table 6-1 contains that information, based on the species groupings needed for the RUM.[22]

Table 6-1
Estimated Catch by Species Groups for Coastal California Sites under Current Conditions (Fish per Angler per Hour)

Species/Species Group	Boat	Shore
Small game	0.192	0.418
Striped bass	0.002	N/A
Bottom fish	0.145	0.730
Flatfish	0.096	0.227
Big game	0.057	N/A
Salmon	0.009	N/A
Sea basses	0.231	0.353
Other species	0.104	0.267
Other small fish	0.080	0.615
No target	0.238	0.569
Jacks	0.065	N/A

Source: EPA (2004b)

Our next task is to determine at which sites anglers will experience increases in catch if I&E were reduced. For the impinged and entrained species, we researched whether information was available on the typical range (in miles) of the affected species but faced a paucity of data. Therefore, we assume that the relevant fish species would stay within the Southern California Bight and would be caught there.

Section 4.4 above contains the details of the augmented harvest of recreational fish I&E. For each year in the assessment, we grouped the increase in recreational harvest to correspond to the species groupings used in the RUMs, as shown in Table 6-1 above. We also aggregated the I&E impacts together for valuation purposes. To determine the portions of the augmented catch that would be experienced by boat anglers and shore anglers, we used the catch rates above in Table 6-1 as weights. For example, shore anglers catch roughly twice as many small game fish as do

[22] See EPA (2004b) for a listing of the various species within the species groups. All of the recreational species impinged and entrained at HBGS are in the flatfish and bottom fish groups.

boat anglers. Thus, approximately two-thirds of the increased harvest of small game fish was allocated to shore anglers and approximately one-third of it was allocated to boat anglers. Within the defined geographic area, the increased catch is distributed evenly across all trips. That is, each boat or shore site gets an equal share of the increased catch.

Table 6-2 contains the expected equilibrium changes in catch for the relevant sites. Because I&E at HBGS affect only species in the bottom and flatfish groups, no other catch rates are affected.

Table 6-2
Expected Changes in Catch by Species Groups for the First Impacted Year

Species/Species Group	Boat	Shore
Bottom fish	0.0001	0.0003
Flatfish	0.00001	0.0002

The statistical model used in estimating a RUM is the conditional logit. The conditional logit evaluates a specific outcome conditional on the available alternatives. In fishing models, the conditional logit evaluates the selection of a particular fishing site based on the characteristics of that site and the characteristics of other fishing sites. The output from the conditional logit is the vector of coefficients for each site characteristic. Each coefficient reflects the importance of that site characteristic in the site choice decision. Maximum likelihood estimation is used to estimate the values of the coefficients in the conditional logit. Given the characteristics of all options available to the anglers, the conditional logit estimates coefficients that maximize the likelihood that we would observe the anglers' actual choices.

To understand maximum likelihood techniques, picture the site choice decision as a hill. There are many points on the surface of the hill, but only one point on the top. Many different combinations of the relative importance for site characteristics could reflect site choice decisions, but only one combination of coefficients most accurately reflects anglers' actual decisions. Maximum likelihood estimation moves step by step up the hill using different combinations of coefficients for the site characteristics, trying to best fit the importance of the characteristics to actual behavior. The final coefficients are those that maximize the likelihood that the observed site choice decisions are predicted by the model.

Table 6-3 presents the coefficients from the CCR models. The travel cost parameter has been previously discussed. It is negative, indicating that additional time or travel expenses decrease angler utility when all other site features are held constant. The marina/dock variable and the jetty variable indicate whether those features exist at the site. In the shore model, we would expect anglers to prefer sites with piers but avoid sites with boat ramps. In the boat model, we would expect boat anglers to avoid sites with piers. However, the negative sign on the marina/dock variable is counterintuitive. The EPA hypothesizes that the negative sign reflects insufficient data. We add that it could also indicate congestion at ramps, to the extent that queuing at boat ramps reduces trip satisfaction.

The remaining variables in Table 6-3 reflect the catch rate variables for the southern California models. It is worthwhile to note that the species group catch rates correspond to anglers targeting the species. For anglers without a target species, the catch rate reflects all fish caught. The logical interpretation of these coefficients relates the catch rate coefficients to the travel cost coefficient. Because each coefficient reflects the relative importance of that characteristic, the results in Table 6-3 tell us the additional costs anglers are willing to incur to catch one more fish of each species.[23]

Table 6-3
Coefficients in the EPA California Models

Variable	Boat Model		Shore Model	
	Estimated Coefficient	t-statistic	Estimated Coefficient	t-statistic
Travel Cost	–0.0524	–73.39	–0.0827	–49.67
SQRT ($Q_{small\ game}$)	1.5578	12.10	1.9067	7.33
SQRT ($Q_{striped\ bass—North}$)	3.3437	7.82	1.9558	9.89
SQRT ($Q_{jacks—South}$)	11.9676	25.00	N/A	N/A
SQRT ($Q_{sea\ basses—South}$)	0.5443	5.51	0.1873	0.57
SQRT (Q_{bottom})	1.8420	15.58	0.7824	5.24
SQRT ($Q_{flatfish—North}$)	2.7179	12.71	2.4743	5.00
SQRT ($Q_{flatfish—\ South}$)	4.4960	21.81	1.6156	6.98
SQRT ($Q_{big\ game—North}$)	2.9221	5.51	N/A	N/A
SQRT ($Q_{big\ game—South}$)	1.5820	10.27	N/A	N/A
SQRT ($Q_{salmon—North}$)	5.5201	23.88	N/A	N/A
SQRT($Q_{salmon—South}$)	4.2645	5.63	N/A	N/A
SQRT ($Q_{sturgeon—North}$)	17.3385	10.21	N/A	N/A
SQRT ($Q_{other—North}$)	N/A	N/A	3.0937	5.28
SQRT ($Q_{other—South}$)	1.4604	2.30	1.7437	1.50
SQRT ($Q_{other\ small\ fish}$)	N/A	N/A	1.1416	6.63
SQRT ($Q_{no\ target}$)	0.4074	10.22	0.5255	8.23
Marina/Dock	N/A	N/A	–0.2206	–3.86
Marina/Dock— North	0.4235	10.17	N/A	N/A
Marina/Dock— South	–1.1688	–17.40	N/A	N/A
Pier/Jetty	–0.7106	–23.30	0.4777	12.81

Source: EPA (2004b)

The calibrated RUM uses the information in Tables 6-1, 6-2, and 6-3 to estimate the current value of consumer surplus, based on the current level of I&E. To simulate the value of consumer surplus based on I&E reductions at HBGS, we augment catch rates to reflect the conclusions of the population analyses in Section 4. This increased catch rate for affected coastal fishing sites in southern California is incorporated into the calibrated RUM while all other site characteristics for these sites are held constant. In addition, all sites characteristics, including the catch rates,

[23] Dividing the expected catch coefficient by the travel cost coefficient reveals the marginal value of additional catch by species. This calculation reveals marginal values rather than average values because substitution effects can lead to additional costs associated with catching the fish.

are held constant for the remaining sites. Angler behavioral responses to the changes in expected catch are identified by simulation. The calibrated RUM is re-run and provides an estimate of consumer surplus. Subtracting the original consumer surplus (with current levels of I&E) from the revised consumer surplus (with reduced levels of I&E) provides the potential benefits to recreational anglers that are uniquely attributable to I&E reductions at HBGS. This procedure is repeated for each year in the assessment. Table 6-4 depicts the change in trips to sites where catch is expected to increase.

Table 6-4
Change in Number of Trips to Sites with Increase in Expected Catch

Year	Bottom Fish	Flatfish
2007	0	0
2008	0	4.6
2009	0	7.1
2010	179.1	7.6
2011	132.1	7.7
2012	141.1	7.3
2013	135.4	49.3
2014	135.6	43.1
2015	135.2	37.8
2016	135.8	39.6
2017	136.6	40.2
2018	137.6	39.9
2019	138.9	39.9
2020	131.7	40.0
2021	135.4	40.0
2022	136.5	40.1
2023	135.7	40.1
2024	135.9	40.1
2025	135.8	40.2
2026	135.8	40.2
2027	135.8	40.3

Commercial Fishing Benefits

Commercially important species caught from California's marine waters may be sold locally or shipped to foreign markets. Most reach the market fresh, but some are frozen, particularly

Economic Benefit Estimates

California spiny lobster and California halibut. Northern anchovy, queenfish, shiner perch, and white croaker are used as baitfish. Northern anchovy also are used as animal feed and fertilizer; in fact, only a limited number of northern anchovy are used for human food.

As described in Section 5, we estimate benefits to commercial fishing by positing demand elasticity and the time period over which producer surplus is eroded. Elasticity varies by the type of market. Thus, commercial benefits are linked to the dynamic framework in a conceptually appropriate manner. Table 6-5 provides background information on commercially harvested species, as well as the economic specification employed to evaluate economic impacts.

Table 6-5
Market and Uses for Commercial Fish

Commercial Species	Geographic Extent of Market	Fresh, Frozen, or Canned	Used for Nonfood Purposes	Used for Bait	Specified Demand Elasticity
Northern anchovy	Much of the frozen product goes to Europe and Asia	Canned, fresh, frozen	Fish meal and oil, soluble protein for animal consumption; fertilizer	Yes	-1.0 to -3.0
California halibut	Fresh product is sold locally Much of the frozen product goes to Europe and Asia	Fresh (filleted), frozen	None	No	-0.01 to -1.0
California spiny lobster	Fresh product is sold locally Sold to the European Union (especially Spain) and to Japan	Fresh, frozen	None	No	-0.01 to -1.0
Commercial crabs	Sold in fresh fish markets	Fresh	None	No	-0.01 to -1.0
Diamond turbot	Local	Fresh	None	No	-0.01 to -1.0
Queenfish	Local	Fresh	None	Yes	-0.01 to -1.0
Shiner perch	Local	Fresh	None	Yes	-0.01 to -1.0
White croaker	Fresh product is sold in Los Angeles and Orange Counties	Fresh	None	Yes	-0.01 to -1.0

Sources: California Department of Fish and Game (2003; 2007f); Chetrick (2006); Hackett and Krachey (2001); Pomeroy and Dalton (2005); Radtke and Davis (2000)

In order to predict the impact of an increase in harvest on market prices, we need to identify the geographic extent of the relevant market(s) for each affected commercial species. We follow the logic described above for the geographic area over which recreational catch will increase. We assume that the market for the increased catch is contained within the ports in Los Angeles County in the Bight and the ports in Orange County. These ports include:

- San Pedro
- Los Angeles
- Terminal Island

- Wilmington
- Long Beach
- Seal Beach
- Huntington Beach
- Newport Beach
- Balboa Beach
- Dana Point

The California DFG compiles commercial catch data by species and by port that includes pounds harvested and dockside price (California DFG 2006b). For 2006, we use these data to estimate the potential consumer surplus gains, as described in Section 5 above, for the commercial harvest increases that may result from reducing I&E at HBGS. Table 6-6 below contains the results.

Table 6-6
Benefits to Commercial Fisheries near HBGS

Year	White Croaker	California Halibut	Northern Anchovy	Rock Crab
2008	0.0	0.0	1.5	0.0
2009	0.0	0.0	1.1	0.0
2010	32.7	0.0	1.1	0.0
2011	30.2	0.0	1.1	0.7
2012	35.9	0.0	1.2	0.7
2013	38.1	64.8	1.2	0.7
2014	40.8	75.7	1.1	0.7
2015	42.7	80.8	1.2	0.7
2016	44.4	94.7	1.2	0.7
2017	45.8	101.2	1.2	0.7
2018	47.0	106.5	1.2	0.7
2019	48.1	112.6	1.2	0.7
2020	41.2	115.8	1.2	0.7
2021	43.5	118.8	1.2	0.7
2022	43.4	122.0	1.2	0.7
2023	43.6	124.7	1.2	0.7
2024	43.8	127.0	1.2	0.7
2025	43.8	129.1	1.2	0.7
2026	43.9	131.1	1.2	0.7
2027	43.9	132.8	1.2	0.7

Quantification of Uncertainty in Benefits

EPA requires that a benefits assessment include uncertainty analysis but does not specify methods (EPA 2004a, p. 41,647). In statistical analysis, the term *uncertainty* refers to the statistical reliability of estimates. Benefit estimates are most useful when the causes of uncertainty are clearly identified and quantified. This section discusses uncertainty in benefit estimates and the approach taken to quantify the uncertainty associated with the benefits of reducing I&E at HBGS.

There are numerous sources of uncertainty that may lead to imprecision or bias in benefit estimates in this analysis. Following Finkel (1990), uncertainty can be classified into two general types (EPA 2002):

- The first is structural uncertainty, which reflects limited understanding of the appropriate model and relationships among model parameters. Structural uncertainty is an unresolved issue that is inherent in this assessment and all such evaluations that require simplifying complex natural processes.
- The second is parameter uncertainty, which reflects imprecision in the specific numeric values of model parameters.

Structural uncertainties will generally lead to inaccuracies, rather than imprecision, in economic and biological impact estimates (EPA 2004a). EPA does not offer support for this contention. However, in practice, the ability to evaluate such uncertainties is limited. Accordingly, the uncertainty analysis conducted for this effort focuses primarily on parameter uncertainty.

This analysis employs a Monte Carlo analysis to quantify the effects of uncertainty on benefits. The Monte Carlo analysis combines uncertainty in input parameters with the benefits estimation model to quantify uncertainty in 316(b) compliance benefits. The approach takes specified distributions for each variable input, randomly selects a value from each distribution, and then combines the estimates within the framework of the site-calibrated benefits transfer and 316(b) compliance requirements. The resulting combination of the various inputs creates an estimate of compliance benefits.

The Monte Carlo analysis repeats this process of drawing from the various input distributions 1,000 times, each time drawing randomly from the designated ranges of values for calculating economic benefits in a 316(b) framework. Each repetition produces a different estimate of compliance benefits. The resulting distribution of outcomes from the 1,000 draws produces the range of potential 316(b) compliance benefits that explicitly addresses uncertainty.

Figure 6-2 provides an illustrative example. The figure shows that several different components determine the economic benefits associated with reductions in I&E. The illustration shows that there is a distribution associated with each component and the distributions may have different properties. For example, the distribution on the travel cost per trip may be a typical bell curve, whereas the distribution associated with catch rates may be more skewed to the right.

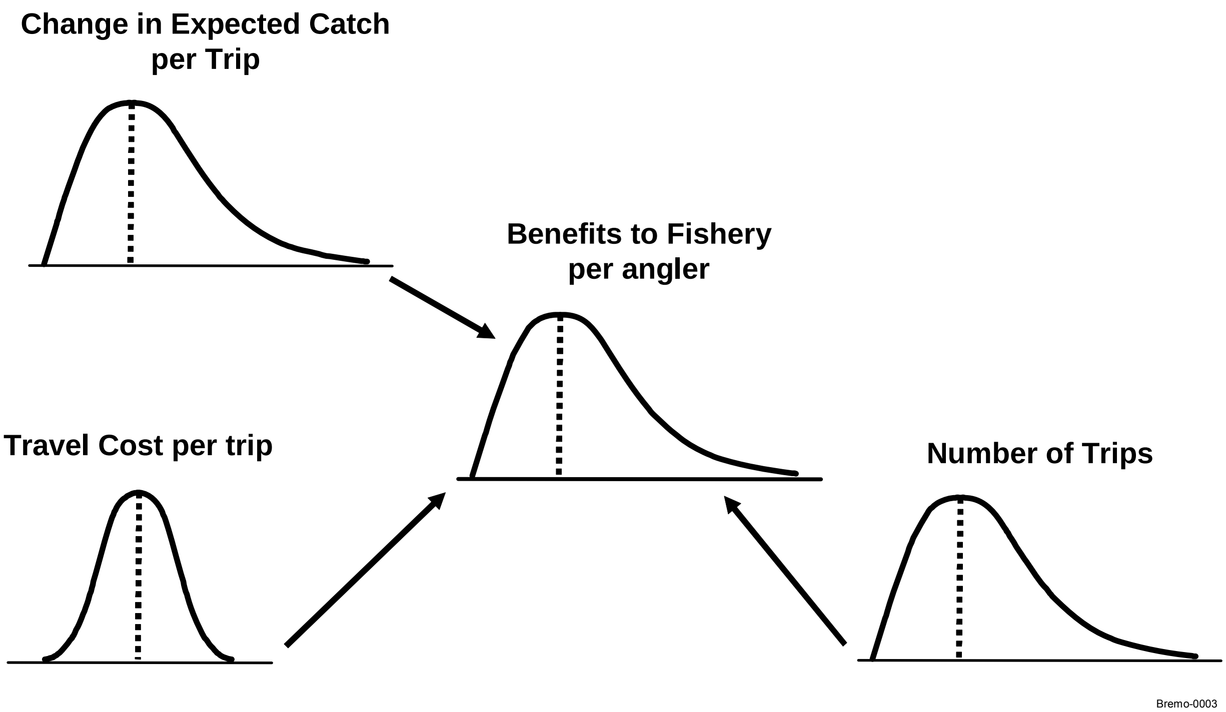


Figure 6-2
Illustration of Monte Carlo Analysis of Recreational Fishing Benefits

As Figure 6-2 shows, the Monte Carlo analysis draws from each element influencing economic benefits to determine the distribution of economic benefits. For example, in one draw, the analysis may draw a low estimate from the distribution of catch rates, but then draw a high estimate from the number of trips and a mid-level estimate from the travel cost per trip. Putting all three of these estimates together produces one estimate of economic benefits. The analysis then draws a value for each component again. This time it may draw a mid-level estimate from each element. The process is repeated 10,000 times to produce the distribution of economic benefits.

Qualitative Assessment of Nonuse Benefits

Section 5.2 revealed the circumstances under which nonuse benefits should be quantified. In the final Phase II Rule, EPA noted that

> In cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not necessary. (EPA 2004a, p. 41,647–41,648).

Economic Benefit Estimates

The I&E data presented earlier in Section 4 reveal that no threatened and endangered species are affected by the CWIS at Huntington Beach Generating Station (see Section 3). Accordingly, we adopt a qualitative discussion of nonuse benefits.

The original concept of nonuse values is credited to Krutilla (1967), who argued that individuals do not have to be active consumers of unique, irreplaceable resources in order to derive value from the continuing existence of such resources. He wrote that "when the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals" (p. 779).

Krutilla's argument has two crucial components. First, nonuse values are related to unique resources. Second, nonuse values are related to the continuing existence of a resource. Thus, it follows that common resources that suffer from limited injury do not generate significant nonuse values.

This perspective has pervaded the economic literature in the years since Krutilla introduced it. The economic literature emphasizes the relationship between nonuse values and both the uniqueness of the resource in question and the irreversibility of the loss or injury (Freeman 1993). Freeman summarizes this relationship as follows:

> …economists have suggested that there are important nonuse values in …preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes (p. 162).

As Freeman's text indicates, common resources (i.e., resources that are not unique) that do not experience irreversible losses are not likely to generate significant nonuse values, if any at all. These principles indicate that there are not meaningful nonuse effects, those uniquely associated with the uncaught sport fish, resulting from reducing I&E at the Huntington Beach Generating Station.

As previously noted, the I&E data for HBGS demonstrate that no threatened or endangered species are affected. This is important because of the relationship between the uniqueness of the resource, the irreversibility associated with changes to the resource, and the extent of potential nonuse values. Because there are no threatened and endangered species associated with I&E at HBGS, the species being impinged and entrained are not unique resources and the effect on these resource is not irreversible. Therefore, the nonuse benefits associated with reducing I&E at the plant are small, if anything at all. Accordingly, no additional evaluation is recommended.

Summary of Economic Benefits

The annual economic benefits of reducing impingement at all units by 13 percent and entrainment at Units 1&2 by 90 percent are based on the dynamic fishery modeling and economic impact methodologies described earlier. Mean quantitative estimates of impacts, decomposed by species and category (recreational, commercial, forage), are depicted in Table 6-6.[24]

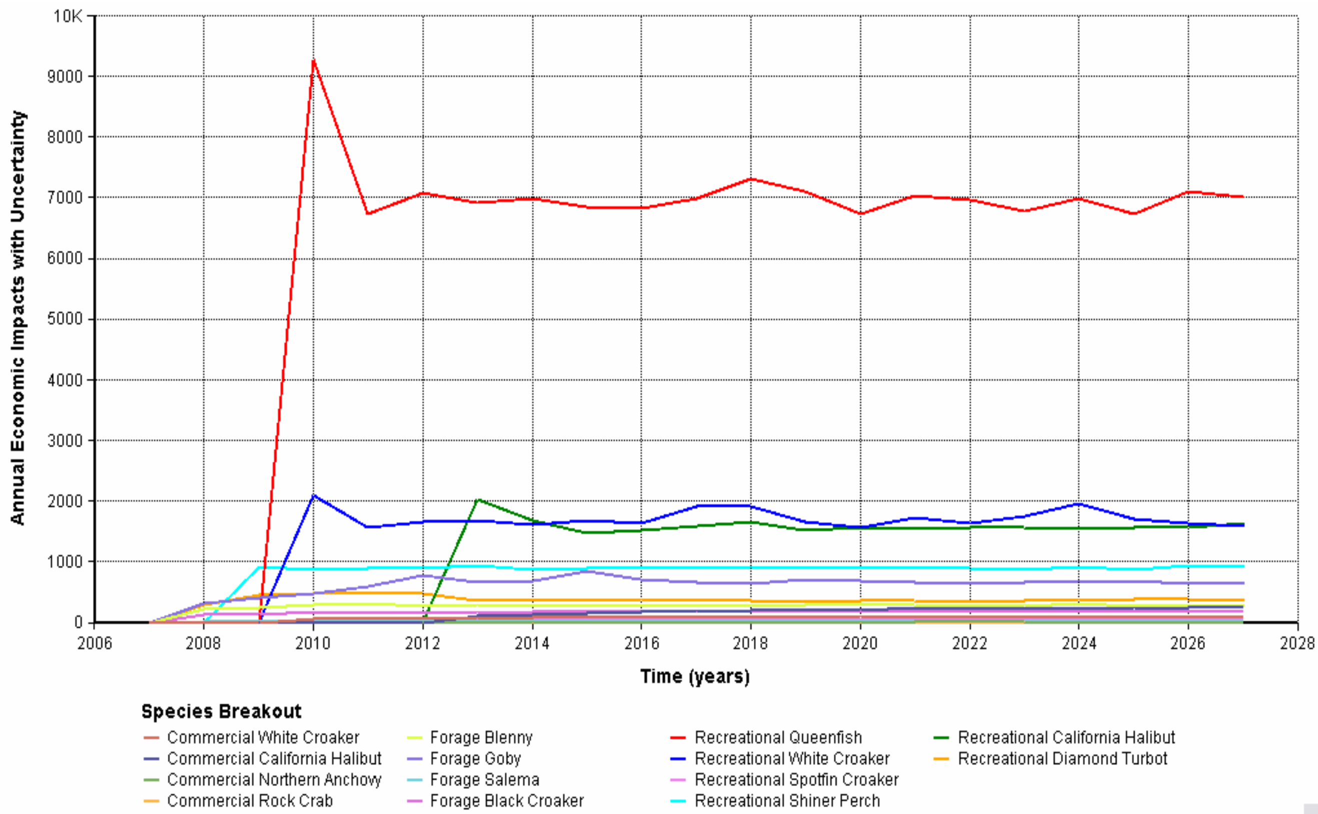


Figure 6-3
Mean Annual Economic Benefits by Species and Category

[24] Quantitative estimates of nonuse are not included for reasons stated previously.

Economic Benefit Estimates

Parameter uncertainty (as opposed to model uncertainty) manifests in supply impacts and demand responses.[25] Biological uncertainty (i.e., change in the supply of fish) in this model is incorporated via mathematical calibration of population dynamic models to equilibrium conditions. Economic uncertainty (i.e., the change in value associated with the change in supply of fish) is incorporated via transferred statistical significance parameters (recreational) and mathematical bounding based on professional judgment (commercial).[26] With these caveats, and with methodologies reflecting the uncertainty discussion earlier in Section 6, upper (95 percent) and lower (5 percent) bounds on the total annual economic impact are depicted in Figure 6-4.

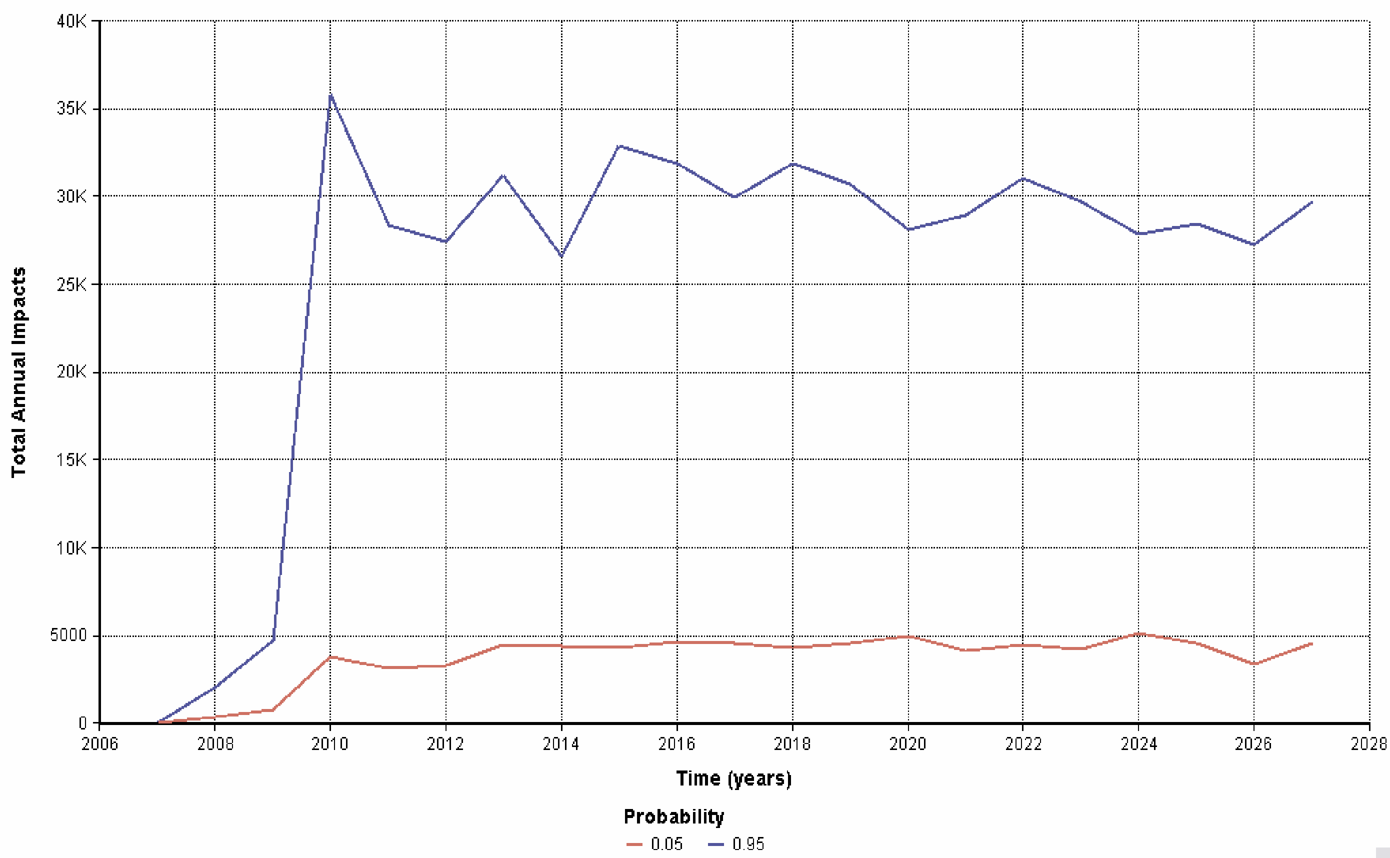


Figure 6-4
Upper and Lower Bound of Total Annual Benefit

[25] Model uncertainty (the inaccuracy associated with the model specification) and sampling uncertainty (the degree to which extrapolated I&E counts reflect actual dynamic annual impacts) are not addressed here.
[26] Uncertainty is incorporated statistically by specifying uniform distributions between upper and lower bounds for commercial benefit parameters.

Both economic theory and requirements of the Phase II Rule indicate that the type (recreational, commercial, use) and timing of dollar-valued benefits influence their relative value. Present-value concepts provide the mathematical structure for equilibrating these values. Here, consistent with Phase II Rule requirements, recreational benefits are discounted at 3 percent and commercial benefits (including that generated from recaptured forgone productivity attributable to forage loss) are discounted at 7 percent. Impacts are quantified as if the I&E reduction began in 2007 and continues for 25 years.[27]

The timing of biological impacts exhibits an appropriate lag.[28] This feature is common to dynamic population models and reflects the time taken to transition between life stages. Economic benefits associated with the change in catch do not occur with a lag. Thus, the model presumes that commercial and recreational anglers adjust their behavior in the same year catch changes. The extent to which this assumption is incorrect and resultant estimates are biased has not been evaluated. However, mitigating relationships exist. For example, relatively small behavioral changes (i.e., changes in trips) associated with relatively small changes in catch such as those seen here mean that much of the value comes from current trips where a behavioral response is not required. Conversely, large changes in expected commercial and recreational catch in particular areas are likely to be communicated rapidly. The public nature of 316(b) proceedings would tend to enhance this effect.

With respect to the incorporation of uncertainty in present value calculations, uncertainty is not monetarily valued.[29] Consistent with the philosophy that the estimates provided here are developed with the intention of meeting regulatory as opposed to policy goals, discount rates are specified as certain, known parameters. In fact, true social discount rates are not constant in that they are both time period and context specific.[30]

Under this specification, the expected value (mean) of the net present value is $158,600. Upper (95 percent) and lower (5 percent) are $254,000 and $94,000. The annualized (NPV/20) benefits associated with I&E reductions range from $4,719 to $12,700 with a mean estimate of $7,928.

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[27] In dynamic models, impacts can persist for a limited period. The 25-year cut-off is computationally tractable and viewed as offsetting to the start specification as instantaneous.

[28] For a more detailed discussion and numerical example of catch timing impacts on value, see Bingham, Desvousges, and Mohamed (2003).

[29] Viewing uncertainty in economic benefits as a form of risk similar to the risk associated with any financial instrument or business endeavor theoretically allows conversion of uncertain future benefit to a certain current value. Theoretically means that the methodologies are available. However, identification of required parameters is difficult without markets.

[30] The appropriate discount rate for environmental impacts with potentially dramatic effects (global warming, nuclear waste) has been studied extensively under the rubric "deep discounting." For policy decisions, interdependence of choices and limited resources dictate that such cases impact discount rates across programs. Thus, the relative discount rate across distant dramatic changes (i.e., global warming) and small changes (i.e., I&E reductions) is properly calculated as a result of a choice between two, rather than used as input to choose between the two.

7

REFERENCES

1. Akçakaya, H. R., M. A. Burgman, and L. Ginzburg. 2002. Applied Population Ecology Principles and Computer Exercises Using RAMAS: Second Edition. Available at http://www.ramas.com/contents.htm. Retrieved on March 22, 2007.
2. Allen, L. G., D. J. Pondella, II, and M. A. Shane. 2007. Fisheries independent assessment of a returning fishery: Abundance of juvenile white seabass (*Atractoscion nobilis*) in the shallow nearshore waters of the Southern California Bight. 1995-2005. Fish. Res. 88:24-32.
3. American Sportfishing Association. 2007. Number of license buyers per state, 2001–2005. Available at http://www.asafishing.org/asa/statistics/participation/fishlicense_2001_05.html. Retrieved on September 13, 2007.
4. Beggs, S., S. Cardell, and J. Hausman. 1981. Assessing the potential demand for electric cars. Journal of Econometrics 17(1):1-19.
5. Bingham, M. F, W. H. Desvousges, and A. F. Mohamed. 2003. Comments on Benefit Estimation of EPA's Proposed Phase II 316(b) Rule as Summarized in the Notice of Data Availability: Final Report. Prepared for The Utility Water Act Group, June 2. Triangle Economic Research, Durham, NC.
6. Bockstael, N. E., W. M. Hanemann, and C. L. Kling. 1987. Estimating the value of water quality improvements in a recreational demand framework. Water Resources Research 23(5):951-960.
7. Bockstael, N. E., W. M. Hanemann, and I. E. Strand, Jr. 1986. Measuring the Benefits of Water Quality Improvements Using Recreation Demand Models. Report to the U.S. Environmental Protection Agency. University of Maryland, College Park, MD.
8. Bockstael, N. E., K. E. McConnell, and I. E. Strand. 1991. Recreation. In Measuring the Demand for Environmental Quality, J. B. Braden and C. D. Kolstad, eds. Elsevier Science Publishers B.V., North Holland.
9. Boyle, K. J., and J. C. Bergstrom. 1992. Benefit transfer studies: myths, pragmatism, and idealism. Water Resources Research 28(3):657-663.
10. Brookshire, D. S., and H. R. Neill. 1992. Benefit transfers: conceptual and empirical issues. Water Resources Research 28(3):651-655.
11. Cailliet, G. M., E. J. Burton, J. M. Cope, L. A. Kerr, R. J. Larson, R. N. Lea, D. VenTresca, and E. Knaggs. 2000. Project summary. In Biological Characteristics of Nearshore Fishes of California: Final Report. Available at http://www.dfg.ca.gov/marine/lifehistories/index.asp#summary. Retrieved on December 11, 2007.

References

12. California Department of Fish and Game. 2003. 5. Rock crabs. Available at http://www.dfg.ca.gov/marine/status/report2003/rockcrabs.pdf. Retrieved on October 25, 2007.
13. California Department of Fish and Game. 2006a. Threatened and endangered fishes. Available at http://www.dfg.ca.gov/wildlife/species/t_e_spp/fish.html. Retrieved on July 30, 2007.
14. California Department of Fish and Game. 2006b. Table 20PUB—poundage and value of landings by port, Los Angeles area during 2006. Available at http://www.dfg.ca.gov/mrd/landings06/table20pub.pdf. Retrieved on October 12, 2007.
15. California Department of Fish and Game. 2006c. California recreational fisheries survey 2005 annual review. Available at http://www.dfg.ca.gov/marine/crfs_pfmc0306.pdf. Retrieved on October 11, 2007.
16. California Department of Fish and Game. 2007a. Welcome to the California fishing passport web site. Available at http://www.dfg.ca.gov/fishingpassport/. Retrieved on September 27, 2007.
17. California Department of Fish and Game. 2007b. Public health advisories on fish consumption. Available at http://www.dfg.ca.gov/marine/fishcon1.asp. Retrieved on September 14, 2007.
18. California Department of Fish and Game. 2007c. 2007–2008 California Freshwater Sport Fishing Regulations. Available at http://www.dfg.ca.gov/regulations/07-08-inland-fish-regs.pdf. Retrieved on July 31, 2007.
19. California Department of Fish and Game. 2007d. Commercial fishing licenses and permits. Available at http://www.dfg.ca.gov/licensing/pdffiles/cf_items_10yr.pdf. Retrieved on October 11, 2007.
20. California Department of Fish and Game. 2007e. Trophy black bass certificate program. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/TBB/index.asp. Retrieved on September 27, 2007.
21. California Department of Fish and Game. 2007f. Commercial Fishing Laws and Licensing Requirements: 2007. Available at http://www.dfg.ca.gov/marine/pdfs/commercialdigest2007.pdf. Retrieved on August 7, 2007.
22. California Department of Fish and Game. 2007g. California Law: California Fish and Game Code. Available at http://www.leginfo.ca.gov/cgi-bin/calawquery?codesection=fgc&codebody=&hits=20. Retrieved on August 8, 2007.
23. California Department of Fish and Game, Marine Region. 2007a. Record ocean sportfish. Available at http://www.dfg.ca.gov/marine/faqtrph3.asp. Retrieved on September 27, 2007.
24. California Department of Fish and Game, Marine Region. 2007b. *2007 Ocean Sport Fishing Regulations*. Available at http://www.dfg.ca.gov/marine/oceanfish2007.pdf. Retrieved on July 31, 2007.
25. California Department of Fish and Game, Marine Region. 2007c. State managed commercial fisheries: cabezon, greenlings and sheephead (CGS). Available at http://www.dfg.ca.gov/Mrd/cgs.html. Retrieved on August 8, 2007.

26. California Department of Fish and Game, Marine Region. 2007d. Popular features. Available at http://www.dfg.ca.gov/MRD/index_regs.html. Retrieved on August 9, 2007.

27. California Energy Commission. Undated. Biological resources. Available at http://www.energy.ca.gov/sitingcases/elsegundo/documents/applicants_files/afc_cd-rom/VOLUME%201A/5.6.pdf. Retrieved on October 23, 2007.

28. California Fish and Game Commission. 1998. California's marine life management act. Available at http://www.fgc.ca.gov/mlma/introduction.html. Retrieved on September 18, 2007.

29. California Office of Environmental Health Hazard Assessment. 2003. Fish: site-specific advisory information. Available at http://www.oehha.ca.gov/fish/so_cal/index.html. Retrieved on August 6, 2007.

30. California Regional Water Quality Control Board, Santa Ana Region. 2002. Order No. R8-2002-0014, waste discharge requirements for sewage collection agencies in Orange County within the Santa Ana region. Available at http://www.swrcb.ca.gov/rwqcb8/pdf/sso/ssostaffrpt.pdf. Retrieved on September 14, 2007.

31. California Seafood Council. 1997. Facts in brief. Available at http://ca-seafood.ucdavis.edu/facts/industry.htm. Retrieved on September 19, 2007.

32. California State Coastal Conservancy. 2000. Wetland profile: Anaheim Bay. Available at http://images.google.com/imgres?imgurl=http://www.wrpinfo.scc.ca.gov/coast/wetland_images/historic/seal_beach_hist.gif&imgrefurl=http://www.wrpinfo.scc.ca.gov/coast/dbs/profile.asp%3FSITEID%3D22&h=884&w=559&sz=57&hl=en&start=1&um=1&tbnid=RMCBuQ0dWmiRDM:&tbnh=146&tbnw=92&prev=/images%3Fq%3D%2522shipping%2Bchannel%2522%2B%252B%2B%2522Huntington%2BBeach%2522%2B%252B%2BCalifornia%26svnum%3D10%26um%3D1%26hl%3Den%26sa%3DN. Retrieved on September 17, 2007.

33. Cameron, T. A. 1985. A nested logit model of energy conservation activity by owners of existing single family dwellings. The Review of Economics and Statistics 67(2):205-211.

34. Carlson, J. K., E. Cortés, and D. M. Bethea. 2003. Life history and population dynamics of the finetooth shark (carcharhinus isodon) in the northeastern Gulf of Mexico. Fishery Bulletin 101(2):281–292. Available at http://fishbull.noaa.gov/1012/06carlso.pdf. Retrieved on March 22, 2007.

35. Caulkins, P. P., R. C. Bishop, and N. W. Bouwes, Sr. 1986. The travel cost model for lake recreation: a comparison of two methods for incorporating site quality and substitution effects. American Journal of Agricultural Economics 68(2):291-297.

36. CephBase. 2003. Cephalopod prey in the wild. Available at http://www.cephdev.utmb.edu/preydb/preydb.cfm. Retrieved on October 23, 2007.

37. Chetrick, J. 2006. Trends in U.S. and world lobster production, imports, and exports. Available at http://www.fas.usda.gov/ffpd/Fishery_Products_Presentations/Lobster_2006/lobster_2006.ppt#268,1,Trends in U.S. and World Lobster Production, Imports and Exports. Retrieved on October 25, 2007.

References

38. City of Huntington Beach. 2006. Welcome to Huntington Beach. Available at http://www.ci.huntington-beach.ca.us/. Retrieved on August 9, 2007.
39. DeLorme. 2005. Southern and Central California Atlas and Gazetteer. DeLorme, Yarmouth, ME.
40. Desvousges, W. H., M. F. Bingham, J. C. Kinnell, A. F. Mohamed, and K. T. Kuhns. 2005. Review and Response to the EPA's Response to Comments from the American Chemistry Council et al. and Accompanying Triangle Economic Research (TER) Report. Prepared for the Utility Water Act Group, General Electric Company, American Chemistry Council, American Forest and Paper Association, American Iron and Steel Institute, American Public Power Association, and American Petroleum Institute. April 20. Triangle Economic Research, Durham, NC.
41. Desvousges, W. H., F. R. Johnson, and H. S. Banzhaf. 1998. Environmental Policy Analysis With Limited Information: Principles and Applications to the Transfer Method. Edward Elgar, Cheltenham, UK.
42. Desvousges, W. H., M. C. Naughton, and G. R. Parsons. 1992. Benefit transfer: conceptual problems in estimating water quality benefits using existing studies. Water Resources Research 28(3):675-683.
43. DeVoretz, D. J., and K. G. Salvanes. 1993. Market structure for farmed salmon. American Journal of Agricultural Economics 75:227-233.
44. EPRI. 2005. Parameter Development for Equivalent Adult and Production Foregone Models. EPRI, Palo Alto, CA.
45. Feder, H. M., C. H. Turner, and C. Limbaugh. 1974. Observations in fishes associated with kelp beds in southern California. Available at http://content.cdlib.org/xtf/view?docId=kt9t1nb3sh&brand=default&doc.view=entire_text. Retrieved on October 23, 2007.
46. Feenberg, D., and E. S. Mills. 1980. Measuring the Benefits of Water Pollution Abatement. Academic Press, New York.
47. Finkel, A. M. 1990. A simple formula for calculating the "mass density" of a lognormally distributed characteristic: applications to risk analysis. Risk Analysis 10(2):291-301.
48. Freeman III, A. M. 1993. Nonuse values in natural resource damage assessment. In R. J. Kopp and V. K. Smith (eds.), Valuing Natural Resource Assets: The Economics of Natural Resource Damage Assessment. Resources for the Future, Inc., Washington, DC.
49. Getz, W. M., and R. G. Haight. 1989. Population Harvesting: Demographic Models of Fish, Forest, and Animal Resources. Princeton University Press, Princeton, NJ.
50. Grumbles, Benjamin. 2007. Implementation of the decision in *Riverkeeper, Inc. v. EPA*, remanding the cooling water intake structures Phase II regulation. U.S. Environmental Protection Agency, Washington, DC.
51. GSA (U.S. General Services Administration). 2006. Privately owned vehicle (POV) mileage reimbursement rates. Available at http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_BASIC&contentId=9646. Retrieved on September 5, 2006.

52. Hackett, S. C., and M. Krachey. 2001. An Economic Overview of the California Wetfish Industry Complex. Available at http://ca-seafood.ucdavis.edu/news/wetfish/wf_econ.pdf. Retrieved on October 25, 2007.
53. Hardin, G. 1968. The tragedy of the commons. Science 162:1243-1248.
54. Hein, C. L., B. M. Roth, A. R. Ives, and M. J. V. Zanden. 2006. fish predation and trapping for rusty crayfish (orconectes rusticus) control: a whole-lake experiment. Canadian Journal of Fisheries and Aquatic Sciences 63(2):383-393.
55. Hensher, D. A. 1991. The use of discrete choice models in the determination of community choices in public issue areas impacting on business decision making. Journal of Business Research 23(4):299-309.
56. Huang, K. S., and B.-H. Lin. 2000. Estimation of food demand and nutrient elasticities from household survey data. Technical Bulletin Number 1887. U.S. Department of Agriculture, Washington, DC.
57. Huntington Beach Events.com. 2007. Huntington Beach events. Available at http://www.huntingtonbeachevents.com/2007ap14.html. Retrieved on September 20, 2007.
58. International Pacific Halibut Commission. 2007. Halibut Commission completes 2007 annual meeting. Available at http://www.iphc.washington.edu/halcom/newsrel/2007/nr20070123.htm. Retrieved on August 8, 2007.
59. Jackson, D. 2006. Albackore's Gulp! only west coast fall surf slam. Available at http://www.fishingexpeditions.com/html/surf_slam.html. Retrieved on September 20, 2007.
60. Jones, K. Undated. Dana Point Harbor fishing pier. Available at http://www.pierfishing.com/resources/index.php?id=piers:dana_point_harbor_fishing_pier. Retrieved on August 9, 2007.
61. Judd, Tim. 1998. The sequestering of secondary compounds from sponges by nudibranchs. Available at http://www.colostate.edu/Depts/Entomology/courses/en570/papers_1998/judd.html. Retrieved on October 24, 2007.
62. Kling, C. L., and J. A. Herriges. 1995. An empirical investigation of the consistency of nested logit models with utility maximization. American Journal of Agricultural Economics 77(November):875-884.
63. Kling, C., and C. Thomson. 1996. The implications of model specification for welfare estimation in nested logit models. American Journal of Agricultural Economics 78(Feb):103-114.
64. Krutilla, J. V. 1967. Conservation reconsidered. American Economic Review 57(4):777-786.
65. Lane, D. E., and C. W. Hill. 1975. The marine resources of Anaheim Bay. Available at http://content.cdlib.org/xtf/view?docId=kt6n39n885&brand=calisphere&doc.view=entire_text. Retrieved on October 23, 2007.
66. Leslie, P. H. 1945. On the use of matrices in certain population mathematics. Biometrika 33:183-212.

References

67. LIMPETS. Undated. The Pacific mole crab. Available at http://limpetsmonitoring.org/docs/Crab_Factsheet.pdf. Retrieved on November 15, 2007.
68. Los Angeles County Department of Beaches and Harbors. Undated. Welcome to Marina Del Rey. Available at http://beaches.co.la.ca.us/BandH/Marina/Main.htm. Retrieved on September 27, 2007.
69. Mansfield, E. 1988. Microeconomics Theory and Applications: Shorter Sixth Edition. W.W. Norton & Company, New York.
70. MBC Applied Environmental Sciences and Tenera Environmental, Inc. 2007. Draft Report Huntington Beach Generating Station Clean Water Act Section 316(b) Impingement Mortality and Entrainment Characterization Study. Prepared for AES Huntington Beach. February 26. MBC Applied Environmental Sciences, Costa Mesa, CA.
71. McConnell, K. E. 1992. Model building and judgment: implications for benefit transfers with travel cost models. Water Resources Research 28(3):695-700.
72. McFadden, D. 1997. Modelling the choice of residential location. In The Economics of Housing, Volume 1, J. M. Quigley, ed. Elgar, Northampton, MA.
73. Morey, E. R., W. D. Shaw, and R. D. Rowe. 1991. A discrete-choice model of recreational participation, site choice, and activity valuation when complete trip data are not available. Journal of Environmental Economics and Management 20(2):181-201.
74. Muncy, R. J. 1984. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico)—pinfish. U.S. Fish and Wildlife Service FWS/OBS-82/11.26. U.S. Army Corps of Engineers, TR EL-82-7. 18 pp.
75. National Marine Fisheries Service Northwest Regional Office. 2007a. Groundfish regulations. Available at http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/Regulations/Index.cfm. Retrieved on August 8, 2007.
76. National Marine Fisheries Service Northwest Regional Office. 2007b. Salmon fishery management. Available at http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Salmon-Fishery-Management/Index.cfm. Retrieved on August 8, 2007.
77. National Marine Fisheries Service Northwest Regional Office. 2007c. Highly migratory species program. Available at http://swr.nmfs.noaa.gov/hms/hms.htm. Retrieved on August 8, 2007.
78. National Marine Fisheries Service Southwest Regional Office. 2007a. Coastal pelagic species. Available at http://swr.nmfs.noaa.gov/fmd/cps/cps.htm. Retrieved on August 8, 2007.
79. National Marine Fisheries Service Southwest Regional Office. 2007b. Highly migratory species program. Available at http://swr.nmfs.noaa.gov/hms/hms.htm. Retrieved on August 8, 2007.
80. National Oceanic and Atmospheric Administration. 2006. 2007 Pacific halibut catch sharing plan for Area 2a. Available at http://www.nwr.noaa.gov/Groundfish-Halibut/Pacific-Halibut/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=36164. Retrieved on September 27, 2007.

81. National Oceanic and Atmospheric Administration. 2007. International fisheries; Pacific tuna fisheries; restrictions for 2007 purse seine and longline fisheries in the eastern tropical Pacific Ocean. Available at http://a257.g.akamaitech.net/7/257/2422/01jan20071800/edocket.access.gpo.gov/2007/E7-10718.htm. Retrieved on September 27, 2007.

82. National Oceanic and Atmospheric Administration Shark Population Assessment Group. 2006. Population dynamics. Available at http://www.sefscpanamalab.noaa.gov/shark/researchareas.htm. Retrieved on May 10, 2007.

83. Newbold, S. C., and R. Iovanna. 2007a. Population level impacts of cooling water withdrawals on harvested fish stocks. Environ. Sci. Technol. 41(7):2108-2114.

84. Newbold, S. C., and R. Iovanna. 2007b. Supplemental information for "Population level impacts of cooling water withdrawals on harvested fish stocks." U.S. EPA, National Center for Environmental Economics, Washington, DC.

85. Neyman, J., and E. S. Pearson. 1933. On the problem of the most efficient tests of statistical hypotheses. Phil. Trans. Roy. Soc. London, Ser. A 231:289-337.

86. Office of Environmental Health Hazard Assessment. 2003. Fish: site-specific advisory information. Available at http://www.oehha.ca.gov/fish/so_cal/index.html. Retrieved on August 6, 2007.

87. Orange County Health Care Agency. 2007. Ocean water protection program: ocean and bay water closures, postings & advisories. Available at http://www.ocbeachinfo.com/. Retrieved on September 18, 2007.

88. Pacific Fishery Management Council. 2006. Council recommends pacific sardine harvest guideline for 2007. Pacific Council News 30(4):9. Available at http://www.pcouncil.org/newsletters/2006/Winter_2006.pdf. Retrieved on August 8, 2007.

89. Pauly, D., and V. Christensen. 1995. Primary production required to sustain global fisheries. *Nature* 374:255-257.

90. Pollard, J. H. 1973. Mathematical Models for the Growth of Human Populations. Cambridge University Press, Cambridge, UK.

91. Pomeroy, C., and M. Dalton. 2005. Market channels and value added to fish landed at Monterey Bay area ports. Available at http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1038&context=csgc. Retrieved on October 23, 2007.

92. Public Service Electric and Gas Company (PSEG). 1999. Permit Renewal Application, NJDPES Permit No. NJ0005622, Salem Generating Station. March 4.

93. Quinlan, J. A., and L. B. Crowder. 1999. Searching for sensitivity in the life history of Atlantic menhaden: inferences from a matrix model. Fisheries Oceanography 8(s2):124-133.

94. Radtke, H. D., and S. W. Davis. 2000. Description of the U.S. West Coast Commercial Fishing Fleet and Seafood Processors. Available at http://www.psmfc.org/efin/docs/fleetreport.pdf. Retrieved on October 23, 2007.

References

95. *Riverkeeper, Inc., Natural Resources Defense Council, Waterkeeper Alliance, Soundkeeper, Inc., Scenic Hudson, Inc., Save the Bay-People for Narragansett Bay, Friends of Casco Bay, American Littoral Society, Delaware Riverkeeper Network, Hackensack Riverkeeper, Inc., New York/New Jersey Baykeeper, Santa Monica Baykeeper, San Diego Baykeeper, California Coastkeeper, Columbia Riverkeeper, Conservation Law Foundation, Surfrider Foundation, State of Rhode Island, State of Connecticut, State of Delaware, Commonwealth of Massachusetts, State of New Jersey, State of New York, Appalachian Power Company, Illinois Energy Association, Utility Water Act Group, PSEG Fossil LLC, PSEG Nuclear LLC, Entergy Corporation v. United States Environmental Protection Agency, Stephen L. Johnson, in his official capacity as Administrator of the United States Environmental Protection Agency*. 2007. United States Court of Appeals for the Second Circuit. Docket Nos. 04-6692-ag(L), 04-6693-ag(CON), 04-6694-ag(CON), 04-995-ag(CON), 04-6696-ag(CON), 04-6697-ag(CON), 04-6698-ag(CON), 04-6699-ag(CON). January 25, 2007.

96. Sabaton, C., L. Siegler, V. Gouraud, J. L. Baglinière, and S. Manné. 1997. Presentation and first applications of a dynamic population model for brown trout, salmo trutta l.: aid to river management. fisheries management and ecology 4(6):425–438.

97. San Diego Sportfishing Council. Undated. San Diego sportfishing online. Available at http://www.sportfishing.org/. Retrieved on September 27, 2007.

98. Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. Bull. Inter-Amer. Trop. Tuna Commission 1:27-56.

99. Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bull. Inter-Amer. Trop. Tuna Commission 2:247-268.

100. Sheckler, D. 1999. Arch rock cove. Available at http://www.saintbrendan.com/cdnaug/anacapa8.html. Retrieved on October 24, 2007.

101. Sherman, Peter. 1998. Revised draft, derivation of 'wholly disproportionate' test re CWA Section 316. Memo to Martha Segall, U.S. Environmental Protection Agency Engineering and Analysis Division. September 14.

102. Smith, V. K. 1992. On separating defensible benefit transfers from smoke and mirrors. Water Resources Research 28(3):685-694.

103. Smith, V. K., G. L. van Houtven, and S. Pattanayak. 2002. Benefit transfer via preference calibration: "prudential algebra" for policy. Land Economics 78(1):132-152.

104. Southern California Wetlands Recovery Project. 2007. WRP regional strategy: county objectives. Available at http://www.scwrp.org/pdfs/RS-Ch4-County-Objectives.pdf. Retrieved on September 17, 2007.

105. Sportfishingreport.com. 2007. Catch. Available at http://www.sportfishingreport.com/pages/landingdetail.php?landing_id=12. Retrieved on August 6, 2007.

106. State Water Resources Control Board. 2006. Proposed 2006 CWA Section 303(d) list of water quality limited segments. Available at http://www.swrcb.ca.gov/tmdl/docs/303dlists2006/final/r8_final303dlist.pdf. Retrieved on September 7, 2007.

107. Stockteam.com. 2007. Grunion run in Huntington Beach, California. Available at http://www.stockteam.com/grunion.html. Retrieved on September 21, 2007.

108. Tietenberg, T. 2006. Environmental and Natural Resource Economics: Seventh Edition. Addison Wesley, Boston.

109. U.S. Census Bureau. 2007a. State and county quick facts: Orange County, California. Available at http://quickfacts.census.gov/qfd/states/06/06059.html. Retrieved on August 9, 2007.

110. U.S. Census Bureau. 2007b. State & county quickfacts: California. Available at http://quickfacts.census.gov/qfd/states/06000.html. Retrieved on September 13, 2007.

111. U.S. Environmental Protection Agency. 2000. Guidelines for Preparing Economic Analyses. Report Number 240-R-00-003. USEPA, Washington, DC.

112. U.S. Environmental Protection Agency. 2002. Economic and Benefits Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule. Report Number 821-R-02-001. February. U.S. EPA, Washington, DC.

113. U.S. Environmental Protection Agency. 2004a. National pollutant discharge elimination system—final regulations to establish requirements for cooling water intake structures at Phase II existing facilities; final rule. Federal Register Vol. 69, No. 131 (Friday, July 9):41,576–41,693.

114. U.S. Environmental Protection Agency. 2004b. California Regional Analysis. Available at http://www.epa.gov/waterscience/316b/phase2/casestudy/final/chb2.pdf. Retrieved on October 12, 2007.

115. U.S. Environmental Protection Agency. 2007. What you need to know about mercury in fish and shellfish. Available at http://www.epa.gov/waterscience/fishadvice/advice.html. Retrieved on August 6, 2007.

116. U.S. Fish and Wildlife Service. 2003. 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: California. Available at http://www.census.gov/prod/2002pubs/fhw01-ca.pdf. Retrieved on July 27, 2007.

117. U.S. Fish and Wildlife Service. 2007. USFWS threatened and endangered species system (TESS). Available at http://ecos.fws.gov/tess_public/SpeciesReport.do?groups=E&listingType=L. Retrieved on July 27, 2007.

118. Vitale, P. 2007. Surface Water Ambient Monitoring Program Report: Anaheim Bay and Huntington Harbour Sediment and Water Column Toxicity Study. Available at http://www.swrcb.ca.gov/swamp/regionalreports.html#rb8. Retrieved on September 7, 2007.

119. Wägele, H., and A. Klussmann-Kolb 2005. Opisthobranchia (mollusca, gastropoda)—more than just slimy slugs. Shell reduction and its implications on defence and foraging. Frontiers in Zoology 2:3.

120. Wessells, C. R., and J. L. Anderson. 1992. Innovations and progress in seafood demand and market analysis. Marine Resource Economics 7:209-288.

References

121. Wessells, C. R., and J. E. Wilen. 1994. Seasonal patterns and regional preferences in Japanese household demand for seafood. Canadian Journal of Agricultural Economics 42:87-103.

122. Zerbe, R. O., Jr., and D. D. Dively. 1994. Benefit-Cost Analysis in Theory and Practice. Harper Collins College Publishers, New York.

A

AN OVERVIEW OF BENEFIT-COST ANALYSIS

At the individual level, decision-making includes at least an informal comparison of benefits and costs. In the economics literature, comparing benefits and costs has been formalized in the theories of rational expectations, utility maximization, and choice (Friedman and Savage 1948; Hensher 1991; Brent 1995; Kling and Herriges 1995; Hanley, Wright, and Adamowicz 1998; Blamey et al. 2000; Blamey and Bennett 2001). With respect to private enterprise, survival in commercial activity is guided by the criterion that over time, total revenues must meet or exceed total costs. This requirement and attendant profit motivation of firms dictate that survival in the commercial arena requires explicit valuation of projects in terms of net monetized benefit to the firm. The selection of projects in the private sector based on monetized expectations leads naturally to conferring benefits on certain population segments, including employees, consumers, and (through taxes) the public. It is, in fact, this process that underlies the prices formed in markets for goods such as cars and houses. Adam Smith (1776) metaphorically identified the link between the surplus associated with private interest and socially optimal outcomes under certain conditions as an "invisible hand." Despite the appeal of Smith's "invisible hand," the set of conditions under which self-interest promotes optimal social outcomes is not observed generally.[31] For this reason, social valuation of projects and input to decision-making is often important for understanding aggregate impacts.

Benefit-cost analysis (BCA) provides a consistent method for evaluating the contribution of public policies to economic efficiency. BCA may be performed to evaluate policies before (ex ante) their implementation to help in policy selection or after (ex post) their implementation to learn of the actual consequences of the policy. BCA incorporates widely accepted principles of resource management, such as:

- In a world of limited natural, human, and financial resources, it is desirable to achieve any given goal at the least possible cost.
- When faced with multiple goals, we should allocate our scarce resources among these goals so as to achieve the greatest net benefit.[32]

BCA takes its instruction from the precepts of market exchange where the contributions to and decrements from social welfare of individuals' resource allocation decisions are estimated in dollars. Among other advantages, using dollars as the preference metric provides a measure of

[31] In the case of environmental regulation, it is the presence of externalities that makes evaluating the social cost and benefit associated with private decision-making necessary for choosing socially optimal decisions (allocation of resources).

[32] For economists, BCA is the *sine qua non*. A panel of 42 economists from academia, the private sector, and government, including three Nobel Laureates, addressed an *amicus* brief to the U.S. Supreme Court, confirming their view that benefit-cost analysis is essential for good policymaking (Arrow et al. 2000).

the intensity of individuals' preferences and provides a comparable measure of both benefits and costs. BCA can incorporate nonmarket valuation methods for nonpriced, but valued, goods when those values can be reliably measured.[33]

Markets, where buyers and sellers engage in voluntary exchange, are widely viewed as the best available institutional arrangement currently available for effectively addressing resource allocation decisions for most goods and services. Markets, which are underpinned by private property, reveal the quantities of a commodity consumers wish to purchase at a given price and thus reflect the value of the commodity to demanders. They also reveal the quantities of a commodity that producers are willing to provide and thus reflect the cost of the commodity to suppliers. The market quantities of goods and services resulting from the interaction of demanders and suppliers are efficient in the sense that it is not possible to make any person better off without making at least one other person worse off.

Markets do not perform well, however, for a class of goods termed "public goods." Pure public goods are both nonexcludable and nonrivalrous. They are nonexcludable in that, once provided, it is very costly or even impossible to prevent anyone from consuming the good. They are nonrivalrous in that their consumption by one person does not diminish the quantity of the good available to others. National defense and clean air are examples of pure public goods.

The line between private goods of the market and public goods is a fuzzy and shifting one. Many predominately private goods have some degree of publicness and visa versa. For example, a home with an attractive exterior is available for all to enjoy; a highway can be closed to those with improper vehicles or those who are unwilling to pay the toll. Both changes in public attitudes and changes in technology are responsible for the shifts.

Because of the nonexcludability of public goods, efficient markets will not develop for them. One of the roles of government is to provide public goods to society. However, governments have a problem to solve: what public goods in what quantities to provide? One way to address the question is to attempt to emulate the outcomes of a market by providing those public goods in the quantities that increase efficiency. Properly performed, BCA provides estimates of the contribution to economic efficiency (which may be negative) of putative and actual public policies.

This appendix provides a primer on BCA after first describing its legislative origins. The appendix closes with a discussion of the application of BCA for identifying Best Technology Available (BTA) and outlines regulatory requirements for a site-specific determination of BTA.

Legislative Origins of BCA

The French engineer Jules Dupuit (1844) first proposed employing BCA to evaluate a public works project. He employed aggregate measures of individual welfare to make comparisons of

[33] Section 5 provides a discussion of methodologies available for measuring certain kinds of nonmarket services. Appendix B contains a discussion of the challenges associated with reliably measuring other kinds of nonmarket services.

the benefits and costs of a bridge. The British economist Alfred Marshall further developed BCA formalizing its role in political economics and establishing the foundation for most empirical studies in welfare economics (Fuguitt and Wilcox 1999).

The *U.S. Flood Control Act of 1936* provided the first regulatory inclusion of BCA in the U.S. The Act suggested that "the Federal Government should improve or participate in the improvement of navigable waters or their tributaries including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs." The *Flood Control Act of 1936* stated that floods were "a menace to national welfare" and asserted that "flood control on navigable waters or their tributaries is a proper activity of the Federal Government" in cooperation with other governmental entities. Thus, the *Flood Control Act of 1936* initiated the process of applying economic evaluations to public investment decisions (Shabman 1997). It bears noting that this directive provided only minimal requirements, that benefits need only exceed costs to justify a project, and that the phrase "to whomsoever they occur" precludes consideration of distributional (equity) impacts.

The Flood Control Act of 1936 vested responsibility for addressing the risks of floods across the nation to the U.S. Army Corps of Engineers. The primary methods envisioned for addressing flood risks were significant construction projects, such as dams and reservoirs that would impact the hydrology of entire river systems (Barry 1997). Executing the Act potentially has difficult requirements, such as advanced risk assessment (floods), and the Act fails to explicitly consider potential impacts, such as overbuilding in flood plains. Nevertheless, using project evaluation tools was considered the proper approach to evaluating and selecting flood-management projects.

The *U.S. Reclamation Project Act of 1939* reinforced the implementation of BCA and required that the Bureau of Reclamation weigh the benefits and cost of irrigated water (43 *U.S.C.* 485h[c]). BCA was soon required of the U.S. Army Corps of Engineers. The first applications of the Corp's federally legislated BCA were somewhat ad hoc (Fuguitt and Wilcox 1999; Watkins undated). BCA was generally considered an ancillary task and given little weight in the decision-making process.

However, in the post-war era of the late 1940s and the early 1950s, BCA began to be considered an important and useful tool for analyzing public expenditures. The so-called "*Green Book*" (for the color of its cover) was developed and revised in the 1950s to establish and disseminate a set of guidelines for water planning and management. The heart of these guidelines focused on economic efficiency, which is still the cornerstone of BCA. As government and academic economists discovered the potential contribution of this method of project evaluation, BCA quickly became the accepted standard for assessing public investment projects. Significant early examples of the application of BCA include evaluations of a London subway (Foster and Beesley 1963), disease control (Klarman 1965), and the (now called) Chunnel (Ministry of Transport 1963).[34]

In these initial applications of BCA to public investment projects, a conceptual foundation for the comparison of benefits and costs was absent. Rather, these applications supported

[34] See Mishan (1975) for a concise review of these studies.

government investment in public infrastructure with the presumptive advantage of the ability to choose optimal projects with a fixed amount of funds.[35]

By the late 1970s, regulators heeded industry's demands for a balanced consideration of social benefits associated with the costs of the regulation (Fuguitt and Wilcox 1999). Advances in economic theory and practice as well as the growth in regulatory agencies during the 1970s led to the promulgation of several increasingly detailed executive orders and Office of Management and Budget (OMB) circulars. These directives outlined the general principles and procedures for conducting BCA for the federal government. Agency-specific guidelines provided more detailed guidance and examples. Three executive orders are especially noteworthy:

- Promulgated in 1978, the Carter Administration's Executive Order 12044 provided the first requirement that BCA should be used to weigh compliance costs against derived benefits from regulations. Executive Order 12044 required Regulatory Impact Analyses, a close cousin of BCA. This order required government agencies to "prepare a regulatory analysis" weighing the costs and benefits of "regulations identified as significant" (43 *Fed. Reg*. 12663).[36]
- Issued in 1981, the Reagan Administration's Executive Order 12291 built on Executive Order 12044, effectively augmenting the scope of regulations deemed as "significant." Besides expanding the scope of which regulations would require a BCA, Executive Order 12291 stipulated that "regulatory action shall not be taken unless the potential benefits to society outweigh the potential costs" (43 *Fed. Reg*. 12663) and that "regulatory objectives shall be chosen to maximize net benefits to society" (43 *Fed. Reg*. 12663). Although Executive Order 12291 expanded the scope of BCA, like its predecessors, this Order did not establish a uniform standard for quantifying and comparing benefits and costs. Executive Order 12291 remained the basis for BCA for about 12 years.
- President Clinton's Executive Order 12866 supplanted Executive Order 12291 on September 30, 1993. It retained the fundamental tenets of Executive Order 12291 while increasing the scope of regulations requiring a BCA prior to their implementation. President Clinton recognized some of the practical and legal obstacles to President Reagan's order, but he still endorsed the view that regulations should be designed to maximize net benefits.

Under the Clean Water Act (CWA), the idea of weighing the regulatory benefits relative to costs appears in Section 304(b)(1)(B), which addresses effluent limitation guidelines. The section reads:

> Factors relating to the assessment of best practical control technology currently available shall include…consideration of the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, and shall also take into account the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process

[35] When the budget and number of projects are fixed, net benefits are maximized by selecting projects with the highest benefit-to-cost ratios first, thus simplifying the selection process.

[36] Significant regulations were ultimately defined as those that would result in "a) an annual effect on the economy of $100 million or more; or b) a major increase in costs or prices or individual industries, levels of government, or geographic regions" (43 *Fed. Reg.* 12663).

> changes, non-water quality environmental impact (including energy requirements), and such other factors as the Administrator deems appropriate.

The judicial history of this Section states that "[t]he balancing test between total cost and effluent reduction benefits is intended to limit the application of technology only where the additional degree of effluent reduction is wholly out of proportion to the costs of achieving such marginal level of reduction for any class or category of sources" (*Kennecott v. United States EPA*). Additionally, the judicial history of the CWA supports the concept of weighing the benefits and costs of the "Best Practicable Technology," which is defined as the "average of the best existing performance ... within each industrial category" (*Kennecott v. United States EPA*).

Regarding Section 316(b) of the CWA, the notion of BCA first appears *In the Matter of Public Service Company of New Hampshire* 10 ERC 1257 (May and Van Rossum 1995). This case, commonly called the Seabrook II Decision, was rendered in 1977 and held that no formal BCA was *required* under 316(b) (TetraTech Inc. 2002). However, the ruling stated that some consideration of the relationship between benefits and costs was applicable because Section 316(b) did not require implementation of technology whose cost was "wholly disproportionate" to its environmental benefits. Again, although this ruling supported consideration of regulatory benefits and costs, it gave no formal guidelines for determining "wholly disproportionate" costs, nor did it provide guidance on the measurement of benefits and costs.

Following the Seabrook II Decision, the "wholly disproportionate" cost test has been applied differently in various cases depending on the specific facts of the case. The lack of uniformity of the "wholly disproportionate" cost test has been legally enshrined through case law, where the test has been called "a relatively subsidiary" task (*BASF Wyandotte Corp. v. Costle*) that "need not be precise" (*Weyerhauser Co. v. Costle*). Thus, the EPA applies the test ad hoc and has a long history of both finding specific proposals "wholly disproportionate" as well as finding them acceptable.

In perhaps the most directly relevant statement, the EPA addressed the "wholly disproportionate" cost test in its recent revisitation of the Phase II Rule of Section 316(b) of the CWA. In the Final Rule, the EPA reaffirmed the place of the "wholly disproportionate" cost test in considering compliance costs, stating that "should facilities in these other industrial categories face compliance costs wholly disproportionate to those EPA considered and found to be economically practicable in today's economic analysis, they can seek alternative requirements" (66 *Fed. Reg.* 65311). Furthermore, the EPA provided that "should an individual new facility demonstrate that costs of regulatory compliance for a new facility would be wholly out of proportion to the costs EPA considered and determined to be economically practicable, the Director would have authority to adjust best technology available requirements accordingly" (66 *Fed. Reg.* 65322) and to create a mechanism for the practical implementation of the findings of a BCA.

In 2004, EPA finalized its Phase II 316(b) Rule, which contains a provision that potentially allows reduced compliance standards based on the results of BCA (69 *Fed. Reg.* 41576–41693). Compliance under this provision requires that the facility demonstrate that the costs of meeting the standards are "significantly greater" than the associated economic benefits. However, on January 25, 2007 the Second Circuit Court of Appeals released a ruling that disallowed many significant components of the EPA's Phase II § 316(b) rule for cooling water intake structures

(*Riverkeeper et al. v. U.S. Environmental Protection Agency*), including the benefit-cost test. In response to the Second Circuit Court ruling, EPA has suspended the Phase II Rule and directed that all permits for Phase II facilities be considered on a Best Professional Judgment basis as described at 40 *CFR* § 401.14 (Grumbles 2007; 72 *Federal Register* 37107).

Microeconomic Foundations of BCA

In a society characterized by competitive markets, prices allocate resources. In that market setting, the numbers of buyers and sellers are such that the actions of individual buyers and sellers do not significantly impact commodity prices. The primary paradigm for understanding how market-clearing prices are reached in perfect competition is the well-known model of demand and supply. This predictive model also provides normative insights, for it can be used to discover the value and cost of alternative quantities of a commodity.

In this model, the market demand for a consumer good reflects the aggregate consumption rate of a commodity that consumers will purchase for all prices. Theoretical reasoning and empirical studies both confirm that such demand curves will slope downward as illustrated in Figure A-1a. The market supply for a commodity reflects the aggregate production rate which producers will provide for all prices. Theoretical reasoning and empirical studies confirm that supply curves will slope upward as illustrated in Figure A-1.b. The tension between consumers and producers results in the establishment of a stable equilibrium where the quantity demanded and supplied are equated: P_1, Q_1 in Figure A-1.c.

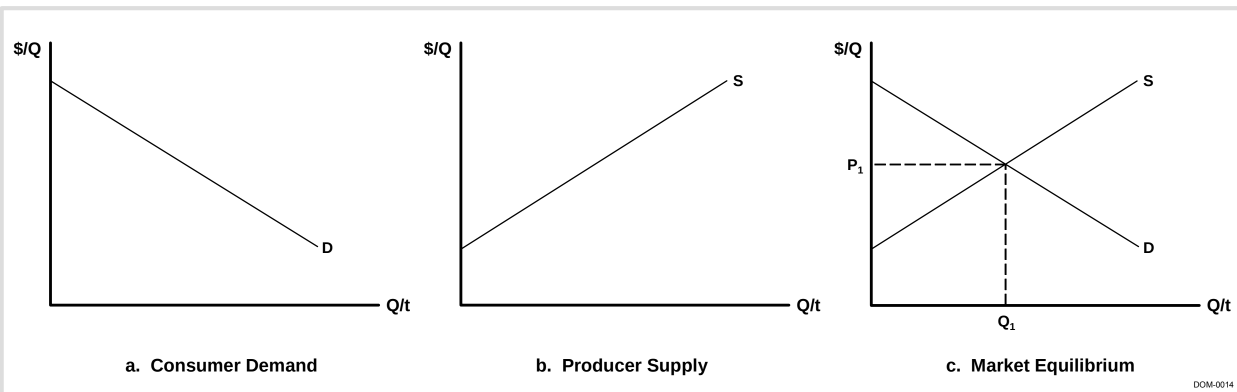


Figure A-1
Competitive Market Outcome

In competitive markets, a stable equilibrium results from the interaction of demand and supply.

The consumer's demand curve also shows the marginal valuation of each consumption rate. For example, take the step demand curve for a hypothetical consumer as shown in Figure A-2. In the figure, if the price is $10, the consumer would purchase 1 unit of the good. If the price were $8, the consumption rate would be 2, revealing that the increment in consumption is only worth $8 (or fractionally more) to the consumer.

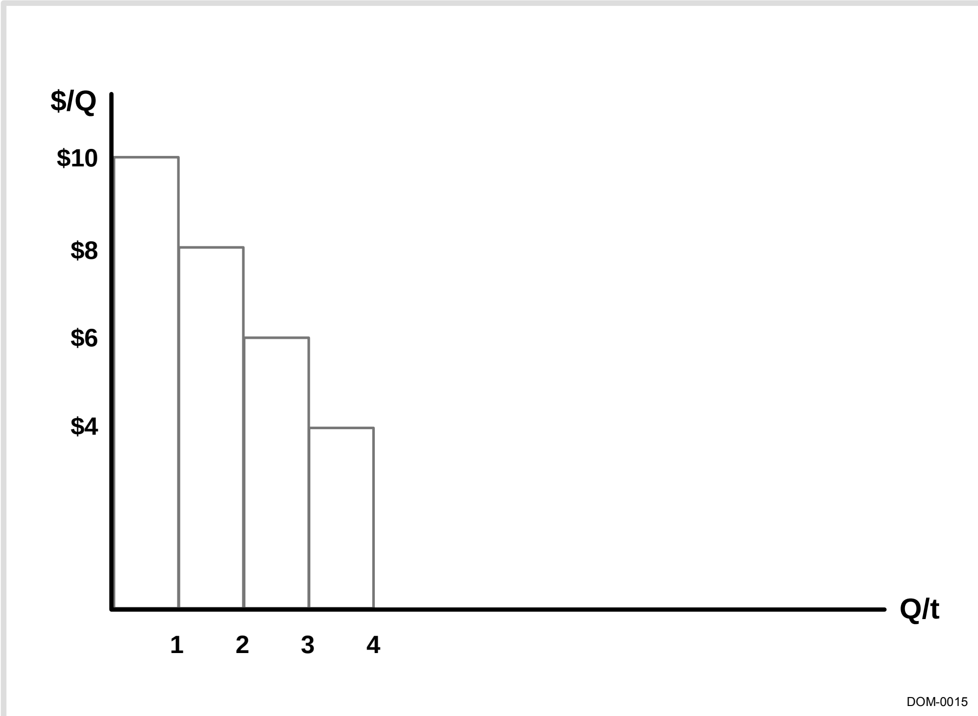


Figure A-2
Step Demand Curve

The step demand curve is useful for demonstrating how a demand curve may be interpreted.

Repeating this interpretation along the demand curve reveals the consumer's marginal valuation (MV) of additional amounts of the commodity. It can also be interpreted as the maximum the consumer would be willing to pay for an increment of the good. The area under the marginal valuation or demand curve represents the total valuation for each consumption rate. For example, 3 units of the good in Figure A-2 are worth $24 (i.e., $10 + $8 + $6) to the hypothetical consumer. It is the maximum amount of money per unit time the consumer would be willing to pay for a given amount of the good rather than to forego it entirely.

In competitive markets, a single price confronts all consumers and they select the consumption rate for the good that maximizes their economic welfare (utility). The consumer's utility-maximizing consumption rate is where her marginal cost of the good (its price) is equal to her marginal benefit (MV or demand), Q_1 in Figure A-3. Thus, as shown in the figure, there is a difference between what the consumer pays for her selected quantity of the good ($P_1 * Q_1$) and the total value of that consumption rate to the consumer (the entire area under the demand curve or value B_1 in the lower panel of Figure A-3). This difference, the shaded area of Figure A-3, is consumer surplus, the critical metric of consumer welfare because it is the difference between the value of the consumption rate to her and what she actually pays.

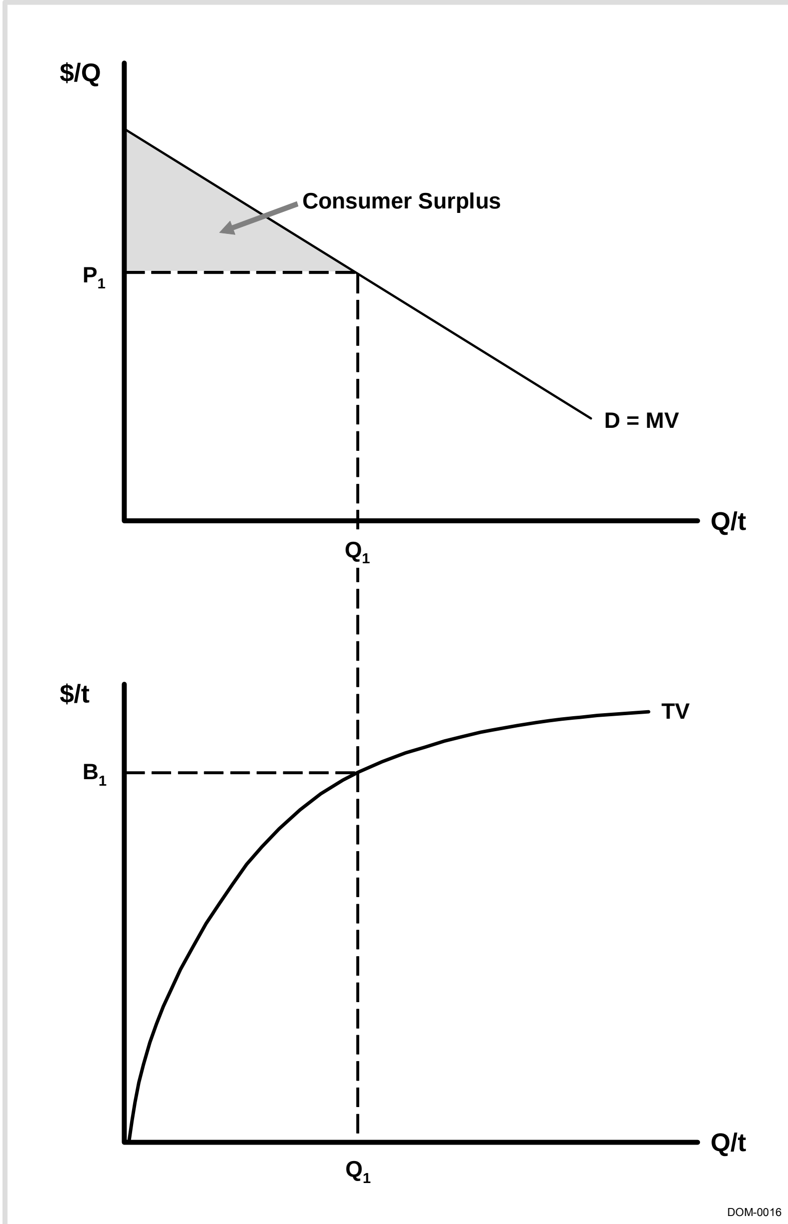


Figure A-3
Consumer Surplus

Consumer surplus is the difference between the total amount of money paid for a given quantity of a good and the maximum amount the consumer would be willing to pay for that quantity.

The producer's supply curve also shows the marginal cost of each production rate. For example, take the step supply curve for a hypothetical producer as shown in Figure A-4. In the figure, if the price is $2, the producer would produce 1 unit of the good. If the price were $4, the production rate would be 2, revealing that the increment in production costs the producer $2. This supply curve reflects the producer's marginal cost of additional amounts of the commodity. It can also be interpreted as the minimum amount of money the producer would require to provide an increment of the good. The area under the marginal cost (supply) curve represents the total cost for each production rate. For example, 3 units of the good in Figure A-4 cost $12 (i.e., $2 + $4 + $6) to the hypothetical producer. The area under the supply curve is the minimum amount of money per unit time the producer would need to provide a given amount of the good.

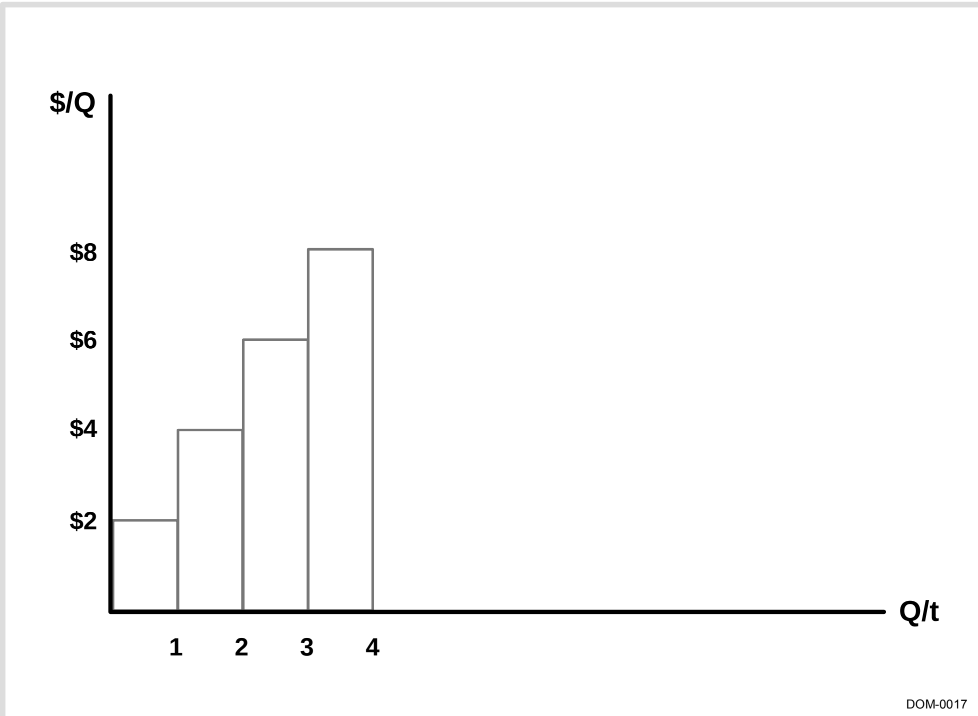


Figure A-4
Step Supply Curve

The step supply curve is useful for demonstrating how a supply curve may be interpreted.

In competitive markets, a single price confronts all producers and they select the production rate for the good that maximizes their economic welfare (profits). A producer's profit-maximizing production rate is where his marginal cost of providing the good is equal to the marginal benefit (price), Q_1 in Figure A-5. Thus, as shown in the figure, there is a difference between what the producer receives for his selected quantity of the good (P_1 * Q_1), and the total cost of that production rate (the area under the supply curve or value C_1 in the lower panel of Figure A-5. This difference, the shaded area in Figure A-5, is producer surplus, the critical metric of producer welfare. It is the difference between his cost of the production rate and what he actually receives. Producer surplus is also called economic profit.[37]

[37] Economic profit differs from the more familiar accounting profit. Accounting profit is total revenue minus expenditures. Economic profit is total revenue minus all costs, both actual expenditures made for purchased inputs plus the implicit rental of capital (resources) owned by the firm. As supply curve reflects the opportunity costs (not accounting costs) of production, producer surplus is the economic profit earned.

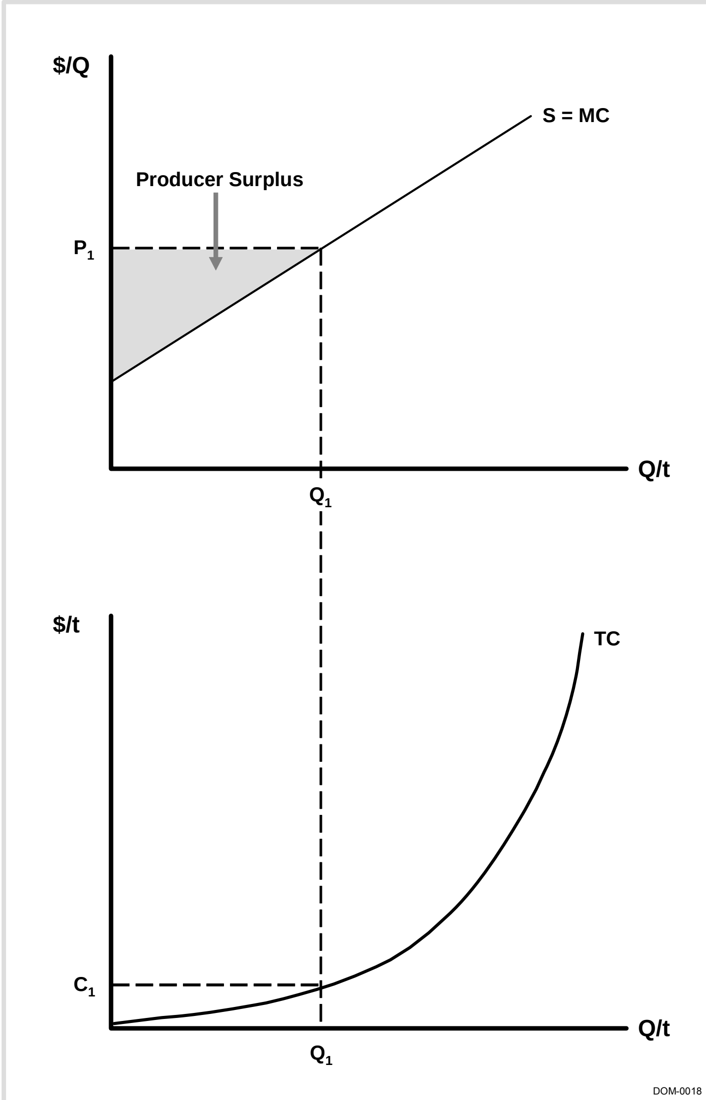


Figure A-5
Producer Surplus

Producer surplus is the difference between the total amount of money received for a given quantity of a good and the minimum amount the producer would require to provide that quantity.

Social surplus is the sum of consumer surplus and producer surplus. In competitive markets, the social surplus is maximized. In Figure A-6a, the market clearing price is P_0. Consumer surplus is represented by area P_0ab, producer surplus by area P_0bc. The social surplus is represented by area abc. In Figure A-6b, consumers' total benefit or (value) curve is shown along with the total cost curve of producers. Social surplus is measured here as TB–TC. As shown in Figure A-6c, production/consumption rates for the commodity between 0 and Q_1 all add to economic welfare, but it is rate Q_0 that maximizes social surplus.[38]

[38] Compare this outcome to the project evaluation requirements of the Flood Control Act of 1936, that benefits must be in excess of its costs to justify a project. Many "projects" in Figure A.6 would meet that requirement, including some that would only marginally improve economic welfare because they are near the points where the social surplus function meets the 0 axis (i.e., 0 and Q_1).

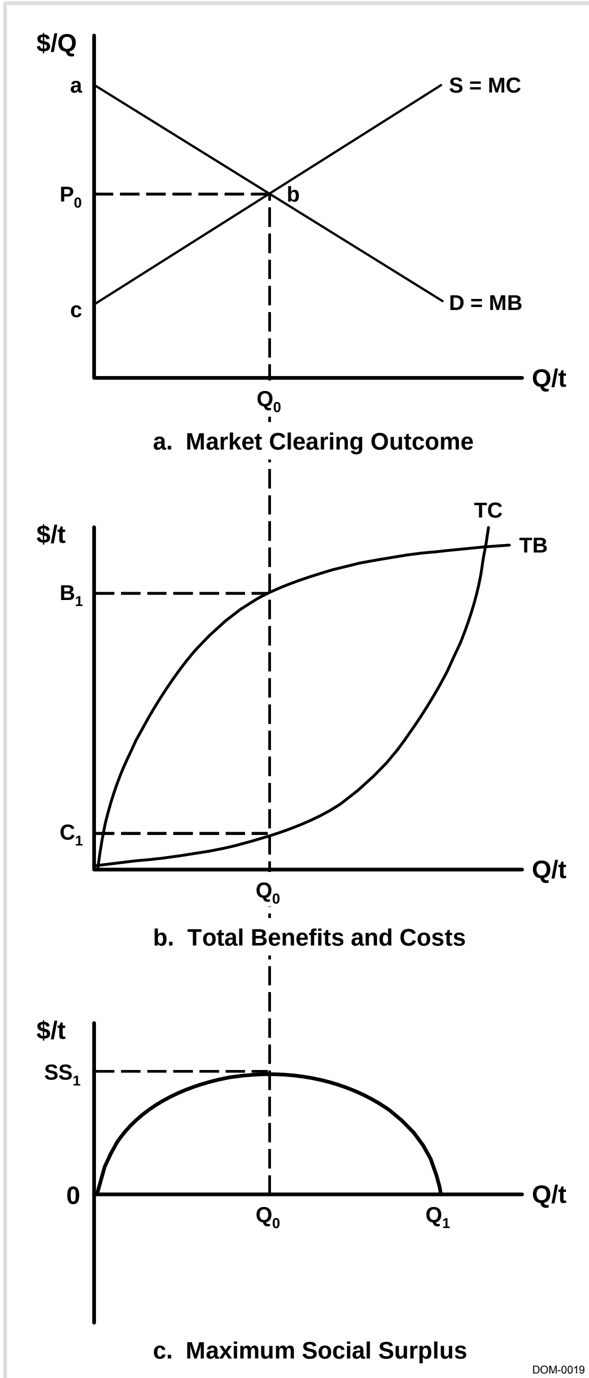


Figure A-6
Social Surplus

Social surplus, the sum of consumer and producer surplus, is maximized in competitive markets.

An Overview of Benefit-Cost Analysis

A Simple Example Application of BCA

To illustrate the application of the microeconomic foundations of BCA, consider the following simple example. Suppose there was a project that lowered the cost of a competitively produced good and that all the impacts of the project were registered in the market for that good. Should the project be undertaken based on BCA?

In the market where the impacts are found, the market supply curve shifts downward reflecting the lower cost of production with the project. In Figure A-7, the new market clearing outcome is P_2,Q_2. Changes in the social surplus, that is, the net benefits of the project (ignoring its costs for the moment), are the social surplus *with* the project minus the social surplus *without* it. In Figure A-7 the change is represented by area ade-abc or cbde. Thus, if the hypothetical project cost less than the amount represented by the shaded area of Figure A-7, it would add to economic welfare.

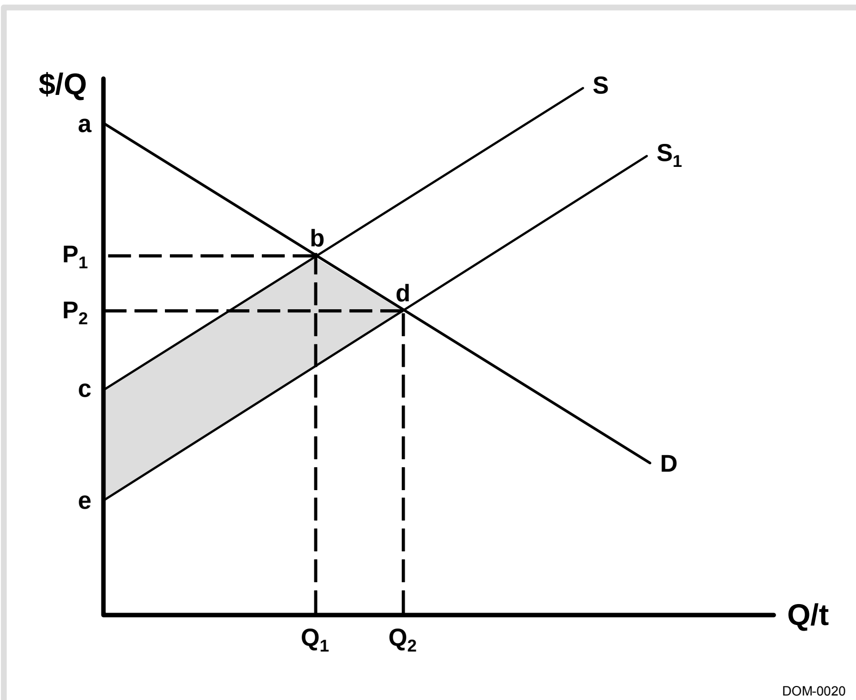


Figure A-7
Net Benefits of Hypothetical Project
Ignoring the costs of the project, the shaded area shows the contribution of the project to the social surplus.

Figure A-8a shows the change in consumer surplus for the hypothetical project. Consumer surplus increases on the original consumption rate, Q_1, due to the lower price, and also increases due to the increment in consumption from Q_1 to Q_2. Thus consumer surplus increases by the area represented by P_1bdP_2 in Figure A-8a. Consumers gain economic welfare with the project.

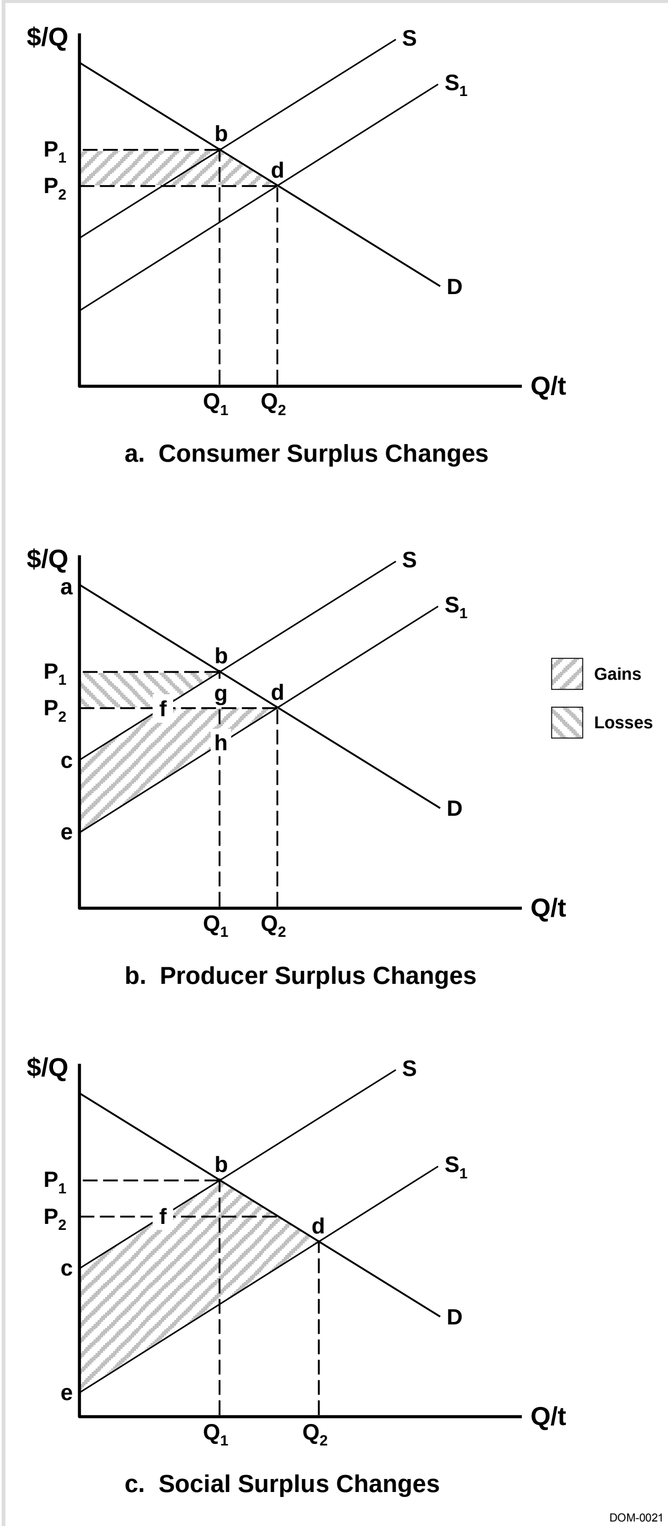


Figure A-8
Social Surplus Approach to BCA

The distribution of the change in social welfare between consumers and producers may also be estimated in this model.

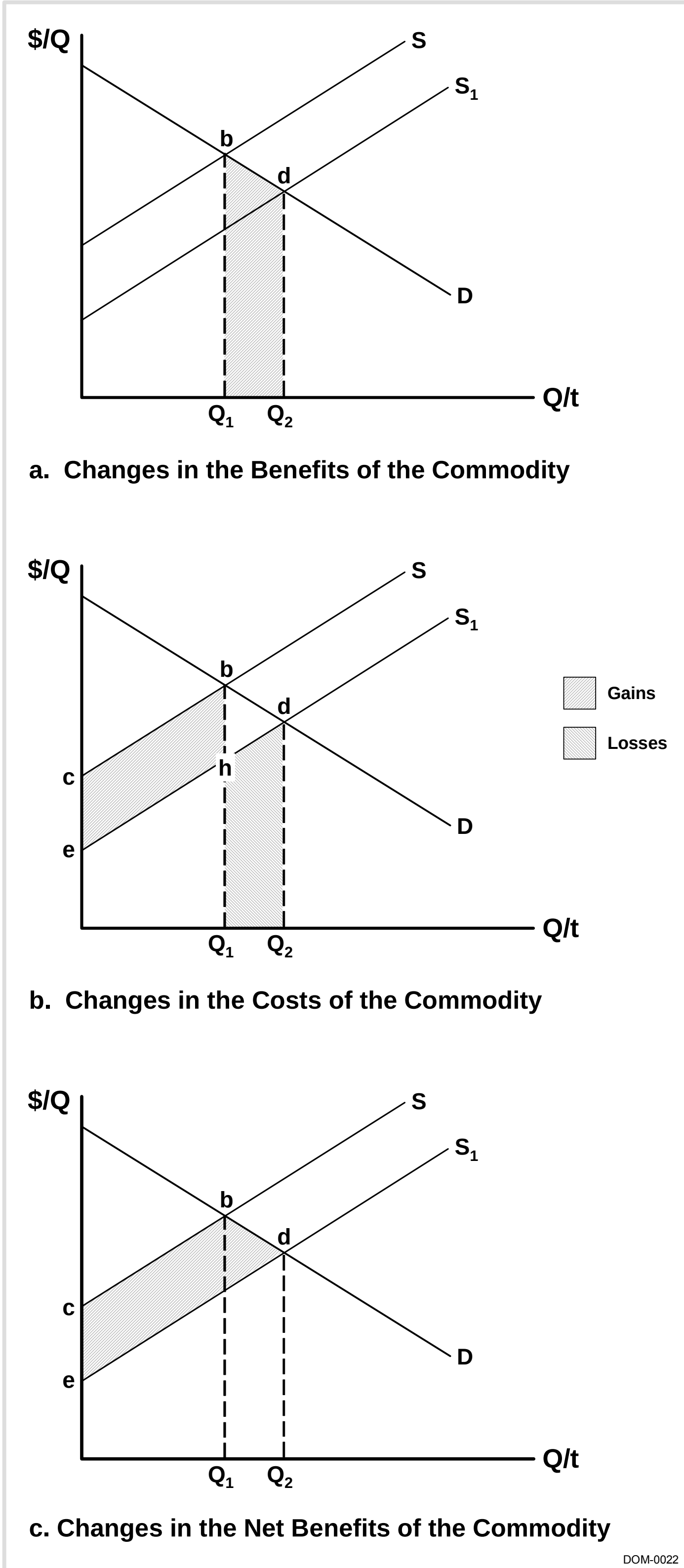
The impact of the hypothetical project on producer surplus is more complex. Producer surplus declines on the original production rate, Q_1, due to the lower price shown in the area represented by P_1bfP_2 but increases by the area represented by cfghe due to the lower cost of production with the project. On the quality increment, producer surplus increases by the area represented by gdh. Thus on balance, producer surplus changes by the algebraic sum of the gains and losses or – (P_1bfP_2) + (cfde), as shown in Figure A-8b.

The net change in the social surplus provided by the hypothetical commodity is the algebraic sum of the changes in the components of the social surplus, as shown in Figure A-8c. Some of the consumer surplus gains are offset by producer surplus loss, specifically the area represented by P_1bfP_2. Thus, this is a transfer in incomes, not a net loss to society (i.e., to consumers plus producers). This result also illustrates the argument advanced by Harberger (1971), that the changes in individuals' welfare should be aggregated without regard to whom they accrue. Table A-1 summarizes the changes shown in Figure A-8.

Table A-1
Changes in Consumer and Producer Welfare in Figure A-8

Changes	Area in Figure A-8
Changes in consumer surplus	+ (P_1bdP_2)
Changes in producer surplus	– (P_1bfP_2) + (cfghe) + (gdh) = – (P_1bfP_2) + (cfde)
Changes in the social surplus: Change in consumer surplus + change in producer surplus	+ (P_1bdP_2) – (P_1bfP_2) + (cfde) = (fdb) + (chde) = cbde

An alternative perspective is to directly evaluate the changes in the benefits and costs of the commodity *with* the project. In Figure A-9, the total benefits of consumption increase by the area represented by Q_1bdQ_2 (Figure A-9a). The total costs of production decrease on the *without* project output rate, Q_1, by the amount represented by area cbhe but increase by the area represented by Q_1hdQ_2 (Figure A-9b) to supply the additional output. The change in economic welfare with the project (ignoring its costs) is the benefits minus costs or the area represented by cbde in Figure A-9c (also see Table A-2). An important insight of this analysis is that an institutional arrangement is needed to ensure that the increment in consumption goes to the highest-valued consumers and that the increment in costs comes from the lowest-cost producers. Competitive markets create such an outcome.



a. Changes in the Benefits of the Commodity

b. Changes in the Costs of the Commodity

c. Changes in the Net Benefits of the Commodity

Figure A-9
Net Benefits Approach to BCA

The aggregate benefits and costs of the project may also be estimated in this model.

Table A-2
Changes in Net Benefits in Figure A-9

	Area in Figure A-9
Changes in the total benefits of the commodity	Q_1dbQ_2
Changes in total costs of the commodity	– (cbhe) + (Q_1hdQ_2)
Changes in the net benefits of the commodity: Change in total benefits – change in total costs	(Q_1dbQ_2) – [–(ecbh) + (Q_1hdQ_2)] = cbde

Welfare and Equity Considerations of BCA

As set out above, competitive markets lead to an allocation of society's resources that maximizes economic welfare (social surplus). Behind this outcome is the assumption that economic decision makers have all relevant information to make their consumption and production decisions and that they are motivated by self-interest to do the best they can with the opportunities available to them. This was the predominant view among economists since first articulated by Adam Smith (1776) in the *Wealth of Nations*: "It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest."

Under certain highly restrictive conditions, the self-interested actions of individuals and firms lead to maximum values of aggregate social benefits. However, in general these conditions are not met. In particular, the productive or consumptive actions of firms and individuals cause unintended impacts, or externalities, to some other part of society. This concept of *externalities* and associated economic inefficiencies was originally identified by Coase (1960). Both the idea and the appropriate economic remedy have subsequently been incorporated into standard microeconomic theory.

Many of these externalities are in the form of discharges to the natural environment that are broadly termed pollution.[39] The generation of electricity can also lead to externalities in the form of fish mortality. When the producing firm does not pay for its impacts to these resources, it tends to overconsume them, leading to less than optimal allocation of society's scarce resources.

On its surface, the economic remedy for a production-based externality is straightforward—the firm causing the externality is induced to *internalize* it by being forced to pay the true cost of its impact. Internalize in this context means that the producing *firm* bears all of the costs of production internally rather than allowing some of these costs externally. This approach was originally proposed by Pigou (1932) and has since received the somewhat inaccurate moniker "Pigouvian tax." In fact, this approach is best considered a fee because its economic purpose is increasing efficiency by market correction—not raising revenue.[40] Under the Pigouvian

[39] Pollution is a primary, but not unique, type of externality. Additional significant categories of externalities include (but are not limited to) negative impacts to health, property values, and business or personal income. Additionally, externalities can also be positive (e.g., the beekeeper's bees that pollinate his neighbors' fruit trees).
[40] The primary identifying feature of an economically efficient market is that the social cost of producing the final unit (marginal cost) is equal to the social benefit of producing the final unit (marginal benefit).

approach, the sector causing an externality pays a fee by unit that equates total production cost to the true social cost (lost social benefit) of producing each unit. As with the well known result under perfect competition (Smith 1776), when faced with the true costs of production, the sector adjusts operations in an individually efficient manner that, when aggregated, leads to a socially optimal outcome.[41]

Two important features are critical to understanding the Pigouvian approach. The first is that because this approach focuses on economic efficiency, it is not expected to eliminate impacts. The idea that some positive amount of a negative externality like pollution can be socially optimal is anathema to many. However, it is a logical extension of the recognition that curtailing the externality will have costs as well as benefits and that the social surplus is maximized when these are equated at the margin. The strength of this approach implicitly causes the profit-maximizing firm to weigh the costs of reducing the externality against social costs (lost benefits). Thus in the absence of easy fixes with large benefits, we expect a certain amount of impact to continue. Because of this feature, the Pigouvian approach has sometimes been criticized as providing a "license to pollute." In fact, this is a distorted view of a common situation in which the marginal social costs of abatement rise as impacts diminish and that the marginal social benefits of abatement diminish as impacts get small.[42]

The second important feature is that unit fees are not paid to injured parties. Doing so leads to an additional inefficiency. To understand why, consider a power producer impacting a fishery. Paying anglers to fish in a reduced quality fishery induces them to use this lower valued resource at increased social cost rather than substituting a more valuable resource at reduced social cost.

When a market is impacted by an externality, there is a rationale for some form of economic intervention. As we have seen, this intervention can potentially be supported by knowledge of the social costs and social benefits at each level of production. One approach for guiding such intervention involves employing BCA. In policy-making, BCA is a customary procedure for organizing information on the advantages and disadvantages of public projects. Under the Pigouvian approach, the benefit-cost framework is valuable because money provides a consistent way to compare physically dissimilar inputs and outcomes. Monetization allows investment costs and environmental benefits and costs to be evaluated similarly in terms of their claim on scarce resources relative to social priorities.

Since Pigou, Coase (1960) has argued that government intervention may not be necessary to address the inefficiency in resource allocation associated with externalities. He has shown that private negotiation between the two parties can result in an optimal allocation of resources. However, the conditions required for this approach to be successful are quite restrictive. Further, the continued existence of an externality frequently demonstrates the ineffectiveness of such arrangements.

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[41] At lower levels of production, increased social benefit is available with increased production. At higher levels of production, increased social benefit is available at decreased levels of production.

[42] To see the folly of attempting to eliminate all impacts in this situation, consider the stated goal of the 1972 amendment to the Clean Water Act, which intended to eliminate all discharges into navigable waterways by 1985.

An Overview of Benefit-Cost Analysis

The usefulness of BCA in making decisions that affect groups of people is limited to the acceptance of the outcomes by potentially competing stakeholder groups. Understanding the equity implications of benefit-cost based decision-making using any criteria requires first understanding that benefits and costs accrue to people. Specifically, for any policy decision, there is not only an aggregate benefit and cost, but also individuals who are affected both positively (winners) and negatively (losers).

Although it applies the principles of the positive economic model, BCA is intrinsically a tool of normative economics. Stated simply, it is a way of determining what is, in some sense, "best" for society. Unfortunately, making this determination can be easier said than done. Mishan (1981) writes:

> In positive economics it is simpler to test the significant implications for our hypotheses than to test the set of assumptions or postulates from which they are deduced …. In normative economics, it is the other way round: … [it requires] ascertaining the validity of the conclusions from the realism of the assumptions adopted (p. 24).

In other words, even if a BCA fully and accurately measures every individual's welfare change for a specific policy change, its ability to determine whether the policy is best for society ultimately depends on the degree to which society accepts its ethical foundation.

Among the earliest contexts for BCA are the works of Hicks (1939) and Kaldor (1939), who independently proposed a policy criterion for maximizing net benefits.[43] The Kaldor-Hicks criterion established that by maximizing net benefits, winners from any decision are able to compensate losers. By comparison with "significantly greater" and "wholly disproportionate," the Kaldor-Hicks criterion can be considered a "greater than" criterion. It advises that when expected costs exceed expected benefits, by any amount, the project is not undertaken.[44] In contrast, the "significantly greater" language in the Phase II Rule of Section 316(b) of the CWA requires project implementation despite costs being greater than benefits in some instances. As a result, "significantly greater" presumably requires a higher standard for inaction. That is, the significantly greater test will result in project implementation in more instances than would a benefit-cost comparison under the Kaldor-Hicks criterion.

A difficulty with the Kaldor-Hicks or "greater than" criterion is the distributional consequence when benefits and costs accrue to different sectors. Consider the case of a power generator whose impingement and entrainment impacts cause economic losses to commercial fishing in a closed-access fishery. This power generator is able to pass along its compliance costs to consumers. The estimated costs of applying the low-cost technology are not "significantly greater" than expected benefits accruing to commercial fishing. In this situation, the 316(b) rule indicates that installation of the technology is required. When the technology is installed, benefits accrue to a limited number of commercial fisherman and costs are distributed across

[43] Other standards for decision-making identified in the economics literature include the Pareto criterion (no one is made worse off and at least one is better off) and the Little (1957) criteria, which require that the Hicks-Kaldor criteria is satisfied and the resulting change improves the distribution of income (where improvement is judgment-based).

[44] Note that this criterion does not consider uncertainty in the magnitude or outcome of benefits or costs. Moreover, it is a minimum criterion because it considers a project in isolation of other projects.

many households in the form of increased electricity rates. In this case, the remedy is a cost to a greater number of people than it is a benefit. By comparison, imagine that the power producer operates in a competitive market and has impacts to a recreational fishery. In this case, the technology financing presumably is passed through to owners of corporate stock and debt in the form of reduced dividends, growth, or increased default risk (decreased bond value). The benefits accrue to recreational anglers.

The strict application of a benefit-cost test for policy problems essentially requires that the policymaker accept efficiency as an objective. While there are clearly competing objectives and decision criteria, efficiency is widely regarded as an important consideration for decisions that affect society. One reason for this is that utilitarian efficiency sums values across all individuals in society and is, therefore, not inherently exclusive or elitist. In this way it reflects many of the underlying values in a democratic society. Another reason is that it incorporates values that are implicit in individuals' trade-offs. In other words it is based on a conceptual model (described above in "Microeconomic Foundations of BCA") that assumes that individuals' preferences are reflected in the choices they make, and it proceeds from there by assuming that they are the best judges of what is best for them. Therefore, this notion of "consumer sovereignty" is grounded in the utilitarian efficiency model, and it also reflects commonly held individualistic values and opposition to overly paternalistic government.[45] A final reason why efficiency is regarded as an important societal objective is that it imposes a similar type of discipline on government as individuals generally impose on themselves. By forcing policymakers to balance benefits and costs, it forces them to recognize unavoidable resource constraints on society, in much the same way that individuals face budget, time, and other resource constraints.

The objective of efficiency is not inherently inequitable; however, it does not consider directly the *distribution* of policy benefits and costs in society. The ethical foundation of benefit-cost analysis is open to challenge to the extent that society does care *who* gains and *who* loses (and whether they can be identified and compensated), and society cares about the original position of the gainers and losers (e.g., the underlying distribution of income).

However, while the strict application of BCA ignores the distributional implications of the policy, there is no inherent reason why it must. Indeed, BCA can identify policy winners and losers and the magnitude of their gains and losses. Distributional weights can be applied to these values to reflect the social consensus regarding the desired relationships among these stakeholders. Completely understanding the implications of any particular comparator—be it "significantly greater" or any other terminology—also requires an understanding of how benefits and costs are determined and distributed.

Using BCA to Identify the Best Technology Available

Under the requirements of the Clean Water Act, EPA must identify the "best technology available" (BTA) for addressing the threats to environmental quality arising from cooling water intake structures (CWIS) and recommend an action. In many situations there are a potentially

[45] For a critique of this point, see Railton (1990) and Sagoff (1994).

large number of CWIS technology alternatives. To apply the principles presented in "Microeconomic Foundations of BCA" involves completing the following steps.

1. *Identify technologically feasible CWIS alternatives*. Identify CWIS technology alternatives for the specific site, including technology combinations and the capital and operating costs of their implementation.
2. *Estimate the market responses to the CWIS alternatives*. Develop estimates of the impacts on all market goods affected by the CWIS alternatives.
3. *Estimate the nonmarket responses to the CWIS alternatives*. Develop estimates of the response of ecological systems to the alternatives and the services provided by those systems.
4. *Value market and nonmarket outcomes*. Develop estimates of the value to stakeholders of the market and nonmarket outcomes.
5. *Identify, quantify, and analyze sources of uncertainty*. Construct confidence intervals for each critical parameter to summarize the range of uncertainty for each estimate. Indicate which elements cannot be put into dollar terms and why.
6. *Identify the economically efficient alternative*. Compute the net benefits of each alternative and identify the gainers and losers. Identify the CWIS technology—which could include a combination of alternatives—for which net benefits are the largest.

This approach systematically incorporates considerations of parameter uncertainty in the analysis. Thus, decision makers can see both the expected net benefits of each alternative and the expected distribution of those net benefits. Depending on the nature of the benefits and costs, decision makers may choose to favor a lower net-benefit alternative with a tighter distribution of expected net benefits over one that has a higher expected net-benefit value but also has more uncertainty regarding the outcomes.

Because of a lack of information or the limits of available methodologies, it may not be possible to correctly monetize all possible benefit or cost categories. In such cases, the BCA should qualitatively describe the benefits and costs in question. For alternatives where monetized benefits fall short of costs, decision makers may decide whether or not the likely value of identified, nonmonetized net benefits is large enough to justify the investment.[46]

Using BCA to Support Site-Specific Determination

The benefits and costs of compliance alternatives are highly context-specific. A given alternative implemented in one location will have a different magnitude and distribution of benefits and cost when made in a different location. Thus, BTA cannot be identified on an industry, regional, plant-type, or water body-type basis, except when a group of sites is truly similar in all relevant aspects, including physical effects, environmental effects, and the value of the associated environmental services. For example, a pristine lake in a region with few

[46] Where substantial risks are involved, decision makers may be able to quantify the monetary value of the risks and include it as a cost associated with that alternative. This approach is the way financial markets absorb information about investments with varying risks.

recreation alternatives is not comparable for BTA evaluation purposes to a lake with low baseline water quality in a region with abundant substitute recreation alternatives.

The Phase II Rule allows for a site-specific determination of BTA if the costs of compliance using EPA's suggested approaches are estimated to be "significantly greater" than estimates of associated benefits. A facility demonstrating that the costs of complying with the rule are likely to be "significantly greater" than the benefits of compliance must submit three supporting documents. These include a Benefit Valuation Study (BVS), a Comprehensive Cost Evaluation Study, and a Site-Specific Technology Plan.

The BVS values the natural resource services associated with the recreational, commercial, and forage fish impinged and entrained at a facility. The EPA gives specific guidance on what information must be included in the BVS. Specifically, the BVS must include:

1. A description of the methodology(ies) used to value commercial, recreational, and ecological benefits (including any nonuse benefits, if applicable).
2. Documentation of the basis for any assumptions and quantitative estimates. If using an entrainment survival rate other than zero, submit a determination of entrainment survival at the facility based on a study approved by the Director.
3. An analysis of the effects of significant sources of uncertainty on the results of the study.
4. A narrative description of any nonmonetized benefits that would be realized at the site if the facility were to meet the applicable performance standards and a qualitative assessment of their magnitude and significance.
5. If requested by the Director, a peer review of the items submitted in the BVS. The facility must choose the peer reviewers in consultation with the Director, who may consult with EPA and Federal, State, and Tribal fish and wildlife management agencies with responsibility for fish and wildlife potentially affected by the facility's CWIS. Peer reviewers must have appropriate qualifications, which correspond to the materials to be reviewed.

The Comprehensive Cost Evaluation Study evaluates the costs of implementing technological, operational, and/or restoration measures to meet the performance standards for the facility. The Comprehensive Cost Evaluation Study will consist of engineering cost estimates for implementing design and construction technologies, operational measures, and/or restoration measures that would comply with 316(b) performance standards. These cost estimates are then used in conjunction with benefits estimates from the BVS to conduct benefit-cost tests and compare them with benefits presented in the BVS to determine if costs are "significantly greater" than benefits.

Specifically, the Comprehensive Cost Evaluation Study must include the following components:

1. Engineering cost estimates of technologies, operational measures, and/or restoration measures that would be needed to meet the applicable performance standards
2. Demonstration of cost-cost and benefit-cost tests
3. Engineering cost estimates to document the cost of technologies, operational measures, and/or restoration measures in the Site-Specific Technology Plan.

Cost categories should include capital costs for installation of the technologies, the net operation and maintenance (O&M) costs, the net revenue losses (lost revenues minus saved variable costs) associated with net construction downtime, and any pilot study costs associated with on-site verification and/or optimization of the technologies or measures.

The Site-Specific Technology Plan does not consider costs, but builds on the information found in the Comprehensive Cost Evaluation Study with more detailed information on how the proposed technological, operational, and/or restoration measure will be used to achieve the relevant performance standards.

References

1. Arrow, K. J., Elizabeth E. Bailey, William J. Baumol, Jagdish Bhagwati, Michael J. Boskin, David F. Bradford, Robert W. Crandall, Maureen L. Cropper, Chistopher C. Demuth, George C. Eads, Milton Friedman, John D. Graham, Wendy L. Gramm, Robert W. Hahn, Paul L. Joskow, Alfred E. Kahn, Paul R. Krugman, Lester B. Lave, Robert E. Litan, Randall W. Lutter, Paul W. Macavoy, Paul W. Mccracken, James C. Miller III, William A. Niskanen, William D. Nordhaus, Wallace E. Oates, Peter Passell, Sam Peltzman, Paul R. Portney, Alice M. Rivlin, Milton Russell, Richard L. Schmalensee, Charles L. Schultze, V. Kerry Smith, Robert M. Solow, Robert N. Stavins, Joseph E. Stiglitz, Laura D'andrea Tyson, W. Kip Viscusi, Murray L. Weidenbaum, Janet L. Yellen, and Richard J. Zeckhauser. 2000. Brief amici curiae for the Supreme Court of the United States, *American Trucking Associations, Inc., et al. v. Carol M. Browner, U.S. Environmental Protection Agency, et al.* AEI-Brookings Joint Center for Regulatory Studies, Washington DC.
2. Barry, J. M. 1997. Rising Tide: The Great Mississippi Flood of 1927 and How It Changed America. Simon and Schuster, New York.
3. *BASF Wyandotte Corp. v. Costle*. 598 F.2d 637, 656 (1st Cir. 1979).
4. Blamey, R., and J. Bennett, eds. 2001. The Choice Modelling Approach to Environmental Valuation. Edward Elgar Publishing, Inc., Northampton, MA.
5. Blamey, R. K., J. W. Bennett, J. J. Louviere, M. D. Morrison, and J. Rolfe. 2000. A test of policy labels in environmental choice modelling studies. Ecological Economics 32(2):269-286.
6. Brent, R. J. 1995. Applied Cost-Benefit Analysis. Edward Elgar Publishing Limited, Cheltenham, UK.
7. Coase, R. 1960. The problem of social cost. Journal of Law and Economics 3:1-44.
8. Dupuit, J. 1844. De la mesure de l'utilité des travaux publics. Annales de Ponts et Chaussées, Second Series, Volume 8. Translated as: Dupuit, J. (1952), On the measurement of utility of public works, International Economic Papers 2:83-110. English translation reprinted as pages 255-283 in K. J. Arrow and T. Scitovsky (1969), Readings in Welfare Economics. Richard D. Irwin, Homewood, Illinois.

9. *Flood Control Act of 1936*, 74th Congress, 2nd Sess., CHS. 651, 688 (June 20, 22, 1936). Available at http://www.ccrh.org/comm/cottage/primary/1936.htm. Retrieved on May 25, 2006.
10. Foster, C. D., and M. E. Beesley. 1963. Estimating the social benefit of constructing an underground railway in London. Journal of The Royal Statistical Society Series A (General), Vol.126, Part I.
11. Friedman, M., and L. P. Savage. 1948. The utility analysis of choices involving risk. Journal of Political Economy 56:279-304.
12. Fuguitt, D., and S. Wilcox. 1999. Cost-Benefit Analysis for Public Sector Decision Makers. Quorum Books, Westport, CT.
13. Grumbles, Benjamin. 2007. Implementation of the decision in *Riverkeeper, Inc. v. EPA*, remanding the cooling water intake structures Phase II regulation. Washington, DC: U.S. Environmental Protection Agency.
14. Hanley, N., R. E. Wright, and V. Adamowicz. 1998. Using choice experiments to value the environment. Environmental and Resource Economics 11(3-4):413-428.
15. Harberger, A. C. 1971. Three basic postulates for applied welfare economics: an interpretive essay. Journal of Economic Literature 9(3):785-797.
16. Hensher, D. A. 1991. The use of discrete choice models in the determination of community choices in public issue areas impacting on business decision making. Journal of Business Research 23(4):299-309.
17. Hicks, J. R. 1939. The foundations of welfare economics. Economic Journal 49 (December):696-712.
18. Kaldor, N. 1939. Welfare propositions in economics and interpersonal comparisons of utility. Economic Journal 49(145):549-552.
19. *Kennecott v. United States EPA*. 780 F.2d 445, 448 (4th Cir. 1985).
20. Klarman, H. E. 1965. Syphilis control problems. In Measuring Benefits of Government Investments, ed. R. Dorfman. Brookings Institution, Washington, DC.
21. Kling, C. L., and J. A. Herriges. 1995. An empirical investigation of the consistency of nested logit models with utility maximization. American Journal of Agricultural Economics 77(November):875-884.
22. Little, I. 1957. A Critique of Welfare Economics 2nd Edition. Oxford University Press.
23. May, J. R., and M. K. Van Rossum. 1995. The quick and the dead: fish entrainment, entrapment, and application of Section 316(b) of the Clean Water Act. Vermont Law Review 20(2)Winter:402.
24. Ministry of Transport, U.K. 1963. Proposals for a Fixed Channel Link. Cmnd. 6137.
25. Mishan, E. J. 1975. Cost Benefit Analysis: An Informal Introduction. Allen and Unwin Limited, London.
26. Mishan, E. J. 1981. Introduction to Normative Economics. Oxford University Press, New York, NY.

27. Pigou, A. C. 1932. The Economics of Welfare, Fourth Edition. Macmillan and Co., London.
28. Railton, P. 1990. Benefit-cost analysis as a source of information about welfare. In Valuing Health Risks, Costs and Benefits for Environmental Decision Making: Report of a Conference. National Academy Press, Washington, D.C.
29. Sagoff, M. 1994. Should preferences count? Land Economics 70(2):127-144.
30. Shabman, L. 1997. Making benefit estimation useful: lessons from flood control experience. Water Resources Update Autumn(109):19-23.
31. Smith, A. 1776. An Inquiry into the Nature and Causes of the Wealth of Nations. Methuen and Co., Ltd., London. Edwin Cannan, ed. 1904. Fifth edition.
32. TetraTech Inc. 2002. Evaluation of cooling system alternatives proposed Morro Bay Power Plant. Available at http://www.swrcb.ca.gov/rwqcb3/MorroBayDNA/Reports/TetraTechMBPP.pdf. Retrieved on August 11, 2006.
33. Watkins, T. Undated. An introduction to cost benefit analysis. Available at http://www2.sjsu.edu/faculty/watkins/cba.htm. Retrieved on May 25, 2006.
34. *Weyerhaueser Co. v. Costle*. 590 F.2d 1011, 1048 (D.C. Cir. 1978).

B
NONUSE VALUATION

Nonuse values are the values that people hold for natural resource services that they do not use. These services may include ecological services, such as habitat for fish and wildlife. Or, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist. As the rule points out, the economic literature commonly refers to two components of nonuse values as bequest (or altruistic) values and existence values, respectively (EPA 2004b, p. A9-3).

Currently, the only methods available for estimating nonuse values are survey-based techniques that ask respondents to value, choose, rate, or rank natural resource services in a hypothetical context. The reliability of this approach for evaluating nonuse impacts is questionable. The relevant literature has long noted and thoroughly documented the difference between people's stated intentions and actual behaviors (Kemp and Maxwell 1993). This difference between intentions and behavior is called hypothetical bias. Researchers in the natural resource arena recognized hypothetical bias more than 25 years ago, defining it as the potential error due to not confronting an individual with a real situation (Rowe, d'Arge, and Brookshire 1980).

The two sections of this appendix describe the two primary techniques available for nonuse valuation: contingent valuation (CV) and stated preference (SP) surveys. These sections provide overviews of the techniques, summarize the data and analysis requirements of each approach, discuss each method's advantages and disadvantages, and provide examples. The third section of this appendix describes the progression of nonuse valuation in 316(b) applications. The final section of this appendix describes strategies for instances where the EPA will require a quantitative estimate of nonuse values.

Contingent Valuation (CV) Methodology

The contingent valuation (CV) method for estimating the value of natural resource services involves a direct survey of individuals to elicit their willingness to pay (WTP) for different levels of services.[47] For example, the survey may ask respondents a question such as, "What is the maximum amount you would pay to restore wild salmon runs in the Columbia River Basin?"[48] The responses are analyzed to determine the average WTP for preserving wild salmon runs. This

[47] See Hausman (1993) and Arrow et al. (1993) for a more detailed critique of CV.
[48] Natural resource economists have used a variety of question formats. This question is an open-ended format. Alternatives include bidding games, payment cards, and referendum or dichotomous-choice. In the dichotomous choice format, respondents are offered a particular payment amount and allowed to accept or reject that amount. See Mitchell and Carson (1989) for a detailed discussion.

Nonuse Valuation

method requires that individuals be able to express their value for marginal changes in the fishery and, furthermore, that their responses to hypothetical questions indicate their actual valuations of the changes described in the questions.

The CV method attempts to establish, through the course of a survey, a hypothetical market where environmental changes can be sold like commodities. Thus, the main task of the CV survey is to neutrally, accurately, and credibly present the commodity to be traded and the mechanism through which the trading will occur. In most cases, the commodity is some alternative level of environmental quality and the mechanism is some specified policy or investment. In the case of a fishery, the commodity might be a program for removing several dams, which would result in the restoration of wild salmon runs. The survey would describe the current status of the fishery, the degree of improvement, and a way for financing the dam removal. Ultimately, the goal of the CV survey is to establish circumstances that represent the way a market would operate for the resource services. Oral or written descriptions, supplemented by visual aids, are used to make the survey informative and realistic. Careful control is required over the information given to respondents so answers are based on the same information in each interview and all respondents receive sufficient information to perform the valuation task.

In addition to designing the survey, researchers must determine the relevant population for the survey and draw a representative sample. The relevant market is important because average individual WTP estimates must be aggregated over the affected population to determine total WTP. For any study, the analyst must determine whether the relevant market is limited to neighboring counties or includes the entire state or country. Depending on the relevant population, survey administration costs can vary considerably. Identifying the relevant market in a CV study is an important decision, for which data often are limited (Desvousges et al. 1994).

CV studies require expertise in survey development and administration. CV surveys must be thoroughly tested to ensure that the survey instrument collects unbiased information from the respondents, and this process can be very costly. Survey administration costs will vary with the mode selected, with in-person interviews being the most costly.

The level of analytical complexity varies as well, from simple regression analysis to sophisticated modeling, although CV models tend to be less complex than other methods. The value estimate from CV data is typically the average WTP from the survey question. Researchers may model these responses to determine what characteristics of respondents influence their WTP, and some analysis is required to calculate the variance of the responses. Some question formats require models to determine the mean value, such as the dichotomous-choice format where respondents answer Yes or No to a proposed cost rather than provide a value. Nevertheless, these models are well-established in the literature and relatively straightforward to estimate.

Many economists believe that a carefully designed and implemented CV study can reliably measure such use values as the value that anglers place on an increase in fish catch at a site. Using CV to estimate use values is less controversial, and more likely to be reliable, because the respondents' actual behavior and experience with the resource serves as a reference for the hypothetical payment estimates. However, where use values are concrete and have a basis in actual behavior, nonuse values are inherently subjective and difficult to measure. The validity and reliability of CV is questionable in such circumstances because respondents' hypothetical payment for a nonuse service has no behavioral experience to support or test the expressed value. This lack of a linkage between actual behavior and the hypothetical payment makes CV estimates particularly sensitive to variations in survey design, implementation, and analysis.

The main advantage of the CV method is the control it gives the researcher. Researchers can define the commodity to suit their specific needs, as long as the market remains credible. Thus, the researcher is not constrained by the existence of actual sites with the characteristics needed to determine the value for a given environmental improvement.

The main shortcoming of the CV method is its reliance on responses to hypothetical questions, rather than observances of actual behavior. When people are asked for an amount that they would hypothetically be willing to pay for some described commodity, they have little incentive to consider the response carefully. In contrast, when making actual decisions about how to spend their own scarce resources of time and money, people make careful choices. Therefore, economists have long felt that observations of actual behavior more accurately reflect preferences than responses to hypothetical questions do.

Olsen, Richards, and Scott (1991) conducted a CV study in the Pacific Northwest to estimate the existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. The study focused on estimating resource values to both resource users and resource nonusers. Resource nonusers were defined as individuals who had not been involved in the commercial fishing industry and who had not participated in the sport fishery for the last five years. The population consisted of all the Pacific Northwestern households (Washington, Oregon, Idaho, and western Montana) with telephones because the survey was implemented through telephone interviews.

The Social and Economic Sciences Research Center at Washington State University administered the survey. The sample consisted of 695 responses from resource nonusers and 482 from resource users. As part of the valuation procedure, the survey asks two key questions:

- Respondents were asked about their last electric power bill payment (monthly bill) and their estimated average monthly power bill for the year. This question served to introduce the payment vehicle.
- Respondents were then asked to identify the maximum amount they would pay above their average monthly power bill to double the size of the salmon and steelhead runs.

The results show that households are willing to pay $171 million (1989 dollars) annually for a doubling of the salmon steelhead runs, or $68.49 per additional fish added to the river system. These estimates include both use and nonuse values because values for both users and nonusers are contained in the average. Estimated for just anglers in the Columbia River Basin, the average value for doubling the salmon runs is $132.47 per fish, and a marginal value of $54.84 per fish for doubling the catch rate.

This study is typical of CV fish-valuation studies in its inclusion of both use and nonuse values, its focus on highly valued game fish, and its use of a policy that results in a large increase in the fish population. Cooling water intake structure (CWIS) applications, in contrast, will typically involve only use values, common sport fish species, and relatively small changes in fish populations. Therefore, using estimates from CV fishing studies for use in a CWIS-related benefit-cost analysis may require careful interpretation.

Stated Preference (SP) Methodology

Stated-preference (SP) methods are based on the principle that commodities have value because of their attributes. For example, a car has value because of such specific characteristics as size, color, comfort, body style, handling, gas mileage, and price. People generally have preferences among these attributes and are willing to accept trade-offs among them, so a car buyer may be willing to accept less comfort for better handling.[49] An SP survey asks respondents to rank, rate, or choose among a series of different alternatives with different levels of attributes. By analyzing the choices made by respondents, researchers can uncover the underlying preferences for these attributes.

SP methods have been used extensively in marketing research and product development (Cattin and Wittink 1982, Wittink and Cattin 1989). Specific marketing applications have been aimed at new-product identification, market segmentation, advertising, distribution, competitive analysis, and price optimization. In recent years, the SP methods have been applied in the fields of environmental and health economics as an alternative to the CV method. For example, the SP technique has been used to value hunting trips and fishing (Gan and Luzar 1993, MacKenzie 1993, and Roe, Boyle, and Teisl 1996), to explain recreation site choice selection (Adamowicz, Louviere, and Williams 1994), to determine public preferences for siting a noxious facility (Opaluch, et al. 1993), and to estimate customers' WTP for green electricity (Johnson et al. 1995). SP has also been applied to measure changes in fishery services (Banzhaf, Johnson, and Mathews 2001).

Two features are common among all types of SP surveys. First, respondents are asked about commodities with multiple characteristics or attributes. Second, respondents are asked to perform a series of judgment or rating tasks to express their preferences among those attributes.

SP questions can take many forms, each involving a somewhat different cognitive task and a somewhat different perspective on consumer preferences. While each approach has advantages and disadvantages, there is no empirical evidence that one particular elicitation format is clearly superior to others (Huber 1997). Regardless of the question format, an SP study requires sophisticated modeling to uncover the underlying preferences implied by the responses to the SP questions. Furthermore, designing the survey requires high-level expertise to ensure that the information required for the analysis is collected in an unbiased way.

[49]Defining the properties of such preferences has been explored by multi-attribute utility theory (Keeney and Raiffa 1978).

Like CV, SP has the advantage of giving the researcher control to manipulate the content of the survey to suit the needs of the study. However, SP has several advantages over conventional CV approaches. Primarily, SP encourages respondents to explore their preferences for various attribute combinations through a series of choices. The process of explicitly trading off attributes encourages greater respondent introspection than is likely to occur in a traditional CV format. The absence of such introspection has been a major criticism of the validity and reliability of CV estimates (Schkade and Payne 1994).

In addition, SP provides values for individual components of commodities as well as for commodities as a whole in a single survey. The SP method also allows analysts to devise internal consistency checks because respondents provide answers to multiple questions. These internal consistency checks are a significant improvement over the rudimentary technique of using general follow-up questions to assess respondents' motives for answers to single CV questions. Having more information from respondents on their relative preferences for the scenarios allows analysts to systematically evaluate whether a respondent's pattern of answers is plausible and consistent with economic theory used to construct social values.

The SP technique has several potential problems that require careful survey design. First, the SP technique can pose a cognitively challenging task to respondents, particularly if they are unfamiliar with some of the attributes of the commodity to be valued. Furthermore, SP data pose analytical challenges for the researcher because of the dynamic learning process involving both preferences and a particular judgment task. To the extent that respondents become engaged in the learning process, later responses may be better indicators of preferences than earlier responses. It also is possible that fatigue could affect the quality of later responses. Sophisticated modeling of SP data may make it possible to detect such intertemporal effects.

Finally the SP technique, like CV, elicits expressed preferences under hypothetical conditions. As a result, the responses are likewise hypothetical, which implies that respondents do not have to make a real-dollar commitment as they would in a real-market situation. Thus, in that respect, SP does not offer any advantage over CV.

In 2005, EPA issued a draft SP study specifically designed to elicit nonuse values for use in 316(b) applications (EPA 2005).[50] Although the EPA has since abandoned its plans to field this survey throughout the United States, the SP questionnaire is the most informative example of an SP study for 316(b) analysis.[51]

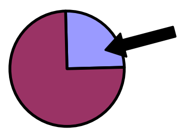
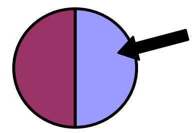
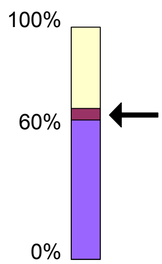
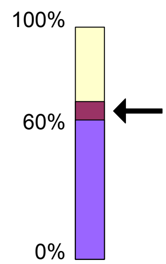
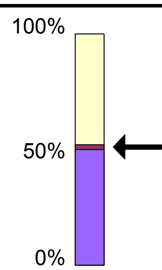
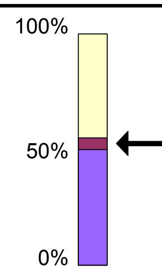
Figure B-1 below contains a sample SP question from the EPA 2005 SP study. In this design, respondents are presented with two different (but not described) technologies for achieving I&E reductions at a facility, Option A and Option B. These two options differ in the number of fish saved per year through I&E reductions, the percentage increase in fish populations over 3–5 years, the percentage increase in recreational and commercial catches, and the increased cost per household. Survey respondents could select either option, or could select neither.

[50] *Supporting Statement For Information Collection Request For Willingness To Pay Survey For §316(B) Phase III Cooling Water Intake Structures: Instrument, Pre-Test, And Implementation (OW-2005-0006-0002)* (hereafter, EPA 2005).

[51] See Desvousges et al. (2005) for a critique of this proposed SP study.

Nonuse Valuation

Question 1. Assume Options A and B would require <u>different technology</u> to prevent fish losses in facilities that use cooling water, and that all types of fish would be affected. How would you vote?

	OPTION A	**OPTION B**
Fish Saved per Year (Out of total lost in cooling water intakes)	 **456 million fish saved per year** **Annual Losses Reduced by ¼**	 **912 million fish saved per year** **Annual Losses Reduced by ½**
Effect on Long-Term Fish Populations (After 3-5 Years)	 **Total Fish Populations Increase to 65%**	 **Total Fish Populations Increase to 68%**
Effect on Annual Recreational and Commercial Catch (After 3-5 Years)	 **Catch Increases to 52%**	 **Catch Increases to 55%**
Increase in Cost of Living for Your Household	**$2 per month** ($24 per year) Cost of new regulations passed on to consumers	**$3 per month** ($36 per year) Cost of new regulations passed on to consumers

Scientists expect that other effects on the environment and economy will be negligible.

Please check <u>one</u>:

- ☐ I would vote for Option A.
- ☐ I would vote for Option B.
- ☐ I would not vote for either option.

Figure B-1
Sample SP Question from the EPA 2005 SP Study

Because the EPA never fielded this study, we cannot provide a discussion of the valuation results. However, Desvousges et al. (2005) conducted a pilot test of this study to learn whether the SP survey designed by the EPA could produce reliable estimates of nonuse benefits. They concluded that the study could not and identified the following problems:

- Respondents are not valuing marginal changes in forage fish populations. Respondents' answers range from use values for specific fish in specific waterbodies to more generalized concerns for the environment. The fact that EPA's survey elicits values other than the nonuse value of forage fish is a fatal flaw.
- The survey responses reveal a consistent pattern of hypothetical bias. The respondents' answers clearly show that they viewed their responses as hypothetical, non-binding answers to a survey, not a genuine commitment of personal resources.
- Respondents' answers are entirely dependent upon the information provided in the survey questionnaire and the accompanying PowerPoint slide show. Barnthouse (2005) shows that the information contained in the EPA survey materials is inaccurate and inconsistent with the scientific literature on the effects of CWIS on the environment.
- EPA also has failed to include information concerning the inherent uncertainty of the effects of CWIS on the environment, which further limits the usefulness of the survey responses.
- Many respondents indicated that they found the survey process to be long, difficult and confusing. Such a finding increases the chances of significant nonresponse bias in the survey. The evident confusion in respondents' answers is yet another source of statistical noise that further lowers the likelihood that this survey would yield useful information.
- Because the survey design does not address whether valuation responses are solely for this specific program or are simply reflections of some larger mental account for protecting fish, it is not possible to fully evaluate the nature of respondents' preferences. That is, the EPA survey design does not try to determine whether people value protecting all fish from all forms of predation and whether the value of reducing the impacts of CWIS on forage fish is a subset of that broader valuation. At a minimum, this survey presents a classic illustration of the conundrum as to whether respondents have preferences for reducing the effects of CWIS on forage fish or whether such preferences are merely an artifact of the survey process.

Role of Nonuse Values in the Phase II 316(b) Rule Development

As discussed in Section 5 of this report, the EPA currently requires that nonuse values be considered in a benefits assessment. In many instances, nonuse values can be treated qualitatively. This section of the appendix describes the various methods that EPA evaluated in its assessment of nonuse values during the period of the proposed rule and the Notice of Data Availability (NODA). The section then presents EPA's guidelines in the Final Phase II Rule for addressing nonuse values.

Nonuse Valuation

EPA Approach: Proposed Rule

In the proposed rule, EPA presented three potential approaches for quantifying nonuse values. These include the Habitat Replacement Cost (HRC) method, the Societal Revealed Preference (SRP) approach, and the Fisher-Raucher approximation. After public comment and further review EPA repudiated these methods. The following sub-sections describe each approach.

Habitat Replacement Cost Method

For the HRC method, the costs estimated by EPA are the total costs of restoring habitats so that they produce ecological services equivalent to those expected from technological alternatives. Numerous reviewers commented that these costs are not benefits. Rather, they are alternative costs for achieving the objectives of the proposed regulation. Mitigation approaches such as stocking and habitat restoration may be acceptable alternatives to technology installation. However, the cost of such alternatives bears no implicit relationship to the benefits of reducing I&E. Therefore, it is important not to confuse this method of mitigation scaling with measuring the benefits of the mitigation.

Appropriate economic measures of benefits require that they be based on the willingness-to-pay principle, and HRC is not based on this principle. In many cases, the cost of developing a resource can substantially exceed the resource's value. Although EPA extensively evaluated HRC during its development of the Phase II Rule, EPA ultimately decided that the HRC method should not be used as a means of estimating benefits due to limitations and uncertainties regarding the application of this methodology (*Fed. Reg.*, Volume 69, No. 131, p. 41,625).

Societal Revealed Preference Method

The second cost-based methodology employed by EPA in the Proposed Rule is called Societal Revealed Preference (SRP). Rather than using the cost of a hypothetical alternative, SRP uses historical costs under prior government mandates to measure benefits. Like the HRC method, this cost-based approach has no foundation in economic theory and is not accepted by economists as a legitimate method of empirical valuation. In fact, the SRP method is a corrupted application of the legitimate revealed preference method. An essential characteristic of revealed preference analysis and not SRP is that willingness to pay is revealed by those who are doing the paying. The SRP methodology takes the fact that a program exists as evidence that its benefits exceed its costs. EPA removed the disputed results of the SRP analyses from its benefits estimates for the final rule.

Fisher-Raucher Approximation

For the Proposed Rule analysis, EPA also presented the Fisher-Raucher or ''50 percent'' rule. This approach approximates nonuse values at 50 percent of recreational use values. The approximation is derived from a comparison of use and nonuse values for water quality improvements (Fisher and Raucher 1984). The 50-percent rule is inappropriate in this context because there is no reason to believe that the ratio of nonuse to use benefits from water quality improvements could be applied to the environmental improvement from reductions in I&E. Moreover, because use values for fish often arise from their *consumption*, there is no conceptual reason to believe that there is a positive association between use and nonuse values in this context. EPA does not employ the 50-percent rule in its final analysis and this approach is not employed in this assessment.

EPA Approach: Notice of Data Availability (NODA)

EPA used two approaches to evaluate nonuse values in the NODA. These include a revised form of the HRC method and the Production Forgone method. After public comment and further review EPA repudiated the revised HRC method. The Production Forgone method is included in EPA's final benefits analysis. The following sub-sections describe each approach.

Revised Habitat Replacement Cost

In the NODA, EPA presented a revised HRC methodology that evaluated nonuse benefits based on estimated willingness-to-pay values for the resource improvements that would be achieved by equivalent restoration. It was based on an approach that combines an estimate of the amount of habitat required to offset I&E losses by means of wild fish production with a benefits estimate of willingness to pay for aquatic habitat preservation/restoration from existing studies.

This approach is fundamentally flawed for a number of reasons (Bingham, Desvousges, and Mohamed 2003). A theoretical shortcoming of this approach is that there is no good reason to presume that willingness-to-pay values for habitat restoration are an appropriate proxy for either the total value or the nonuse value of the fishery resources that would be preserved due to reduced I&E. EPA does not employ this revised HRC approach in its final analysis.

Production Forgone

When calculating benefits for the NODA, EPA valued forage fish based upon their value as inputs to recreational and commercial stocks. The Production Forgone methodology recognizes that the value of forage species is through indirect use rather than nonuse. This methodology passes the biological effects of increased biomass availability through trophic levels until it reaches commercially and recreationally valuable species. At this point, catch changes and recreational and commercial values are calculated. Although commenters disagreed on certain assumptions, the approach was generally accepted.[52] Valuing forage benefits in this manner accounted for nearly all biomass but led to only marginally higher estimates of economic impacts to recreational and commercial fishing.[53]

[52] For example, Barnthouse (2002) indicates that the transfer efficiency is not correct.
[53] The recreational and commercial fishing mortality rates specified by EPA indicate that very few of these fish are expected to die naturally. Valuing forage fish in terms of production forgone added less than 20 percent to total benefits.

Nonuse Valuation

EPA Approach: Final Rule—Qualitative Discussion of Nonuse Values

Although it evaluated a variety of methods for quantifying benefits associated with reductions in I&E losses, EPA ultimately determined that none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits (EPA 2004a, p. 41,624) in the absence of impacts to sustainable populations or threatened and endangered species. In the final Phase II Rule, EPA provides the following guidance on how to assess the nonuse benefits associated with reductions in I&E (EPA 2004a, p. 41,647–41,648):

- Nonuse benefits may arise from reduced impacts to ecological resources that the public considers important, such as threatened and endangered species. Nonuse benefits can generally only be monetized through the use of stated preference (SP) methods. When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information.
- In cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function in a facility's waterbody or watershed, nonuse benefits should be monetized.
- In cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not necessary.

Strategies for Nonuse Value Assessments

In a few rare instances, it may be necessary to evaluate nonuse values in a more rigorous way. For example, if a plant's CWIS were located near habitat for an endangered species, such as a manatee or a sturgeon or a salmon, there may be a need to measure the nonuse value associated with that species. In some instances, rather than quantifying those impacts, it may be possible to reach agreement with the regulatory agency over a restoration program that would offset the impacts on the potentially affected species.

If that alternative is not feasible or acceptable within a jurisdiction, then the last alternative would be to conduct a CV or SP survey. As described earlier, these surveys would involve asking respondents in one form or another how much they would be willing to pay to protect the endangered species in the particular location. Clearly, the most serious limitation of the method is that the responses are based on what people say they would do, not what they would actually pay.

Given these limitations, it is not possible to conduct a survey that would meet most generally accepted reliability criteria. Nonetheless, it could still be in a utility's interest to conduct such a study. For example, even with substantial hypothetical bias, the estimated benefits could be less than the cost of a closed cycled cooling tower, which would enable a less expensive technology to be selected. Alternatively, some restoration programs might be envisioned that would involve substantial life cycle costs for the utility that would not be desirable. Thus, it is important to fully evaluate the potential options before rejecting the notion of quantifying nonuse benefits outright.

Additionally, some factors can lead to better studies. Accordingly, we recommend that a utility:

- Conduct extensive pretesting of the survey questionnaire to ensure that people understand the questions (Mathews, Freeman, and Desvousges 2006).
- Develop a rigorous sampling plan to ensure that the sample is representative of the target population.
- Use the SP form of the valuation question rather than the CV form.
- Include extensive tests for reliability within the survey design to test whether or not the answers conform to established economic principles (Johnson and Mathews 2001).

Even with these steps, hypothetical bias is likely to be present. However, the reliability tests will enable such bias to be evaluated and demonstrated, so that some type of adjustment can be made in the final responses. Such adjustments could be negotiated with the regulators and could even be considered in the determination of the meaning of “significantly greater than.” For example, suppose that the SP survey revealed that costs were three times greater than the benefits of a closed cycle cooling system with no adjustment made for hypothetical or other biases. However, suppose that making the adjustments for bias were to result in costs being five times greater than benefits of a closed cycle cooling system. Calculating such a range would provide the regulator with a greater sense of confidence that even with all possible benefits explicitly included, the costs of closed cycle cooling would be significantly greater than the benefits.

References

1. Adamowicz, W., J. Louviere, and M. Williams. 1994. Combining revealed and stated preference methods for valuing environmental amenities. Journal of Environmental Economics and Management 26:271-292.
2. Arrow, K., R. Solow, P. R. Portnoy, E. E. Leamer, R. Radner, and H. Schuman. 1993. Report of the NOAA Panel on Contingent Valuation. 58 *Fed. Reg.* 4601 *et. seq*. January 15.
3. Banzhaf, M. R., F. R. Johnson, and K. E. Mathews. 2001. Opt-out alternatives and anglers’ stated preferences. In The Choice Modelling Approach to Environmental Evaluation, J. Bennett and R. Blamey, eds. Edward Elgar Publishing, Northampton, MA.
4. Barnthouse, L. 2002. Review of Methodology Used by EPA to Evaluate Impacts of Entrainment and Impingement Losses and Comments on the PISCES (August 2002) Report. Prepared for the Riverkeeper Inc. Prepared for EPRI. LWB Environmental Services, Oak Ridge, TN.
5. Barnthouse, L. W. 2005. Comments on EPA 316(b) “Willingness to Pay” Survey Materials. July. LWB Environmental Services, Inc., Hamilton, OH.

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6. Bingham, M. F., W. H. Desvousges, and A. F. Mohamed. 2003. Comments on Benefit Estimation of EPA's Proposed Phase II 316(b) Rule as Summarized in the Notice of Data Availability: Final Report. Prepared for The Utility Water Act Group. June. Triangle Economic Research, Durham, NC.
7. Cattin, P., and D. Wittink. 1982. Commercial use of conjoint analysis: a survey. Journal of Marketing 46(Summer):44-53.
8. Desvousges, W. H., M. F. Bingham, J. C. Kinnell, A. F. Mohamed, and K. T. Kuhns. 2005. Review and Response to the EPA's Response to Comments from the American Chemistry Council et al. and Accompanying Triangle Economic Research (TER) Report. Prepared for the Utility Water Act Group, General Electric Company, American Chemistry Council, American Forest and Paper Association, American Iron and Steel Institute, American Public Power Association, and American Petroleum Institute. April 20. Durham, NC: Triangle Economic Research.
9. Desvousges, W.H., S.P. Hudson, S.K. Snow, R.W. Dunford, A.R. Gable, M.C. Ruby, and R.A. Sandefur. 1994. Comments on the National Oceanic and Atmospheric Administration's Natural Resource Damage Assessment Proposed Rule. Prepared for NOAA. Durham, NC: Triangle Economic Research.
10. Fisher, A., and R. Raucher. 1984. Intrinsic benefits of improved water quality. Conceptual and empirical perspectives. Advances in Applied Micro-Economics 3:37-66.
11. Gan, C., and E. J. Luzar. 1993. A conjoint analysis of waterfowl hunting in Louisiana. Journal of Agricultural and Applied Economics 25:36-45.
12. Hausman, J. A., ed. 1993. Contingent Valuation: A Critical Assessment. Elsevier Science Publishers, Amsterdam.
13. Huber, J. 1997. What we have learned from 20 years of conjoint research: when to use self-explicated, graded pairs, full profiles or choice experiments. Paper prepared for the Sawtooth Software Conference:1-16. August.
14. Johnson, F. R., W. H. Desvousges, E. E. Fries, and L. L. Wood. 1995. Conjoint analysis of individual and aggregate environmental preferences. TER Technical Working Paper T-9502. Triangle Economic Research, Durham, NC.
15. Johnson, F. R., and K. E. Mathews. 2001. Sources and effects of utility-theoretic inconsistency in stated-preference surveys. American Journal of Agricultural Economics 83(5):1328-1333.
16. Keeney, R. L., and H. Raiffa. 1978. Decisions with Multiple Objectives: Preferences and Tradeoffs. John Wiley and Sons, New York.
17. Kemp, M., and C. Maxwell. 1993. Exploring a budget context for contingent valuation estimates. In Contingent Valuation: A Critical Assessment. J. A. Hausman, ed. Elsevier Science Publishers B.V., Amsterdam.
18. Mackenzie, J. 1993. A comparison of contingent preference models. American Journal of Agricultural Economics 75(3):593-603.
19. Mathews, K. E., M. L. Freeman, and W. H. Desvousges. 2006. How and how much? The role of information in stated choice questionnaires. In Valuing Environmental Amenities

Using Choice Experiments: A Common Sense Guide to Theory and Practice, ed. B. Kanninen. Springer, Dordecht, The Netherlands.

20. Mitchell, R. C., and R. T. Carson. 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method. Resources for the Future, Inc., Washington DC.
21. Olsen, D., J. Richards, and R. D. Scott. 1991. Existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. Rivers 2(1):44-56.
22. Opaluch, J. J., S. K. Swallow, T. Weaver, C. W. Wessells, and D. Wichelns. 1993. Evaluating impacts from noxious facilities: including public preferences in current siting mechanisms. Journal of Environmental Economics and Management 24:41-59.
23. Roe, B., K. J. Boyle, and M. F. Teisl. 1996. Using conjoint analysis to derive estimates of compensating variation. Journal of Environmental Economics and Management 31:145-159.
24. Rowe, R. D., R. d'Arge, and D. S. Brookshire. 1980. An experiment on the economic value of visibility. Journal of Environmental Economics and Management 7:1-19.
25. Schkade, D. A., and J. W. Payne. 1994. How people respond to contingent valuation questions: a verbal protocol analysis of willingness to pay for an environmental regulation. Journal of Environmental Economics and Management 26:88-109.
26. U.S. Environmental Protection Agency. 2004. National pollutant discharge elimination system—final regulations to establish requirements for cooling water intake structures at Phase II existing facilities, final rule. Federal Register Vol. 69, No. 131 (Friday, July 9):41,576-41,693.
27. U.S. Environmental Protection Agency. 2005. Supporting Statement For Information Collection Request For Willingness To Pay Survey For §316(B) Phase III Cooling Water Intake Structures: Instrument, Pre-Test, and Implementation (OW-2005-0006-0002).
28. Wittink, D. R., and P. Cattin. 1989. Commercial use of conjoint analysis: an update. Journal of Marketing 53(July):91-96.

C
ADDITIONAL INFORMATION ON RECREATIONAL SALTWATER FISHING

Table C-1 summarizes the recreational groundfish regulations for 2007 in the Southern Management Area (California Department of Fish and Game, Marine Region 2007a).

Table C-1
Groundfish Regulations in the Southern Management Area

Species	Time Period[a, b, c, d, e]	Depth Limit[a, b, c, d, e]	Daily Bag Limit[b]	Minimum Size Limit[b, f, g]
RCG Complex[a] (including all species of rockfish, cabezon, and greenlings	Boat-based anglers:[c] Open: March–Dec. Closed: Jan.–Feb. Divers, shore-based anglers:[c] Open year-round	May only be taken or possessed in waters *less than* 360 ft (60 fm) deep[a] See exception[h]	10 fish in combination per person See sub-limits for cabezon, greenling, and bocaccio	See individual species and groups
Canary and yelloweye rockfish, cowcod	Closed all year NO RETENTION		NO RETENTION	
Bocaccio	Same as RCG Complex	Same as RCG Complex	1 fish per person Also included in the 10-fish aggregate RCG Complex bag limit	10" total length
Cabezon	Same as RCG Complex	Same as RCG Complex	1 fish per person Also included in the 10-fish aggregate RCG Complex bag limit	15" total length
Kelp or rock greenling	Same as RCG Complex	Same as RCG Complex	2 fish per person Also included in the 10-fish aggregate RCG Complex bag limit	12" total length
Ocean whitefish	Same as RCG Complex	Same as RCG Complex	10 fish per person	None
California sheephead	Same as RCG Complex	Same as RCG Complex	5 fish per person	12" total length
California scorpionfish	Open all year	Jan.–Feb.: may only be taken or possessed in waters *less than* 240 ft (40 fm) deep[a] March–Dec.: may only be taken or possessed in waters *less than* 360 ft (60 fm) deep[a]	5 fish per person	10" total length
Lingcod	All anglers and divers:[c] Open: April–Nov. Closed: Jan.–March, Dec.	Same as RCG Complex	2 fish per person	24" total length

Additional Information on Recreational Saltwater Fishing

Table C-1, continued

Species	Time Period[a, b, c, d, e]	Depth Limit[a, b, c, d, e]	Daily Bag Limit[b]	Minimum Size Limit[b, f, g]
Leopard shark [d]	Divers, shore-based anglers:[c] open all year Boat-based anglers[c] within Newport Bay, Alamitos Bay, San Diego Bay, Mission Bay: open all year *Outside the bays listed above: same as RCG Complex*	Boat-based anglers[c] within Newport Bay, Alamitos Bay, San Diego Bay, Mission Bay: no depth restrictions *Outside the bays listed above: same as RCG Complex*	3 fish per person	36" total length
Pacific sanddabs and "other flatfish" [e] (see Section 28.48, p. 39 of the regulations)	Open all year with certain gear restrictions during Jan. and Feb.[e]	None, although certain gear restrictions apply in depths greater than 360 ft (60 fm)[e]	See Section 28.48 of the regulations	See Section 28.48 of the regulations
Other federal groundfish (see Sections 28.49, 28.51, 28.52, 28.53, 28.57 of the regulations)	Same as RCG Complex	Same as RCG Complex	See Sections 28.49, 28.51, 28.52, 28.53, 28.57 of the regulations	See Sections 28.49, 28.51, 28.52, 28.53, 28.57 of the regulations

[a] In the Cowcod Conservation Areas, fishing is prohibited in waters greater than 120 feet (20 fathoms) deep. Fishing also is subject to the Time Period closures for the Southern Management Area. See Section 27.50 of the regulations for further information on species restrictions.

[b] Subject to in-season change. Call the Recreational Groundfish Fishing Regulations Hotline at (831) 649-2801, visit the Marine Region Web site at www.dfg.ca.gov/mrd, send an e-mail to AskMarine@dfg.ca.gov, or call your nearest DFG office for the latest information.

[c] Divers and shore-based anglers are exempt from season and depth restrictions affecting the RCG complex, ocean whitefish, California sheephead, and other federally managed groundfish (except for lingcod). However, when spear fishing during a boat-based closure, only spear fishing gear is allowed aboard any vessel or watercraft. Also, when angling from shore during a boat-based closure, no vessel or watercraft may be used to assist in taking or possessing species included in this table. The following definitions describe boat-based and shore-based anglers, and divers:

- Boat-based anglers are those who fish from boats or vessels of any size or any other type of floating object, including kayaks and float tubes.
- Shore-based anglers are those who fish from beaches, banks, piers, jetties, breakwaters, docks, and other manmade structures connected to the shore.
- Divers are spear fishermen entering the water either from the shore or from a boat or other floating object.

[d] The sport fishery for leopard shark inside Newport Bay, Alamitos Bay, Mission Bay, and San Diego Bay is exempt from season and depth restrictions that affect other federally managed groundfish.

[e] In closed areas or during closed periods, Pacific sanddab, butter sole, curlfin sole, flathead sole, rex sole, rock sole, and sand sole (defined as "Other Flatfish" in Section 1.91(a)(10)) may ONLY be taken using the following gear: up to 12 No. 2 (or smaller) hooks and up to 2 lb. of weight.

[f] See regulations for information on gear restrictions and fillet lengths.

[g] Total length is the longest straight-line measurement from the tip of the head with the mouth closed to the end of the longest lobe of the tail. A measurement illustration is available on page 71 of the *2007 Ocean Sport Fishing Regulations* booklet.

[h] EXCEPTION: During the open season, groundfish may be possessed in closed areas and in water depths closed to fishing only aboard vessels in transit with no fishing gear in the water. See sub-section 27.20(b) of the regulations.

Source: California Department of Fish and Game, Marine Region (2007a)

An angler may take or possess no more than 20 finfish of all species combined and not more than 10 of any species, except as provided in the *2007 Ocean Sport Fishing Regulations*. Within the overall daily bag limit of 20 finfish, special limits apply as follows:

- Prohibited—garibaldi; broomtail and gulf grouper; white shark, except with a permit issued for scientific or educational purposes; green sturgeon, which must be released and reported on a Sturgeon Fishing Report Card; and giant (black) sea bass, except that an angler may keep two giant sea bass per day when fishing south of the U.S.-Mexico border with a valid Mexican license or permit
- One fish—white sturgeon, which must be reported on a Sturgeon Fishing Report Card; Pacific halibut, only from May 1–October 31; marlin; sevengill and sixgill shark
- Two fish—salmon; striped bass; broadbill swordfish; and blue, thresher, or shortfin mako shark
- Three fish—Trout, except that taking steelhead rainbow trout from ocean waters is prohibited; and white seabass, except that only one white seabass may be taken in waters south of Pt. Conception between March 15 and June 15
- Five fish—California halibut.

As of May 1, 2007, the California Department of Fish and Game Ocean Salmon Project—Marine Region (2007) prohibited the retention of coho salmon or steelhead trout in any ocean fishery.

Table C-2 lists the site characteristics of Huntington Beach waters and also lists substitute saltwater fishing sites and their characteristics.

Additional Information on Recreational Saltwater Fishing

Table C-2
Site Characteristics of Huntington Beach and Substitute Saltwater Fishing Sites

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Agua Hedionda Lagoon		Fishing, boating, boat ramp	California halibut, spotfin croaker	1
Anaheim Bay		Fishing, wildlife watching, boating, marina, boat ramp, picnicking. Adjoins Seal Beach National Wildlife Refuge.	California halibut, diamond turbot, sculpin, surfperch	1
Batiquitos Lagoon		Fishing, birdwatching, no boating	California halibut, diamond turbot	
Belmont Pier		Fishing, fishing pier	Barracuda, bonito, mackerel, jacksmelt, queenfish, shark, topsmelt, walleye surfperch, white croaker	
Bolsa Bay		Fishing, fishing pier, wildlife watching. Adjoins Bolsa Chica Ecological Reserve.	Barracuda, halibut, mackerel, sand bass, sculpin	1
Cabrillo Pier		Fishing, fishing pier	Croaker, halibut, mackerel, queenfish, surfperch	
Catalina Island		Fishing, boating	Barracuda, calico bass, lingcod, rockfish, white seabass, yellowtail	
Dana Point Harbor		Fishing, fishing pier, boating, boat ramp, charters	Barracuda; black seaperch; bonito; California halibut; corbina; diamond turbot; jacksmelt; opaleye; Pacific mackerel; pileperch; queenfish; rays; rubberlip and white seaperch; sargo; sharks; shinerperch; small kelp bass; spotfin, white, and yellowfin croaker; spotted sand bass. Anglers caught state-record corbina and yellowfin croaker at Dana Point Harbor.	1
Fiesta Bay		Adjoins Northern Wildlife Reserve and Kendall-Frost marsh. Fishing, boating, boat ramps, jet skiing, water skiing.		2
Gulf of Santa Catalina		Fishing, boating, fishing pier, boating tours, excursions, whale watching	Blackperch, blacksmith, calico bass, California scorpionfish, California sheephead, grass rockfish, halfmoon, jacksmelt, kelp rockfish, kelp seaperch, ocean whitefish, opaleye, rainbow seaperch, rock wrasse, rubberlip seaperch, shinerperch, topsmelt, white sea bass, yellowtail	

Table C-2 (Continued)

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Horseshoe Kelp		Fishing	Albacore, bluefin and yellowfin tuna, calico bass, rockfish, sculpin, white croaker, white seabass, yellowtail	
Huntington Beach	3.5 miles of shoreline	Adjoins Huntington Beach State Park and Bolsa Chica Ecological Reserve. Fishing, fishing pier, fishing derbies, boating, boat ramps, boat tours, marinas, swimming, surfing, camping, volleyball, AVP Pro Beach Volleyball Tour events, marathons and other athletic events, concerts, festivals, other special events.	Bass, bat ray, bonito, cabezon, California grunion, California halibut, corbina, halfmoon, jacksmelt, mackerel, opaleye, perch, queenfish, ray, sand bass, sanddab, sardine, sculpin, shark, shovelnose guitarfish, sole, surfperch, tuna, turbot, yellowfin croaker. Anglers caught state-record jack mackerel (5 lbs., 8 oz.) and bat ray (181 lbs.) at Huntington Beach.	2
King Harbor		Fishing, boating, boat ramp, boat rentals, charters		1
Long Beach		Fishing, boating, boat ramps, marina, charters, whale watching, harbor tours, Belmont Pier	Barracuda, bocaccio, bonito, calico bass, California sheephead, corbina, croaker, halfmoon, halibut, mackerel, perch, queenfish, rockfish, sand bass, sanddab, sargo, sculpin, surfperch, white seabass, whitefish, yellowtail. Angler caught state-record pile perch on February 26, 2007.	2
Malibu Pier		Fishing, fishing pier, boating, kayaking, charters, boat tours, surfing	Halibut, rockfish, queenfish, sea bass	
Marina del Rey		Fishing; fishing dock; fishing derbies; boating; boat ramps; boat rental; charters; cruises; whale watching; largest marina on the West Coast; WaterBus during the summer; near Aubrey Austin, Chace, and Admiralty Parks and North Jetty Walkway; picnicking; concerts; parades; fireworks; swimming; biking; windsurfing; kayaking; special events; 19 anchorages	Barracuda, calico bass, dorado, halibut, marlin, rock cod, sand bass, tuna, wahoo, white sea bass, yellowtail	2

Additional Information on Recreational Saltwater Fishing

Table C-2 (Continued)

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Mission Bay	2,000 acres	Fishing, boating, boat ramps, sailing, jet skiing, water skiing, marinas, sea kayaking, camping, playgrounds, beaches, swimming, wind surfing, picnicking, volleyball, softball, horseshoes, bicycling, jogging, wildlife reserves, visitor center, San Diego Aquatic Center	Barracuda; bonito; calico, sand, and spotted sea bass; corvine; mackerel; white seabass; yellowfin croaker	5
Newport Bay		Adjoins Newport Municipal Beach, Newport Beach Jetties, and West Oceanfront and Grant Street beaches. Fishing, fishing pier, boating, boat ramp, boat rentals, charters, swimming, RV camping.	Bonito, corbina, croakers, halibut, marlin, sand bass, spotted bay bass. Anglers caught state-record corbina and spotted sand bass from Newport Bay and blue marlin from the Balboa portion of the bay.	1
Pacific Ocean		Fishing, at least 23 fishing piers, boating, boat ramps, beaches, swimming, whale watching, volleyball, hiking. Adjoins many parks, including Pacific Ocean Park, Crystal Cove State Park, Corona del Mar State Beach, Inspiration Point, Little Corona del Mar beach, Lookout Point Park, and Rocky Point in Corona del Mar.	Albacore tuna; barred sand bass; barred seaperch; bigeye tuna; black, spotfin, white, and yellowfin croaker; black and walleye surfperch; blacksmith; blue, brown, grass, and olive rockfish; bocaccio; cabezon; California barracuda; California corbina; California halibut; California lizardfish; California scorpionfish; California sheephead; chub mackerel; giant sea bass; halfmoon; horn shark; jack mackerel; jacksmelt; kelp bass; kelp greenling; leopard shark; ocean whitefish; opaleye; queenfish; rubberlip seaperch; sanddab; sargo; shortfin mako shark; spotted sand bass; striped bass; treefish rockfish; turbot; white seabass. Anglers caught state-record barred sand bass, barred seaperch, bigeye tuna, cabezon, California barracuda, California sheephead, giant sea bass, kelp bass, leopard shark, ocean whitefish, opaleye, scorpionfish, shortfin mako shark, spotfin croaker, and treefish rockfish from the Pacific Ocean.	16

Additional Information on Recreational Saltwater Fishing

Table C-2 (Continued)

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Point Dume		Part of Point Dume State Preserve. Fishing, fishing pier (Paradise Cove), swimming, diving, surfing, nature trails, wildlife watching.	Barracuda, bass, bonito, croaker, yellowtail	
Point Vicente Palos Verdes		Fishing, diving, picnicking, hiking, whale watching	Barracuda, bluefin tuna, bonito, calico bass, croaker, halibut, sand bass, sea bass, sheephead, yellowtail	
Redondo Pier		Fishing, fishing pier, boating, excursions, arcade, boardwalk, whale watching	Corbina, halibut, mackerel, sardine	
San Diego Bay		Fishing, at least 4 fishing piers, boating, boat ramps, marinas, fishing charters, sea kayaking, adjacent parks, "Day at the Docks"	Abalone, albacore and bluefin tuna, barracuda, barred sand bass, bass, bat ray, big-eyed tuna, bonito, calico bass, covina, croaker, dorado, flounder, halibut, mackerel, Pacific bonefish, shark, skipjack tuna, spotted bay bass, white sea bass, yellowfin, yellowtail. Anglers caught state-record thresher shark and skipjack tuna from San Diego Bay.	5
San Pedro Bay		Fishing	Croaker, sardine, queenfish	
San Pedro Channel		Fishing, boating, charters	Sardine	
Santa Barbara Channel		Fishing, fishing pier, boating, boat ramps, swimming, whale watching, island excursions	Albacore, barracuda, blue and mako shark, bluefin tuna, bonito, calico bass, dorado, halibut, ling cod, mackerel, rockfish, sheephead, striped marlin, wahoo, white sea bass, whitefish, yellowfin tuna, yellowtail	2
Santa Monica Bay		Fishing, fishing pier	Barracuda, barred bonito, calico bass, bonito, California halibut, guitarfish, mackerel, queenfish, salema, sand bass, sculpin, seaperch, surfperch, thornback, yellowfin croaker, yellowtail. Angler caught state-record yellowfin croaker from Santa Monica beach.	
Short Bank		Fishing	Croaker	
White's Point		Fishing, wildlife watching	Kelp bass, rockfish, sculpin, white croaker	

Sources: DeLorme (2005); Jackson (2006); Jones (undated); California DFG, Marine Region (2007a, 2007b, 2007c, 2007d); Los Angeles County Department of Beaches and Harbors (undated); San Diego Sportfishing Council (undated)

Additional Information on Recreational Saltwater Fishing

References

1. California Department of Fish and Game, Marine Region. 2007a. 2007 Ocean Sport Fishing Regulations. Available at http://www.dfg.ca.gov/marine/oceanfish2007.pdf. Retrieved on July 31, 2007.
2. California Department of Fish and Game, Marine Region. 2007b. Record ocean sportfish. Available at http://www.dfg.ca.gov/marine/faqtrph3.asp. Retrieved on September 27, 2007.
3. California Department of Fish and Game, Marine Region. 2007c. State managed commercial fisheries: cabezon, greenlings and sheephead (CGS). Available at http://www.dfg.ca.gov/Mrd/cgs.html. Retrieved on August 8, 2007.
4. California Department of Fish and Game, Marine Region. 2007d. Popular features. Available at http://www.dfg.ca.gov/MRD/index_regs.html. Retrieved on August 9, 2007.
5. California Department of Fish and Game, Ocean Salmon Project—Marine Region. 2007. "2007 Ocean Salmon Sport Regulations." Available at http://www.dfg.ca.gov/mrd/salmonsport07.pdf. Retrieved on August 7, 2007.
6. DeLorme. 2005. Southern and Central California Atlas and Gazetteer. DeLorme, Yarmouth, ME.
7. Jackson, D. 2006. Albackore's Gulp! only west coast fall surf slam. Available at http://www.fishingexpeditions.com/html/surf_slam.html. Retrieved on September 20, 2007.
8. Jones, K. Undated. Dana Point Harbor fishing pier. Available at http://www.pierfishing.com/resources/index.php?id=piers:dana_point_harbor_fishing_pier. Retrieved on August 9, 2007.
9. Los Angeles County Department of Beaches and Harbors. Undated. Welcome to Marina Del Rey. Available at http://beaches.co.la.ca.us/BandH/Marina/Main.htm. Retrieved on September 27, 2007.
10. San Diego Sportfishing Council. Undated. San Diego sportfishing online. Available at http://www.sportfishing.org/. Retrieved on September 27, 2007.

D
ADDITIONAL INFORMATION ON RECREATIONAL FRESHWATER FISHING

California offers several angler recognition programs for inland fishing, as described below.

- Inland Water Fishing Record Program—An angler catching a state-record fish must land the fish unaided. The fish must be weighed on a scale certified by a government agency and in the presence of two witnesses unknown to the angler or diver. A biologist must identify the catch (California DFG 2007a).
- California Fishing Passport Program—The passport lists 150 different species of freshwater and saltwater finfish and shellfish that inhabit waters throughout California. Participating anglers catch and document all of the different species listed, receiving a stamp for each one (California DFG 2007b).
- Trophy Black Bass Program—An angler lands a trophy-size bass and submits an application form for recognition. To qualify, a largemouth bass must weigh at least 10 pounds; smallmouth and spotted bass must weigh at least 6 pounds. Once the catch is verified, the angler receives a certificate. Of the 25 biggest largemouth bass caught in the U.S., 21 were landed from California waters (California DFG 2007c; California DFG, Fisheries Programs Branch 2003).
- California Heritage Trout Challenge—To earn a certificate, an angler catches and photographs six different types of native trout from their historic drainages in California. The angler submits an application along with the photos. There is no time restriction on completing the challenge, but an angler can earn only one certificate per calendar year (California DFG 2007e).

The South Coast Region of the California DFG regulates the fisheries of freshwater bodies near Huntington Beach. Tables D-1 and D-2 summarize the regulations at freshwater substitute sites in the South Coast Region (District) of California (California Department of Fish and Game 2007f). Within the district, substitute sites are located throughout Los Angeles and Orange Counties, as well as in parts of Riverside, San Bernardino, San Diego, and Ventura Counties.

Additional Information on Recreational Freshwater Fishing

Table D-1
Freshwater Fishing Regulations in the South Coast Region of California

Fish	County	Body of Water	Open Season	Size (Total Length)	Bag Limit
Black bass	Los Angeles	Castaic Lake	All year	18-inch minimum	2
	Riverside	Diamond Valley Lake	All year	15-inch minimum largemouth No smallmouth may be kept	5
		Skinner Lake	All year	15-inch minimum	2
	San Bernardino	Silverwood Lake	All year	15-inch minimum	2
	San Diego	Barrett Lake	All year	No fish may be kept	0
		El Capitan Reservoir	All year	15-inch minimum	5
		Lake Cuyamaca	All year	No size limit No smallmouth may be kept	5
		Lake Hodges	All year	15-inch minimum	5
		Upper Otay Lake	All year	Only artificial lures with barbless hooks may be used for any kind of fish No fish may be kept	0
	Ventura	Lake Casitas	All year	12 inches No more than 1 longer than 22 inches	5
	District counties	All other lakes/reservoirs in the district	All year	12-inch minimum	5
		All other rivers/streams and private ponds in the district	All year	No size limit	5
Bullhead	District counties	All district waters	All year	No size limit	No limit
Candlefish	District counties	All district waters, fish taken by dip net	All year	No size limit	25 lb.
Catfish	Los Angeles	Alondra County Park Lake	All year	No size limit	5
		Belvedere Park Lake	All year	No size limit	5
		Cerritos Park Lake	All year	No size limit	5
		Earvin "Magic" Johnson Park Lake	All year	No size limit	5
		Kenneth Hahn Park Lake	All year	No size limit	5
		La Mirada Park Lake	All year	No size limit	5
	San Bernardino	Cucamonga-Guasti Park Lakes	All year	No size limit	5
		Glen Helen Park Lake	All year	No size limit	5
		Mojave Narrows Lake	All year	No size limit	5
		Prado Lake	All year	No size limit	5
		Yucaipa Regional Park Lakes	All year	No size limit	5
	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
		All other waters in the county	All year	No size limit	5
	District counties	All other district waters	All year	No size limit	10
Clams, freshwater	District counties	All district waters, taken by hand or by appliance operated by hand	All year	No size limit	50 lb. in the shell

Table D-1, continued

Fish	County	Body of Water	Open Season	Size (Total Length)	Bag Limit
Coho (silver) salmon	District counties	All district waters	None	No fish may be kept Return to water unharmed	0
Crappie	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
		El Capitan Lake, Lake Hodges	All year	10-inch minimum	25
	District counties	All other district waters	All year	No size limit	25
Crayfish	District counties	All district waters, taken by hand, hook and line, dip net, or trap not larger than 3 ft.	All year	No size limit	No limit
Grass carp	District counties	All district waters	None	No fish may be kept Return to water unharmed	0
Green sturgeon	Statewide	All waters	None	No fish may be kept Report on a Sturgeon Fishing Report Card	0
Lamprey	District counties	All district waters, taken by hand, hook, spear, bow and arrow fishing tackle, dip net, or trap not larger than 3 ft.	All year	No size limit	No limit
Mountain whitefish	District counties	All district waters	Only when trout may be taken in the water body	No size limit	5
Shad, American	District counties	All district waters, fish taken by angling only	All year	No size limit	25
Striped bass	Riverside	Lake Elsinore	All year	18-inch minimum	2
	District counties	All other district waters	All year	No size limit	10
Sunfish	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
	District counties	All other district waters	All year	No size limit	No limit
Tilapia	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
	District counties	All other district waters	All year	No size limit	No limit
Trout, salmon, steelhead	San Diego	All streams, except anadromous waters Only artificial lures with barbless hooks may be used	All year	No size limit	2
	District counties	All anadromous waters	Closed	No trout, salmon, or steelhead may be caught	0
		All district streams, except anadromous waters in Los Angeles, Ventura, Santa Barbara, Orange, San Bernardino, and Riverside Counties Above Rindge Dam on Malibu Creek	All year	No size limit	5
		All district lakes and reservoirs	All year	No size limit	5
White bass	District counties	All district waters	All year	No size limit White bass may not be transported alive	No limit
White sturgeon	Statewide	All district waters Must take bait or lure in its mouth	All year	46–66 inches May possess 3 per year Report on a Sturgeon Fishing Report Card	1

Source: California Department of Fish and Game (2007)

Additional Information on Recreational Freshwater Fishing

Table D-2
Alphabetical List of Waters with Special Fishing Regulations in the South Coast Region of California

County	Body of Water	Open Season	Restriction	Size (Total Length)	Bag Limit
San Bernardino	Bear Creek	All year	Only artificial lures with barbless hooks may be used	No size limit	2
	Big Bear Lake tributaries	Saturday preceding Memorial Day through Feb. 28	5 fish per day 10 in possession	No size limit	5
	Deep Creek from headwaters at Little Green Valley to confluence of Willow Creek	All year	Only artificial lures with barbless hooks may be used	No size limit	2
Los Angeles and Ventura	Piru Creek and tributaries upstream of Pyramid Lake	All year	Only artificial lures with barbless hooks may be used	No size limit	2
	From Pyramid Dam downstream to the bridge about 300 yards below Pyramid Lake	None	Closed to fishing all year	Not allowed	0
	From the bridge approximately 300 yards below Pyramid Lake to the falls about ½ mile above the old Highway 99 bridge	All year	Only artificial lures with barbless hooks may be used	Not applicable	0
Los Angeles	San Gabriel River, west fork and tributaries, upstream of Cogswell Dam, Cogswell Reservoir	All year	Only artificial lures with barbless hooks may be used	No size limit	2
	From Cogswell Dam downstream to the second bridge upstream of the Highway 39 bridge	All year	Only artificial lures with barbless hooks may be used	Not applicable	0
Los Angeles and Orange	San Gabriel River upstream of the Highway 22 bridge to the start of concrete-lined portion of the river channel	Saturday preceding Memorial Day through Nov. 30	Only artificial lures with barbless hooks may be used	No size limit	0 trout or steelhead
Ventura	Santa Paula Creek and tributaries above the falls located 3 miles upstream from the Highway 150 bridge	All year	Bag limit	No size limit	5
	Sespe Creek and tributaries above Alder Creek confluence	All year	Only artificial lures with barbless hooks may be used	Not applicable	0

Source: California Department of Fish and Game (2007)

Anglers also can choose to fish at many freshwater sites located near Huntington Beach. Among the most attractive are those offering both freshwater fishing and other recreation:

- Big Bear Lake, within San Bernardino National Forest, where anglers can catch bluegill, trout, catfish, crappie, largemouth bass, and silver salmon (Bigbear.us 2005).

- Diamond Valley Lake, where anglers can catch catfish, bluegill, crappie, bass, sunfish, and trout. Bass and other fishing tournaments are held at Diamond Valley Lake (Metropolitan Water District of Southern California undated).
- Lake Piru, within the Los Padres National Forest and near Sespe Condor Sanctuary, where anglers can catch bass, bluegill, catfish, crappie, trout, perch, and sunfish (Lake Piru Recreation Area 1998).
- Pyramid Lake, within Pyramid Lake Recreation Area and part of the Angeles National Forest, where anglers can catch bluegill; catfish; crappie; largemouth, smallmouth, and striped bass; and trout (FishingNetwork.net 2004).
- Silverwood Lake, adjoining Silverwood Lake State Recreation Area, San Bernardino National Forest, and the Pacific Crest Trail, where anglers can catch bass, bluegill, catfish, perch, silver salmon, and trout (FishingNetwork.net 2007).

Anglers may purchase a Second-Rod Stamp that is valid only in lakes, reservoirs, and the Colorado River District (California DFG 2007f).

Table D-3 compares several attractive substitute freshwater fishing sites. Table D-4 lists the site characteristics of additional substitute freshwater fishing sites and their characteristics.

Table D-3
Comparison of Substitute Freshwater Fishing Sites

Water Bodies	Freshwater Bass	Bluegill	Catfish	Crappie	Salmon	Trout	Boat Ramp(s)	Noteworthy Facts
Freshwater								
Big Bear Lake	•	•	•		•	•	•	Within San Bernardino National Forest. Marinas adjoin lake. Eight boat ramps are available.
Diamond Valley Lake	•	•	•	•		•	•	Fishing tournaments are held at this lake.
Lake Piru	•	•	•	•		•	•	Within the Los Padres National Forest and near Sespe Condor Sanctuary.
Pyramid Lake	•	•	•	•		•	•	Within Pyramid Lake Recreation Area and part of Angeles National Forest.
Silverwood Lake	•	•	•		•	•	•	Adjoins Silverwood Lake State Recreation Area, San Bernardino National Forest, and Pacific Crest Trail.

Sources: DeLorme (2005); Jones (undated); Sportfishingreport.com (2007); San Diego Sportfishing Council (undated); Bigbear.us (2005); Metropolitan Water District of Southern California (undated); Lake Piru Recreation Area (1998); FishingNetwork.net (2004); FishingNetwork.net (2007)

Additional Information on Recreational Freshwater Fishing

Table D-4
Site Characteristics of Substitute Freshwater Fishing Sites

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Alondra Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Amargosa Creek		Fishing	Trout	
Anaheim Lake	75 acres	Fishing	Bluegill, carp, catfish, largemouth bass, rainbow trout	
Angler's Lake	7 acres	Fishing	Bass, bluegill, catfish, trout	
Appollo Park Lakes	26 acres	Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Ballona Creek		Fishing, boating, wildlife watching		
Barrett Lake	811 acres	Restricted entry. Catch-and-release largemouths. Fishing, boating, canoeing, kayaking, tubing.	Black and white crappie, bluegill, bullhead, catfish, Florida-strain and largemouth bass	
Bear Creek	9 miles	Fishing	Trout	
Belvedere Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Big Bear Lake	3,000 acres	Within San Bernardino National Forest. Fishing, boating, boat ramps, boat rentals, marinas, sailing, water skiing, jet skiing, camping, swimming.	Bluegill, brown and rainbow trout, catfish, crappie, largemouth bass, silver salmon	8
Big Rock Creek		Adjoins Big Rock Creek Wildlife Sanctuary. Fishing, camping.	Trout	
Bouquet Canyon Creek		Fishing	Trout	
Bouquet Reservoir		Fishing	Trout	
California Aqueduct		Fishing	Bass, bluegill, catfish, crappie, green sunfish, striped bass	
Cachuma Lake	3,000 acres	Part of Cachuma Lake Recreation Area. Fishing, fishing derbies, boating, boat ramp, regattas, hiking, lake cruises, camping, nature programs, cabins, marina, playgrounds, family fun center, nature center.	Bluegill, channel catfish, crappie, largemouth and smallmouth bass, rainbow trout, redear sunfish	1
Carr Park Lake	11 acres	Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Castaic Lake (Upper and Lower)	2,235 acres	Part of Castaic Lake State Recreation Area and Angeles National Forest. Fishing, boating, boat ramp, boat rental, marina, sailing, jet skiing, water skiing, boat rental in upper lake, hiking, biking, picnicking, playgrounds, swimming in lower lake.	Black, white crappie; bluegill; carp; channel catfish, largemouth, smallmouth, and striped bass; rainbow trout	1

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Centennial Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Cerritos Park Lake		Fishing, picnicking, playground, ball diamonds	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Cogswell Reservoir		Part of Angeles National Forest. Fishing.		
Corona Lake		Fishing, boating, boat ramp, boat rentals, tubing.	Bass, catfish, tilapia, trout	1
Cottonwood Lake		Fishing	Bass, bluegill, catfish, trout	
Cucamonga-Guasti Park Lakes		Fishing, swimming, picnicking, playground, volleyball, horseshoe pits, picnicking	Bass, catfish, trout	
Deep Creek	36 miles	Fishing, swimming	Trout	
Diamond Valley Lake	4,500 acres	Fishing, boating, boat ramp, boat rentals, fishing tournaments	Blue and channel catfish, bluegill, crappie, Florida and smallmouth bass, green and redear sunfish, rainbow trout	1
Dixon Lake	70 acres	Fishing, camping, picnicking	Black crappie, bluegill, channel catfish, Florida bass, rainbow trout	
Doane Pond	3 acres	Within Palomar Mountain State Park. Fishing, camping, hiking, picnicking.	Bluegill, bullhead, catfish, rainbow trout	
Downy Wilderness Park Ponds		Fishing, picnicking, playground, ball diamonds	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Echo Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
El Capitan Reservoir	1,562 acres	Fishing, boating, boat ramp, boat rentals, tubing, picnicking	Blue and channel catfish, bluegill, bullhead, carp, crappie, Florida bass, green sunfish	1
El Dorado Park Lakes		Fishing, picnicking, playground, ball diamonds, hiking, nature center	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Elizabeth Lake	35 acres	Part of Angeles National Forest. Fishing, boating, boat ramp, picnicking.	Bass, bluegill, catfish, crappie, trout	1
Glen Helen Park Lake		Fishing, swimming, water slides, hiking, camping, hiking, volleyball, picnicking	Channel catfish, largemouth bass, trout	
Green Valley Lake	9 acres	Fishing, non-motorized boating, boat rental, hiking	Bass, catfish, crappie, rainbow trout	
Hansen Dam Lake	9 acres	Fishing, boating, boat ramp	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	1

Additional Information on Recreational Freshwater Fishing

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Harbor Park Lake[a]		Fishing, boating, boat ramp, picnicking	Carp	1
Hesperia Lake	7 acres	Fishing, camping, picnicking	Bluegill, carp, catfish, largemouth bass, sturgeon, trout	
Hollenbeck Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Huntington Park Lake		Fishing, playground, picnicking, ballfields	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Irvine Lake	750 acres	Fishing, boating, boat ramp, boat rentals, marina, camping, picnicking	Blue and channel catfish; bluegill; brook, brown, California golden, and rainbow trout; crappie; largemouth bass; redear sunfish; sturgeon; wiper	1
Jackson Lake	7 acres	Part of Angeles National Forest. Fishing, boating for non-motorized craft, picnicking.	Bluegill, rainbow trout Trout were stocked during the week of 9/17/2007.	
Jenks Lake	10 acres	Fishing, fishing pier, non-motorized boating, swimming, hiking, camping, picnicking	Bluegill, catfish, largemouth bass, rainbow trout, redear sunfish	
Jess Ranch Lakes		Fishing, tubing (bass lake) (privately owned)	Bluegill, bass, catfish, trout	
John Ford Park Lake		Fishing	Catfish, rainbow trout	
Kenneth Hahn Park Lake		Fishing, picnicking, trails, playgrounds, athletic fields	Bluegill, catfish, largemouth bass, rainbow trout	
Laguna Niguel Lake	44 acres	Fishing, boating, boat rental, tubing	Black and white crappie, bluegill, channel catfish, Florida and largemouth bass, rainbow trout	
Lake Casitas	2,700 acres	Adjoins Los Padres National Forest. Fishing, boating, boat ramps, picnicking.	Bluegill, catfish, crappie, Florida and largemouth bass, perch, redear sunfish, trout	2
Lake Cahuilla		Within Lake Cahuilla County Park. Fishing, non-motorized boating, camping, picnicking, horseback riding, hiking.	Bluegill, channel and flathead catfish, largemouth and striped bass, rainbow trout	
Lake Cuyamaca	110 acres	Fishing, boating, boat ramps, boat rental, camping, picnicking, wildlife viewing	Bluegill, channel catfish, crappie, Florida and smallmouth bass, perch, sturgeon, trout	2
Lake Elsinore	3,300 acres	Adjoins Lake Elsinore State Park. Fishing, boating, boat ramps, water skiing, jet skiing, swimming, camping.	Bluegill, carp, catfish, crappie, striped bass	4

[a]A fish consumption advisory attributable to DDT and chlordane has been issued for Harbor Park Lake.

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Lake Evans	86 acres	Part of Buena Vista Aquatic Recreational Area. Fishing, sailing, boating, camping, bicycling, fishing derbies.	Bass, bluegill, carp, catfish, rainbow trout	
Lake Fulmer	3 acres	Fishing, tubing, swimming, picnicking	Bluegill, catfish, largemouth bass, rainbow trout	
Lake Gregory	120 acres	Within Lake Gregory Regional Park. Fishing, non-motorized boating, boat rental, tubing, sail boarding, picnicking, swimming, basketball, volleyball, hiking	Bass, brown and rainbow trout, bullhead, catfish, crappie	
Lake Hemet	420 acres	Within San Bernardino National Forest. Fishing, boating, boat ramp, boat rental, camping.	Bass, bluegill, catfish, rainbow trout	1
Lake Henshaw		Within Cleveland National Forest. Fishing, boating, boat ramps, boat rental, camping, cabins.	Bass, bluegill, channel catfish, crappie, rainbow trout	2
Lake Hodges	1,234 acres	Fishing, boating, boat ramp, sailing, tubing, biking, horseback riding, picnicking	Bluegill, bullhead, carp, channel catfish, crappie, Florida-strain largemouth bass	1
Lake Jennings	85 acres	Within Lake Jennings County Park. Near three other county parks. Fishing, boating, boat ramp, boat rentals, camping, hiking, picnicking, playground, horseshoe pits, nature trail.	Blue and channel catfish, bluegill, crappie, largemouth bass, rainbow trout	1
La Mirada Park Lake		Fishing, playgrounds, tennis and handball courts, fishing derbies	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Lake Morena	220 acres	Within Lake Morena County Park. Fishing, boating, boat ramp, boat rental, camping.	Bluegill, crappie, catfish, German brown and rainbow trout, largemouth bass	1
Lake Perris	1,800 acres	Within Lake Perris State Recreation Area. Fishing, boating, boat ramps, boat rental, horseback riding, stables, camping, picnicking, hunting, museum.	Alabama spotted and largemouth bass, bluegill, bullhead, carp, channel catfish, crappie, crayfish, green and redear sunfish, rainbow trout	3
Lake Piru	1,200 acres	Within the Los Padres National Forest and near Sespe Condor Sanctuary. Fishing, boating, boat ramp, boat rentals, marina, water skiing, camping, swimming, hiking, wildlife watching.	Bass, blue and channel catfish, bluegill, brown and rainbow trout, crappie, perch, redear sunfish	1
Lake Poway	60 acres	Fishing, boating, boat rental, sailing, hiking, camping, picnicking, volleyball, softball, horseshoe pits, horseback riding	Bluegill, channel catfish, Florida bass, rainbow trout	

Additional Information on Recreational Freshwater Fishing

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Lake Sherwood		Adjoins Santa Monica Mountains Recreation Area		
Lake Webb	873 acres	Part of Buena Vista Aquatic Recreational Area. Fishing, boating, boat ramps, jet skiing, camping, bicycling.	Trout	3
Lake Wohlford	146 acres	Fishing, boating, boat ramp, boat rental, camping	Black crappie, bluegill, channel catfish, Florida bass, rainbow trout	1
Legg Lake		Fishing, picnicking, softball fields, bicycling	Bass, bluegill, catfish, crappie, rainbow trout	
Little Rock Creek		Fishing	Trout	
Little Rock Reservoir	150 acres	Part of Angeles National Forest. Fishing, boating, boat ramp, picnicking.	Catfish; German brown, Kamloops, and rainbow trout	1
Lincoln Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Los Angeles River		Fishing	Yellowfin croaker	
Loveland Reservoir		Fishing	Bluegill, catfish, largemouth bass, redear sunfish	
Lytle Creek		Fishing	Trout	
Earvin "Magic" Johnson Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Malibu Creek		Within Malibu Creek State Park. Fishing, swimming, hiking, wildlife watching, horseback riding, camping, picnicking, visitor center.	Trout	
Mile Square Regional Park Lakes		Fishing, picnicking, community park, wilderness area, golfing, ball diamonds, archery, paddle boats	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Mill Creek		Fishing, beach	Rockfish, surfperch	
Miramar Reservoir	162 acres	Fishing, boating, boat ramp, boat rental, marina, tubing, bicycling, jogging, walking, roller blading, picnicking	Bluegill, channel catfish, Florida bass, redear sunfish, trout Trophy-size bass have been caught at Miramar	1
Mojave Narrows Lake		Part of Mojave Narrows Regional Park. Fishing, camping, hunting, horseback riding.	Bass, channel catfish, trout	
Murray Reservoir	171 acres	Fishing, boating, boat ramp, bicycling, jogging, walking, picnicking	Black crappie, bluegill, channel catfish, Florida bass, trout	1

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Oso Reservoir	175 acres	Adjoins O'Neill Regional Park. Fishing, boating, canoeing, rowing, boat rentals, tubing, marina, camping.	Bass	
Otay Lake (Upper and Lower)	1,100 acres (Lower) 20 acres (Upper)	Fishing, boating, boat ramp, boat rental, tubing, picnicking. Tubing and wading allowed in Upper Otay.	Lower: black and white crappie; bluegill; bullhead; blue, channel, white catfish; Florida bass. Angler caught state-record bluegill (3 lbs., 8 oz.) at Lower Otay Lake.	1
Peck Road Water Conservation Park	80 acres	Fishing, picnicking	Bluegill, bullhead, channel catfish, crappie, largemouth bass, rainbow trout	
Perris Reservoir	2,250 acres	Fishing, boating, boat ramps, water skiing, jet skiing, tubing, swimming, camping	Alabama spotted and largemouth bass, bluegill, channel catfish, crappie, rainbow trout	3
Piru Creek		Fishing	Rainbow trout	
Prado Lake	56 acres	Fishing, non-motorized boating, boat ramp, boat rental, camping	Bluegill, bullhead, carp, catfish, largemouth bass, trout	1
Puddingstone Lake	250 acres	Fishing, boating, boat ramp, boat rental, sailing, water skiing, jet skiing, camping	Bluegill, channel catfish, crappie, largemouth bass, perch, rainbow trout	1
Pyramid Lake	1,297 acres	Within Pyramid Lake Recreation Area and part of Angeles National Forest. Fishing, boating, boat ramp, jet skiing, picnicking.	Bluegill; catfish; crappie; largemouth, smallmouth, and striped bass; trout	1
Quail Lake		Fishing.	Catfish, largemouth and striped bass	
Ralph Clark Park Lake		Part of Ralph B. Clark Regional Park. Fishing, picnicking, playgrounds, ballfields.	Bluegill, catfish, largemouth bass, rainbow trout	
Rancho Simi Park Lake	2.5 acres	Fishing, tennis courts, picnicking	Bluegill, carp, catfish, largemouth bass, rainbow trout	
Reflection Lake	17 acres	Fishing, boating, camping, playground, recreation area (privately owned)	Bass, bluegill, catfish, trout	
San Dieguito River	55 miles	Adjoins San Dieguito River Park. Fishing, hiking.		

Additional Information on Recreational Freshwater Fishing

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
San Felipe Creek		Part of San Felipe Creek Ecological Reserve. Fishing, hiking, hunting, wildlife viewing.	Green sunfish, tilapia	
San Gabriel Reservoir		Part of Angeles National Forest. Fishing, picnicking.	Rainbow trout	
San Gabriel River		Western portion is part of Angeles National Forest. Fishing, fishing platforms, canoeing, kayaking, hiking, biking, wildlife watching.	Rainbow trout, steelhead	
San Jacinto River		Fishing, hiking, hunting, camping, picnicking, wildlife watching	Trout	
San Luis Rey River		Fishing, biking	Trout	
San Vicente Reservoir	1,069 acres	Fishing, boating, boat ramp, boat rental, marina, water skiing, tubing, picnicking	Blue, channel, and white catfish; bluegill; bullhead; crappie; Florida bass; green sunfish; trout. Angler caught state-record blue catfish (101 lbs.) at San Vicente Reservoir.	1
Santa Ana River Lakes		Fishing, boating, boat ramp, boat rental (privately owned)	Bass, bluegill, catfish, crappie, sturgeon, trout, wiper. Angler caught state-record channel catfish (52 lbs., 10 oz.) at Santa Ana River Lakes.	1
Santa Ana River, South Fork		Fishing	Green sunfish, trout	
Santa Fe Dam Lake	70 acres	Fishing, electric-powered boating, boat ramp, marina	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	1
Santa Paula Creek		Fishing		
Santee Lakes (four)	7–11 acres	Fishing, non-powered boat rental, camping, picnicking, playgrounds, volleyball, horseshoe pits	Bass, bluegill, channel catfish, trout	
Santiago Creek		Within Santiago Oaks Regional Park and Irvine Regional Park. Fishing, hiking.		
Sespe Creek		Fishing, hiking, camping	Rainbow trout, steelhead	
Silverwood Lake	980 acres	Adjoins Silverwood Lake State Recreation Area, San Bernardino National Forest, and Pacific Crest Trail. Fishing, boating, boat ramp, boat rental, marina, wind surfing, camping, picnicking, swimming, wildlife viewing, biking, hiking, nature trails, visitor center.	Bluegill, brown and rainbow trout, channel catfish, largemouth and striped bass, perch, silver salmon	1

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Skinner Lake	1,200 acres	Fishing, boating, boat ramps, boat rental, marina, sailing, horseback riding, camping	Bluegill, carp, catfish, crappie, largemouth and striped bass, perch, trout	2
Sutherland Reservoir	557 acres	Fishing, boating, boat ramp, tubing, picnicking, waterfowl and turkey hunting	Blue and channel catfish, bluegill, bullhead, carp, crappie, Florida bass, redear sunfish	1
Sweetwater Reservoir		Fishing (limited)	Bass, bluegill, bullhead, carp, catfish, perch, rock bass	
Tri-City Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Vail Lake		Fishing, boating, boat ramp, boat rental, marina, camping	Bass, bluegill, catfish, crappie, trout	1
Yorba Regional Park Lakes		Fishing, picnicking, playgrounds, ballfields	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Yucaipa Regional Park Lakes		Within Yucaipa Regional Park. Fishing, boating, swimming, picnicking, camping, playground, volleyball, horseshoe pits.	Bass, catfish, rainbow trout	

Sources: DeLorme (2005); Sportfishingreport.com (2007); California Department of Fish and Game (DFG) 2007a, 2007b, 2007c, 2007d, 2007e, 2007f; San Diego Sportfishing Council (undated); Bigbear.us (2005); Metropolitan Water District of Southern California (undated); Lake Piru Recreation Area (1998); FishingNetwork.net (2004, 2007)

References

1. Bigbear.us. 2005. Big Bear Lake, California. Available at http://www.bigbear.us/fishreport.html. Retrieved on September 27, 2007.
2. California Department of Fish and Game, Fisheries Programs Branch. 2003. California trophy black bass program. Available at http://www.dfg.ca.gov/fish/documents/TBB_App.pdf. Retrieved on September 20, 2007.
3. California Department of Fish and Game. 2007a. State inland water record fish policy. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/SIWR/SIWR_Policy.asp. Retrieved on September 27, 2007.
4. California Department of Fish and Game. 2007b. Welcome to the California fishing passport web site. Available at http://www.dfg.ca.gov/fishingpassport/. Retrieved on September 27, 2007.
5. California Department of Fish and Game. 2007c. Trophy black bass certificate program. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/TBB/index.asp. Retrieved on September 27, 2007.

Additional Information on Recreational Freshwater Fishing

6. California Department of Fish and Game. 2007d. Public health advisories on fish consumption. Available at http://www.dfg.ca.gov/marine/fishcon1.asp. Retrieved on September 14, 2007.
7. California Department of Fish and Game. 2007e. California heritage trout challenge. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/HTC/HTC_Policy.asp. Retrieved on September 27, 2007.
8. California Department of Fish and Game. 2007f. 2007–2008 California Freshwater Sport Fishing Regulations. Available at http://www.dfg.ca.gov/regulations/07-08-inland-fish-regs.pdf. Retrieved on July 31, 2007.
9. DeLorme. 2005. Southern and Central California Atlas and Gazetteer. DeLorme, Yarmouth, ME.
10. FishingNetwork.net. 2004. Pyramid Lake. Available at http://fishingnetwork.net/socal/pmid.htm. Retrieved on September 27, 2007.
11. FishingNetwork.net. 2007. Silverwood Lake. Available at http://fishingnetwork.net/socal/silver.htm. Retrieved on September 27, 2007.
12. Lake Piru Recreation Area. 1998. You'll love the Lake Piru recreation area. Available at http://www.lake-piru.org/. Retrieved on September 27, 2007.
13. Metropolitan Water District of Southern California. Undated. Diamond Valley Lake. Available at http://www.dvlake.com/. Retrieved on September 27, 2007.
14. San Diego Sportfishing Council. Undated. San Diego sportfishing online. Available at http://www.sportfishing.org/. Retrieved on September 27, 2007.
15. Sportfishingreport.com. 2007. Catch. Available at http://www.sportfishingreport.com/pages/landingdetail.php?landing_id=12. Retrieved on August 6, 2007.

E
SUPPLEMENTAL INFORMATION FOR RECREATION MODEL

Table E-1
Ocean Fishing Sites: Beaches, Boat Ramps, and Piers

County	Place Name	Type	Latitude	Longitude
Santa Barbara	Carpinteria State Beach	Beach	34°25'00"	119°30'00"
Ventura	Emma Wood State Beach	Beach	34°16'51"	119°20'00"
	San Buenaventura State Beach	Pier	34°15'00"	119°15'00"
	San Buenaventura State Beach	Beach	34°15'00"	119°15'00"
	Peninsula Beach	Beach	34°15'00"	119°15'00"
	Peninsula Beach	Boat ramp	34°15'00"	119°15'00"
	McGrath State Beach	Beach	34°15'00"	119°15'00"
	McGrath State Beach	Boat ramp	34°15'00"	119°15'00"
	Mandalay Beach	Beach	34°10'00"	119°15'00"
	Hollywood Beach	Beach	34°10'00"	119°15'00"
	Oxnard Beach	Beach	34°10'00"	119°15'00"
	Oxnard Beach	Boat ramp	34°10'00"	119°15'00"
	Oxnard Beach	Boat ramp	34°10'00"	119°15'00"
	Port Hueneme Beach Park	Beach	34°10'00"	119°10'00"
	Port Hueneme Beach Park	Pier	34°10'00"	119°10'00"
Los Angeles	Leo Carillo State Beach	Beach	34°05'00"	118°55'00"
	Robert H. Meyer Memorial State Beach	Beach	34°00'00"	118°55'00"
	Point Dume State Beach	Beach	34°00'00"	118°50'00"
	Paradise Cove	Pier	34°00'00"	118°45'00"
	Paradise Cove	Beach	34°00'00"	118°45'00"
	Escondido Beach	Beach	34°00'00"	118°45'00"
	Corral Beach	Beach	34°00'00"	118°45'00"
	Surfrider Beach (Malibu Lagoon Beach)	Beach	34°00'00"	118°40'00"
	Malibu Pier	Pier	34°00'00"	118°40'00"
	Malibu Pier	Boat ramp	34°00'00"	118°40'00"
	Las Tunas Beach	Beach	34°00'00"	118°35'00"
	Topanga Beach	Beach	34°00'00"	118°35'00"
	Will Rogers State Beach	Beach	34°00'00"	118°35'00"

Supplemental Information for Recreation Model

Table E-1, continued

County	Place Name	Type	Latitude	Longitude
Los Angeles	Santa Monica Beach	Beach	34°00'00"	118°30'00"
	Santa Monica Municipal Pier	Pier	34°00'00"	118°30'00"
	Santa Monica Municipal Pier	Boat ramp	34°00'00"	118°30'00"
	Ocean Park	Beach	34°00'00"	118°30'00"
	Santa Monica Mountains National Recreation Area	Beach	34°00'00"	118°30'00"
	Venice Beach	Beach	34°00'00"	118°30'00"
	Venice Fishing Pier	Pier	34°00'00"	118°30'00"
	Marina Del Ray Harbor	Pier	34°00'00"	118°25'00"
	Marina Del Ray Harbor	Boat ramp	34°00'00"	118°25'00"
	Marina Del Ray Harbor	Boat ramp	34°00'00"	118°25'00"
	Playa Del Ray	Beach	33°55'00"	118°30'00"
	Playa Del Ray	Boat ramp	33°55'00"	118°30'00"
	Dockweiler State Beach	Beach	33°55'00"	118°25'00"
	Manhattan Beach	Beach	33°55'00"	118°25'00"
	Manhattan Beach Municipal Pier	Pier	33°55'00"	118°25'00"
	Manhattan Beach Municipal Pier	Boat ramp	33°55'00"	118°25'00"
	Hermosa Beach	Beach	33°50'00"	118°25'00"
	Hermosa Beach Municipal Pier	Pier	33°50'00"	118°25'00"
	Redondo Beach Municipal Pier	Pier	33°50'00"	118°25'00"
	Redondo Beach Municipal Pier	Boat ramp	33°50'00"	118°25'00"
	Redondo Sportfishing Pier	Pier	33°50'00"	118°25'00"
	Redondo Beach	Beach	33°50'00"	118°25'00"
	Palo Verdes Shoreline Park	Park	33°45'00"	118°20'00"
	Royal Palms State Beach	Beach	33°45'00"	118°20'00"
	Cabrillo Beach Park	Beach	33°40'00"	118°15'00"
	Cabrillo Beach Park	Boat ramp	33°40'00"	118°15'00"
	Cabrillo Beach Park	Boat ramp	33°40'00"	118°15'00"
	Cabrillo Fishing Pier	Pier	33°40'00"	118°15'00"
	Queensway Bay	Boat ramp	33°45'00"	118°10'00"
	Queensway Bay	Boat ramp	33°45'00"	118°10'00"
	Belmont Pier	Pier	33°45'00"	118°10'00"
	Belmont Shore	Beach	33°45'00"	118°10'00"
	Belmont Shore	Boat ramp	33°45'00"	118°10'00"
	Alamitos Bay	Boat ramp	33°45'00"	118°05'00"
	Alamitos Bay	Boat ramp	33°45'00"	118°05'00"
	Alamitos Bay	Boat ramp	33°45'00"	118°05'00"
Orange	Seal Beach	Beach	33°45'00"	118°05'00"
	Seal Beach Fishing Pier	Pier	33°45'00"	118°05'00"

Supplemental Information for Recreation Model

Table E-1, continued

County	Place Name	Type	Latitude	Longitude
Orange	Sunset Beach	Pier	33°45'00"	118°05'00"
	Sunset Beach	Beach	33°45'00"	118°05'00"
	Sunset Beach	Boat ramp	33°45'00"	118°05'00"
	Sunset Beach	Boat ramp	33°45'00"	118°05'00"
	Trinidad Island	Pier	33°45'00"	118°05'00"
	Bolsa Chica State Beach	Beach	33°40'00"	118°05'00"
	Huntington Beach	Beach	33°40'00"	118°00'00"
	Huntington Beach	Boat ramp	33°40'00"	118°00'00"
	Huntington Harbor	Pier	33°40'00"	118°00'00"
	Huntington State Beach	Beach	33°40'00"	118°00'00"
	Newport Beach	Beach	33°35'00"	117°55'00"
	Newport Beach Pier	Pier	33°35'00"	117°55'00"
	Newport Harbor	Boat ramp	33°35'00"	117°55'00"
	Newport Harbor	Boat ramp	33°35'00"	117°55'00"
	Balboa Beach	Beach	33°35'00"	117°55'00"
	Balboa Beach	Pier	33°35'00"	117°55'00"
	Corona Del Mar State Beach	Beach	33°35'00"	117°52'30"
	Crystal Cove State Park	Beach	33°35'00"	117°50'00"
	Laguna Beach	Beach	33°30'00"	117°50'00"
	Aliso Point County Park	Pier	33°30'00"	117°45'00"
	Doheny State Beach	Beach	33°30'00"	117°40'00"
	Doheny State Beach	Boat ramp	33°30'00"	117°40'00"
	Capistrano Beach	Beach	33°25'00"	117°40'00"
	San Clemente Municipal Pier	Pier	33°25'00"	117°40'00"
	San Clemente State Beach	Beach	33°25'00"	117°35'00"
San Diego	San Onofre State Beach	Beach	33°25'00"	117°35'00"
	Avalon Bay Fishing Pier	Pier	33°20'00"	117°20'00"
	Oceanside Harbor	Boat ramp	33°13'00"	117°25'00"
	Oceanside Harbor	Pier	33°13'00"	117°25'00"
	Oceanside Pier	Pier	33°13'00"	117°20'00"
	Carlsbad State Beach	Beach	33°10'00"	117°20'00"
	South Carlsbad State Beach	Beach	33°05'00"	117°20'00"
	Leucadia State Beach	Beach	33°05'00"	117°20'00"
	Moonlight State Beach	Beach	33°05'00"	117°20'00"
	San Elijo State Beach	Beach	33°00'00"	117°15'00"
	Cardiff State Beach	Beach	33°00'00"	117°15'00"
	Solana Beach	Beach	33°00'00"	117°15'00"
	Torrey Pines State Beach	Beach	32°55'00"	117°15'00"
	Torrey Pines State Reserve	Beach	32°55'00"	117°15'00"
	Crystal Pier	Pier	32°50'00"	117°15'00"
	Fiesta Bay	Boat ramp	32°50'00"	117°15'00"
	Fiesta Bay	Boat ramp	32°50'00"	117°15'00"

Supplemental Information for Recreation Model

Table E-1, continued

County	Place Name	Type	Latitude	Longitude
San Diego	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Ocean Beach Fishing Pier	Pier	32°45'00"	117°15'00"
	Embarcadero Marina Park	Pier	32°40'00"	117°15'00"
	Embarcadero Marina Park	Boat ramp	32°40'00"	117°15'00"
	G Street Pier	Pier	32°40'00"	117°10'00"
	Shelter Island Fishing Pier	Pier	32°40'00"	117°10'00"
	Silver Strand	Boat ramp	32°40'00"	117°10'00"
	National City Launching Ramp	Boat ramp	32°40'00"	117°05'00"
	National City Launching Pier	Pier	32°40'00"	117°05'00"
	Silver Strand State Beach	Beach	32°35'00"	117°10'00"
	Chula Vista Boat Ramp	Boat ramp	32°35'00"	117°05'00"
	Imperial Beach	Pier	32°35'00"	117°10'00"
	Imperial Beach	Beach	32°35'00"	117°10'00"
	Border Field State Park	Beach	32°30'00"	117°10'00"

Attachment 2: Final Agreement for Mitigation for Huntington Beach Generating Station.

Order No. 06- -

BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION
OF THE STATE OF CALIFORNIA

In the Matter of:	)	Docket No.: 00-AFC-13C
	)	
Huntington Beach Generating Station	)	
Retool Project	)	COMMMISSION ORDER
______________________________	)	

The Huntington Beach Generating Station Retool Project ("the Project") was licensed by an emergency proceeding, consistent with an Executive Order from the Governor, during the energy crisis of 2001. Consistent with the Executive Order and the crisis it addressed, the Project was licensed without following the normal licensing procedure timelines of the California Energy Commission ("Commission"). The Project was licensed for refurbishment and operation prior to environmental studies that would normally occur to determine the impact of its once-through cooling systems on the marine biology offshore from the facility.

The Commission required post-licensing studies to determine environmental impact on aquatic life and the payment of suitable mitigation costs if those impacts were found to be significant. In light of the unstudied environmental questions and other aspects of the emergency consideration of the license, the Commission required that the emergency license expire on September 30, 2006, unless the Commission finds that: 1) the Project is in substantial compliance with all conditions of certification; 2) the Project is mitigating its contribution to environmental impacts (i.e., entrainment and impingement of marine organisms) as determined by studies agreed upon by the Project applicant, Commission staff ("staff"), and other interested parties; and 3) all required permits are in force and the Project is in substantial compliance. (Condition Emergency-2.)

The interested parties agreed on the impact study regimen, and these studies were concluded in 2005. Staff, applicant, and other parties have met to determine what the studies indicate, including the actual environmental effect of the Project's operation on the marine environment. Applicant, staff, and other interested parties agree that this impact is best mitigated by enhancement of regional ocean productivity, and that such enhancement should include the purchase, restoration, and preservation of tidal wetlands near the Project site.

The one area of disagreement between applicant, staff, and the parties was with regard to how much marine impact the Project has, based on the agreed to studies and results. This dispute translates into the issue of how much wetland must be acquired, improved, and maintained to mitigate such impact.

This issue came on for hearing at the Commission's September 14, 2006, business meeting. At this meeting both staff and the applicant representatives gave elaborate presentations of their differing methods for determining marine impact. In addition, applicant raised issues about the fairness of the numerical method used to calculate marine impact concerning the first five years of its license (four years during which the Project operated). Staff proposed calculating impact, both for the retrospective five year period and the five year prospective period, based on 100 percent of the Project's permitted operation. However, during the first five years the project had operated at considerably less than its permitted level. The applicant thus argued that the level of mitigation, at least for the initial five-year period, was disproportionate and unfair. The Commission continued the hearing until September 27, 2006, to allow staff, applicant, and interested parties to meet and consider whether the mitigation requirements should reflect actual operation during the first five years, among other issues.

Staff held a public workshop with applicant and interested parties on September 25. At this workshop the participants considered several alternative mitigation proposals submitted by applicant regarding how to best calculate the measure of mitigation that should be required to mitigate the project. These proposals and staff's responses to them are discussed in staff's September 26 memorandum ("Workshop Report") that is the Attachment to this Order.

In the Workshop Report staff indicated that it preferred the mitigation that would be required based on 100 percent of the permit limit (a figure corrected to require $8.58 million worth of habitat restoration) for the entire 10 year period of an extended license or, alternatively, on an operating profile that reflects a reasonably conservative estimate of likely operations. If, in the future, the level of operation (including water used for cooling) exceeds this level, applicant will be required to "true up" its mitigation and provide additional money for habitat restoration. (Staff referred to this level of operation that would require additional "true-up" mitigation as a "soft cap.") However, since both staff and applicant believe that the "reasonable worst case" operating scenario is unlikely to be exceeded, they agree that such a "true up" probably will not be necessary.

The staff's alternative (or compromise) proposal is "Profile 3" on page 4 of the Workshop Report. It requires the restoration and maintenance for 10 years of 66.8 acres of wetlands, which has been translated into $5,511,000 (including $523,712 for maintenance for 10 years) for mitigation from the applicant. A potential (but unlikely) "true up" from operation that exceeds the assumptions on which this number is based is included as part of this proposal.

Order No. 06- -

At the September 27 continued hearing the parties discussed the various mitigation "profiles," and applicant agreed to mitigate in accordance with the terms of "Profile *3* in the Workshop Report. Staff and applicant both believe that "Profile 3 is a reasonable and fair way of calculating the proportionate mitigation of the Project. Based on the evidence of record and the statements of the parties, the Commission agrees, and makes the following findings of fact:

1. The Project uses ocean water for cooling, resulting in impingement and entrainment of marine organisms, which constitutes a significant cumulative impact to regional marine biology.

2. The measure of this impact was not mitigated prior to licensing because of the need to license the Project on an emergency basis pursuant to the 2001 Executive Order.

3. The Project's emergency license will expire on September 30 unless the Commission determines, among other matters, that the applicant is mitigating for Project effects from once-through cooling.

5. Project effects have been determined by elaborate marine biology studies conducted by consultants to the applicant, with oversight from the Commission and other interested agencies.

6. The impacts to marine species from once-through cooling can be offset by increased productivity from regional wetlands, if such wetlands are purchased, improved, and preserved for such purposes.

7. Mitigation for impacts to marine species will be offset by the purchase, improvement, and preservation of 66.8 acres of regional wetlands.

8. The 66.8 acres of regional wetlands that would offset this impact can be improved and maintained for 10 years for $5,511,000, as described in the Attachment.

9. The 66.8 acres of regional wetlands will be acquired, improved, and maintained by the Huntington Beach Wetlands Conservancy.

10. The restoration of 66.8 acres of regional wetlands for improvement and preservation will proportionately mitigate the effects of the Project's once-through cooling on the marine environment.

11. The Project's owners are providing the funding for the purchase of 66.8 acres by lump sum, and therefore are mitigating for the Project's effect on the marine environment.

Order No. 06- -

In view of the above findings, the Commission further finds and orders:

1. The Project is mitigating its contribution to environmental impacts by paying for the purchase, restoration, and maintenance for 10 years of 66.8 acres of tidal wetlands, at a cost of $5,511,000.

2. The Project is in substantial compliance with the conditions of certification.

3. All currently required permits (i.e., the NPDES permit) are in force and the project owner is in substantial compliance with such permits.

4. The Project owner shall provide the $5,511,000 mitigation funding to the Huntington Beach Wetlands Conservancy within 90 days of this order; applicant shall pay the $523,536 maintenance portion of this amount now by lump sum, rather than over a 10-year period, applicant may apply a six percent discount rate to the latter sum.

5. Applicant shall begin monitoring daily intake flows now and report them quarterly to the CPM to determine whether such flows exceed what staff has called the "soft cap."

6. The Huntington Beach Generating Station Retool Project license is hereby extended for an additional five years from the date of this determination, until September 30,2011.

Date: September 27, 2006 ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION

ABSENT

JACKALYNE PFANNENSTIEL
Chairman

JAMES D. BOYD
Commissioner

ABSENT

JOHN L. GEESMAN
Commissioner

ARTHUR H. ROSENFELD
Commissioner

JEFFREY D. BYRON
Commissioner

STATE OF CALIFORNIA —THE RESOURCES AGENCY ARNOLD SCHWARZENEGGER, *Governor*

CALIFORNIA ENERGY COMMISSION
1516 NINTH STREET
SACRAMENTO, CA 95814-5512

September 27,2006 Business Meeting
Agenda Item: 7a

DATE: September 26,2006

TO: California Energy Commissioners and Interested Parties

FROM: Donna Stone, Compliance Project Manager
Paul Kramer, Counsel for Staff

SUBJECT: AES Huntington Beach Generating Station Retool Project (00-AFC-13C)
Report of September 25 Staff Workshop

As suggested by the Energy Commission at its September 14,2006, Business Meeting, Energy Commission staff conducted a staff workshop on September 25, 2006 regarding mitigation for the impingement and entrainment impacts of the AES Huntington Beach Generating Station's (HBGS) once-through cooling system. Prior to the workshop, AES submitted several alternative proposals and staff asked several clarifying questions of AES via email. Attending the workshop were representatives of the Santa Ana Regional Water Quality Control Board, Coastal Commission, State Lands Commission, and the Huntington Beach Wetlands Conservancy. Prior to the workshop, Commissioner Byron sent a letter to the parties asking that they discuss "a mitigation package that would be based on the actual operating history for the first five years of the project, and the full permitted level of operation for the five year extension of the license." Though not explicitly stated in the letter, we presume Commissioner Byron intends an average of the historical and full permitted levels.

In its pre-workshop submittal (attached for reference), AES offered nine scenarios consisting of varying combinations of choices such as the method of determining the area of habitat production foregone (APF), and splitting the mitigating habitat obligation into two parts--one to be provided now and the other to be provided in 2011 if the license is extended. Staff evaluated the proposed scenarios to determine which are consistent with the principles which underlie its original mitigation recommendation, approved by the Siting Committee, for the payment of $7,956,000[1] to restore 104 acres of the Huntington Beach Wetlands and maintain them for 10 years.

The key principle underlying staffs analysis is that the mitigation chosen must be capable, on an annual basis, of replacing the species lost during the year. The capacity of the mitigation, then, must be equal to the highest year's losses. Determining the level of mitigation on an average of several years of historic operating data, either as proposed in several of AES' scenarios or perhaps in Commissioner Byron's letter, would

[1] In making the calculations to prepare this report, we discovered an error in the cost of the 104 restoration proposal. The basic numbers contained in staffs analysis for the Siting Committee Workshop in July and the Commission's September 14 Business Meeting are correct—$74,660 per acre to restore and $784 per acre per year for 10 years for maintenance—but the numbers were not correctly combined. The proper total cost, including restoration and 10 years of maintenance, is $8,580,000, which is shown on the table at the end of this report.

lead to less than full mitigation of impacts in above average years. Similarly, postponing payment of half of the cost of complete mitigation until 2011, to be paid only if the license is extended, fails to provide sufficient mitigation in the near term.

Staff has identified a concept from the proposals that is consistent with our mitigation principles. In Scenario 4b, AES proposes to set a "soft cap" at operating levels that it does not expect to exceed under any reasonably expected scenario. It would provide a mitigation payment based on the APF calculated for those operating levels. Each year it would recalculate the APF on its quarterly flows for units 3 and 4[2]; if that APF exceeds the APF "cap," it would provide an additional mitigation payment for the additional acres and the cap for following years would be the new higher APF.

AES prefers the soft cap approach because it is based on operating parameters closer, but still above, what it expects to achieve rather than the theoretical maximum flows allowed under its permits. The soft cap satisfies staffs mitigation principles so long as the cap is based upon a sufficiently conservative assumption of the highest likely operating results. We are not in favor of setting the cap too low because, even though the formula calls for additional mitigation payments if the cap is exceeded, it is more difficult to provide effective mitigation if the payments are not predictable (i.e., payable at the beginning). Wetlands cannot generally be developed in small pieces. As it is, monies committed today will not result in productive wetlands until at least three to five years from now; delaying payment further delays the provision of that mitigation.

AES has proposed a maximum operating profile that results in an APF of 59.3 acres (Profile 4 in the table below). Mindful of the above concerns, staff favors a more conservative profile, based on a profile proposed by AES prior to the July Siting Committee workshop, that results in a 66.8 acre APF (Profile 3). For comparison purposes, the table also shows staffs original recommendation (Profile 1, 104 acre APF) and the results suggested for discussion by Commission Byron (Profile 2, 72.9 acre APF).

At the workshop, AES expressed a concern that it be able to clearly show future regulators, both at the Energy Commission and other agencies, that the number of acres of mitigation ultimately chosen is related to a specific rate of water flow through the cooling system. For that reason, AES is uncomfortable with the averaging of historical flows and maximum permitted flows; they do not think it will clearly indicate to future regulators exactly what level of activity they have mitigated. Staff shares that concern and prefers the soft cap methodology.

During the workshop, there was some confusion over the amount and timing of maintenance costs. We have since clarified that they are intended to be $784 per acre

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[2] At the staff workshop, AES used the phrase "quarterly average volumetric flows." Staff is concerned that the use of "average" may imply something other than the use of actual flow data. Our presentation of the Profile options in this memo assumes that APFs will he calculated using actual quarterly volumetric flow data.

per year for ten years. AES has proposed paying those costs in a lump sum, calculating the net present value of that payment stream at a discount rate of 12%, the rate of return it says it can earn on its investment capital. We do not believe that the Conservancy can earn such a high rate of return, however, which could result in a shortage of maintenance funds over time. Rather, we propose that AES either negotiate a suitable discount rate with the Conservancy or make the payments as they come due over the next ten years.

SUMMARY

For the reasons described above, staff believes that Profiles 1 and 3 in the table below are consistent with the principles it applied in making its recommendation for mitigation of the HBGS units 3 and 4 cooling system impacts. If Profiles 2, 3 or 4 are chosen, staff recommends that any future mitigation payments required if the APF is exceeded be adjusted for inflation according to an appropriate CPI. No matter which Profile is chosen, AES should make full payment (excepting years 2 through 10 of maintenance) within 90 days of the Commission's decision and begin reporting daily actual intake flows each quarter to the CPM so that we can monitor and recalculate the "soft cap."

Staff Workshop Report
Page 4
September 26, 2006

Profile		1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	APF/ Cost
1-Sept. 14 Staff proposal	% Operation	100%	100%	100%	100%	104 acres
	CW Vol (MGD)	253.5	253.5	253.5	253.5	$ 8,580,000[3]
2-Average permitted maximum and historic flows[4]	% Operation	55%	62%	78%	60%	72.9 acres
	CW Vol (MGD)	139.4	157.2	197.7	152.1	$ 6,014,250[5]
3-AES' proposal prior to July Siting Comm. workshop	% Operation	25%	50%	80%	45%	66.8 acres
	CW Vol (MGD)	63.4	126.8	202.8	114.1	$ 5,511,000[6]
4-Sept. 20 AES Proposal	% Operation	15%	35%	80%	25%	59.3 acres
	CW Vol (MGD)	38.0	88.7	202.8	63.4	$ 4,892,250[7]

Attachments:
September 20, 2006 letter from Eric Pendergrafi (AES) to Paul Richins
September 25, 2006 letter from Commissioner Byron to parties

[3] $7,764,640 + $815,360 for maintenance (ten annual payments of $81,536)
[4] All calculations for this Profile are mathematical averages of existing data and results. They were not run through the ETM model, which may yield a slightly different APF.
[5] $5,442,714 + $571,536 maintenance
[6] $4,987,288 + $523,712 for maintenance
[7] $4,427,338 + $464,912 for maintenance

AES Huntington Beach, L.L.C.

September 20,2006

Transmitted Via **Email**

Paul Richins
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814-5512

Re: AES Huntington Beach Retool Project For Units **3 &** 4
Docket No. **00-AFC-13**

Dear Mr. Richins:

Consistent with the direction provided by the California Energy Commission (CEC) during the business meeting on September **14th,** 2006, AES Huntington Beach (AESHB) submits the attached options for calculating mitigation amounts for consideration by CEC Staff. These options are all based on the science and area of production foregone (APF) methodology recommended by CEC Staff.

As AESHB presented during the business meeting, both the unique nature of this license and the actual or maximum expected operating profile of the units are important factors in determining the proportionate mitigation. The attached proposals are all based on the same underlying assumptions as the CEC Staff proposal. The differences in these proposals reflect various reasonable assumptions regarding plant operations, the term of the certification, and the method to ensure compliance.

AESHB remains committed to compensating for appropriate and proportional entrainment and impingement impacts and we are hopeful that the CEC will find an acceptable alternative among the options we have provided.

Thank you for your consideration.

Respectfully,

Eric Pendergraft
Plant Manager, AES Huntington Beach

cc: Donna Stone, California Energy Commission
Roger Johnson, California Energy Commission
Arlene Ichien, California Energy Commission
Paul Kramer, California Energy Commission
Rick York, California Energy Commission

21730 Newland Street
Huntington Beach, CA 92646
Phone (714) 374-1476
Fax: (714) 374-1495

HBGS Mitigation Proposal - Option l a

Operational Assumptions: An average of the actual volume of circulating water (CW) flow over the first 5 years of the certification and a reasonable estimate of the shaped annual average volume of CW flow over the remaining term of the license.

Profile of Actual Average Circulating Water Volume for the First 5 Years:

% Operation	1st Qtr 10%	2'' Qtr 24%	3rd Qtr 56%	4th Qtr 20%	Annual 27.5%	APF (Acres)
CW Volume (MGD)	25.4	60.8	142.0	50.7	69.7	41.8

Profile of Proposed Average Circulating Water Volume for Remaining Term:

% Operation	1st Qtr 15%	2'' Qtr 35%	3rd Qtr 80%	4th Qtr 25%	Annual 38.8%	APF (Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term Assumption: Through September, 2011

Compliance Method: The actual average volume of CW flow during the second five years of the certification will be determined and reported. Any uncompensated losses at the end of the current license period will be mitigated at a ratio of two acres of wetland restoration for each acre of uncompensated area of production foregone (APF).

Calculation:
Step 1: Average the APF based on the actual circulating water flow volume over the first 5 years and the **APF** based on proposed CW flow profile over the remaining term.

Avg. **APF** = (41.8 acres + 59.3 acres) 1 2 = 50.6 acres

Step 2: Adjust for the term of the certification by dividing by two. Any extension of the license in 2011 would require the second half of the restoration payment.

50.6 acres 1 2 x $74,660/acre = $1,888,898

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 50.6 acres x $784/acre-year = $39,670 per year
$NPV_{@12\%}$ of 10 years maintenance = $224,147

Step 4: Calculate the total:

Mitigation Fee = $1,888,898 + $224,147 = $2,113,045
If extended in 2011: $2,113,045

HBGS Mitigation Proposal - Option 1b

Operational Assumptions: An average of the actual volume of circulating water (CW) flow over the first 5 years of the certification and a reasonable estimate of the shaped annual average volume of CW flow over the remaining term of the license.

Profile of Actual Average Circulating Water Volume for the First 5 Years:

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Annual	APF
% Operation	10%	24%	56%	20%	27.5%	(Acres)
CW Volume (MGD)	25.4	60.8	142.0	50.7	69.7	41.8

Profile of Proposed Average Circulating Water Volume for Remaining Term:

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Annual	APF
% Operation	15%	35%	80%	25%	38.8%	(Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term Assumption: Through September, 2011

Compliance Method: The average CW flow volume will be calculated and reported on an annual basis. Any uncompensated impacts will be paid annually at a mitigation ratio of one acre of wetlands restoration for each acre of APF exceeded.

Calculation:
Step 1: Average the APF based on actual circulating water flow volume over the first 5 years and the APF based on proposed CW flow profile over the remaining term.

Avg. APF = (41.8 acres + 59.3 acres) / 2 = 50.6 acres

Step 2: Adjust for the term of the certification by dividing by two. Any extension of the license in 2011 would require the second half of the restoration payment.

50.6 acres 1 2 x $74,660/acre = $1,888,898

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 50.6 acres x $784/acre-year = $36,670 per year
$NPV_{@12\%}$ of 10 years maintenance = $224,147

Step 4: Total the amounts:

Mitigation Fee = $1,888,898 + $224,147 = $2,113,045
If extended in 2011: $2,113,045

HBGS Mitigation Proposal - Option 2a

Operational Assumplion: A reasonable estimate of the shaped annual average volume of circulating water (CW) flow over the remaining term of the license.

Profile of Proposed Average Circulating Water Volume for Remaining Term:

% Operation	1st Qtr 15%	2nd Qtr 35%	3rd Qtr 80%	4th Qtr 25%	Annual 38.8%	APF (Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term Assumption: Through September, 2011

Compliance Method: The actual average volume of CW flow during the second five years of the certification will be determined and reported. Any uncompensated losses at the end of the current license period will be mitigated at a ratio of two acres of wetland restoration for each acre of uncompensated area of production foregone (APF).

Calculation:
Step 1: Determine the APF based on proposed CW flow profile over the remaining term.

Avg. APF = 59.3 acres

Step 2: Adjust for the term of the certification by dividing by two. Any extension of the license in 2011 would require the second half of the restoration payment.

59.3 acres / 2 x $74,660/acre = $2,213,669

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 59.3 acres x $784/acre-year = $46,491 per year
$NPV_{@12\%}$ of 10 years maintenance = $262,686

Step 4: Total the amounts.

Mitigation Fee = $2,213,669 + $262,686 = $2,476,355
If extended in 2011: $2,476,355

HBGS Mitigation Proposal - Option 2b

Operational Assumption: A reasonable estimate of the shaped annual average volume of circulating water (CW) flow over the remaining term of the license.

Profile of Proposed Average Circulating Water Volume for Remaining Term:

% Operation	1st Qtr 15%	2nd Qtr 35%	3rd Qtr 80%	4th Qtr 25%	Annual 38.8%	AFF (Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term Assumption: Through September, 2011

Compliance Method: The average CW flow volume will be calculated and reported on an annual basis. Any uncompensated impacts will be paid annually at a mitigation ratio of one acre of wetlands restoration for each acre of APF exceeded.

Calculation:
Step 1: Determine the APF based on proposed CW flow profile over the remaining term.

Avg. APF = 59.3 acres

Step 2: Adjust for the term of the certification by dividing by two. Any extension of the license in 2011 would require the second half of the restoration payment.

59.3 acres / 2 x $74,660/acre = $2,213,669

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 59.3 acres x $784/acre-year = $46,491 per year
$NPV_{@\,12\%}$ of 10 years maintenance = $262,686

Step 4: Total the amounts.

Mitigation Fee = $2,213,669 + $262,686 = $2,476,355
If extended in 2011: $2,476,355

HBGS Mitigation Proposal - Option 3a

Operational Assumptions: **An** average of the actual volume of circulating water (CW) flow over the first 5 years of the certification and a reasonable estimate of the shaped annual average volume of CW flow assuming an unlimited license term.

Profile of Actual Average Circulating Water Volume for the First 5 Years:

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Annual	APF
% Operation	10%	24%	56%	20%	27.5%	(Acres)
CW Volume (MGD)	25.4	60.8	142.0	50.7	69.7	41.8

Profile of Proposed Average Circulating Water Volume for Remaining Term:

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Annual	APF
% Operation	15%	35%	80%	25%	38.8%	(Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term Assumption: Unlimited

Compliance Method: The actual average volume of CW flow during the second five years of the certification will be determined and reported. Any uncompensated losses at the end of the current license period will be mitigated at a ratio of two acres of wetland restoration for each acre of uncompensated area of production foregone (APF).

Calculation:
Step 1: Average the APF based on actual circulating water flow volume over the first 5 years and the APF based on proposed CW flow profile over the remaining term.

Avg. APF = (41.8 acres + 59.3 acres) / 2 = 50.6 acres

Step 2: Calculate mitigation cost,

50.6 acres x $74,660/acre = $3,777,796

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 50.6 acres x $784/acre-year = $39,670 per year
$NPV_{@\ 12\%}$ of 10 years maintenance = $224,147

Step 4: Total the amounts.

Mitigation Fee = $3,777,796 + $224,147 = $4,001,943

HBGS Mitigation Proposal - Option 3b

Operational Assumptions: An average of the actual volume of circulating water (CW) flow over the first 5 years of the certification and a reasonable estimate of the shaped annual average volume of CW flow assuming an unlimited license term.

Profile of Actual Average Circulating Water Volume for the First 5 Years:

% Operation	1st Qtr 10%	2nd Qtr 24%	3rd Qtr 56%	4th Qtr 20%	Annual 27.5%	APF (Acres)
CW Volume (MGD)	25.4	60.8	142.0	50.7	69.7	41.8

Profile of Proposed Average Circulating Water Volume for Remaining Term:

% Operation	1st Qtr 15%	2nd Qtr 35%	3rd Qtr 80%	4th Qtr 25%	Annual 38.8%	APF (Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term Assumption: Unlimited

Compliance Method: The average CW flow volume will be calculated and reported on an annual basis. Any uncompensated impacts will be paid annually at a mitigation ratio of one acre of wetlands restoration for each acre of APF exceeded.

Calculation:
Step 1: Average the APF based on actual circulating water flow volume over the first 5 years and the APF based on proposed CW flow profile over the remaining term.

Avg. APF = (41.8 acres + 59.3 acres) / 2 = 50.6 acres

Step 2: Calculate mitigation cost.

50.6 acres x $74,660/acre = $3,777,796

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 50.6 acres x $784/acre-year = $39,670 per year
$NPV_{@12\%}$ of 10 years maintenance = $224,147

Step 4: Total the amounts.

Mitigation Fee: = $3,777,796+ $224,147 = $4,001,943

HBGS Mitigation Proposal - Option 4a

Operational Assumption: A reasonable estimate of the shaped annual average volume of CW flow assuming an unlimited license term.

Profile of Proposed Average Circulating Water Volume **for** Remaining Term:

% Operation	1st Qtr 15%	2nd Qtr 35%	3rd Qtr 80%	4th Qtr 25%	Annual 38.8%	APF (Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term Assumption: Unlimited

Compliance Method: The actual average volume of CW flow during the second five years of the certification will be determined and reported. Any uncompensated losses at the end of the current license period will be mitigated at a ratio of two acres of wetland restoration for each acre of uncompensated area of production foregone (APF).

Calculation:
Step 1: Determine the APF based on proposed CW flow profile over the remaining term.

Avg. APF = 59.3 acres

Step 2: Calculate mitigation cost.

59.3 acres x $74,660/acre = $4,427,338

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 59.3 acres x $784/acre-year = $46,491 per year
$NPV_{@\ 12\%}$ of 10 years maintenance = $262,686

Step 4: Total the amounts.

Mitigation Fee = $4,427,338 + $262,686 = $4,690,024

HBGS Mitigation Proposal - Option 4b

Operational Assumption: A reasonable estimate of the shaped annual average volume of Circulating water flow assuming an unlimited license term.

Profile of Proposed Average Circulating Water Volume for Remaining Term:

% Operation	1st Qtr 15%	2nd Qtr 35%	3rd Qtr 80%	4th Qtr 25%	Annual 38.8%	APF (Acres)
CW Volume (MGD)	38.0	88.7	202.8	63.4	98.2	59.3

Term: Unlimited

Compliance Method: The average CW flow volume will be calculated and reported on an annual basis. Any uncompensated impacts will be paid annually at a mitigation ratio of one acre of wetlands restoration for each acre of APF exceeded.

Calculation:
Step 1: Determine the APF based on proposed CW flow profile over the remaining term.

Avg. APF = 59.3 acres

Step 2: Calculate mitigation cost.

59.3 acres x $74,660/acre = $4,427,338

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 59.3 acres x $784/acre-year = $46,491 per acre
NPV @ 12% of 10 years maintenance = $262,686

Step 4: Total the amounts.

Mitigation Fee = $4,427,338 + $262,686 = $4,690,024

WBGS Mitigation Proposal - Option 5

Operational Assumption: The maximum permitted circulating water flow over the term of the existing license.

Profile of Maximum Circulating Water Volume:

% Operation	1st Qtr 100%	2nd Qtr 100%	3rd Qtr 100%	4th Qtr 100%	Annual 100%	APF (Acres)
CW Volume (MGD)	253.5	253.5	253.5	253.5	253.5	104

Term: Through September, 2011

Compliance Method: Not Applicable

Calculation:

Step 1: Determine the APF based on maximum permitted CW flow.

Avg. APF = 104 acres

Step 2: Adjust for the term of the certification by dividing by two. Any extension of the license in 2011 would require the second half of the restoration payment.

104 acres 12 x $74,660/acre = $3,882,320

Step 3: Calculate the net present value of the maintenance costs over the 10 year term of the existing license assuming a 12% discount rate.

Annual Maintenance Cost = 104 acres x $784/acre-year = $81,536 per year
$NPV_{@12\%}$ of 10 years maintenance = $460,697

Step 4: Total the amounts.

Mitigation Fee = $3,882,320 + $460,697 = $4,343,017
If extended in 2011: $4,343,017

Huntington Beach Generating Station Empirical Transport Model Estimates for Area of Production Foregone Using Seasonal Flow Reduction

August 14,2006

Prepared for:

Mr. Paul Hurt
AES Southland
Huntington Beach. CA

Prepared by:

Tenera Environmental
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805.541.0310

Introduction

This report presents estimates of area of production foregone (APF) for entrainment effects of tlie I-IBGS using two different seasonal flow reductions. A previous report dated July 5,2006 presented APF values calculated using a different set of flow reductions. Tlie estimates presented in this report for nearshore taxa are compared with estimates calculated using a daily flow of 507,000,000 mgd that were presented in the HBGS Entrainment and Impingement Study Final Report (IM&E Report) (MBC and Tenera 2005). The APF estimates for gobies are based on the wetland areas presented in a previous report.

Methods and Results

Tlie average APF for nearshore sandy habitat was recalculated using only tlie taxa that primarily occur in the nearshore areas around I-IBGS as adults. The APF values in the previous report were calculated from tlie original P_M estimates and extrapolated source water areas. Separate P_M estimates were calculated by adjusting tlie intake volume of 253,500,000 mgd (959,602 m^3) using the following two different flow reduction scenarios:

Scenario	Quarter 1 % of Maximum	Quarter 2 % of Maximum	Quarter 3 % of Maximum	Quarter 4 % of Maximum
1	10	24	56	20
2	15	35	80	25

The entrainment estimates from the surveys in each of the periods were calculated using tlie adjusted flows and P_M estimated using the adjusted PE estimates based on the reduced flows. The APF calculation using the revised P_M estimates are presented in Table 1.

The calculation of APF for CIQ gobies involved recalculating the P_M estimate bX including an estimate of the larval gobies in the estuarine habitats in the vicinity of the HBGS. The revised *ETM* estimate for CIQ gobies was calculated using *PE* estimates that incorporates both nearshore and estuarine area larvae. The estimate of APF 103 CIQ gobies was based on the adult habitat in the estuarine areas around dle HBGS. The revised values are presented in Table 1.

HBGS APF Calculations

Table 1. APF values calculated from *ETM* model estimates based on three different flow reductions from 253,500,000 mgd. The *ETM* estimate from the 2005 316(b) Demonstration Report were calculated using an intake volume of 507,000,000 mgd.

Taxa	P_M Alongshore from Report	P_M Flow (10,24,56,20)	P_M Flow (15,35,80,25)	Alongshore Displacement (km)	Area Width (km)	APF Report Estimates (acres [km^2])	APF flow (10.24.56.20) (acres [km2])	APF Flow (15,35,80,25) (acres [km2])
Estuarine Taxon - source water includes estuarine areas				Area (acres [km^2]) =				
unid. gobies	0.0090	0.001 7	0.0024	3397.78 (1375.04)		30.68 (0.12)	5.74 (0.02)	8.19 (0.03)
Coastal Taxa								
spotfin croaker	0.0029	0.0005	0.0007	16.9418	4.45	54.77 (0.22)	9.31 (0.04)	13.41 (0.05)
queenfish	0.0063	0.0018	0.0025	84.8827	4.45	584.3 (2.36)	164.28 (0.66)	234.28 (0.95)
white croaker	0.0071	0.0008	0.0011	47.8364	4.45	374. (1.51)	42.08 (0.17)	59.97 (0.24)
black croaker	0.0012	0.0003	0.0005	19.4240	4.45	25.42 (0.1)	7.05 (0.03)	10.04 (0.04)
blennies	0.0077	0.0010	0.0013	12.8190	4.45	108.26 (0.44)	13.53 (0.05)	17.76 (0.07)
diamond turbot	0.0058	0.0006	0.0007	16.9325	4.45	107.62 (0.44)	10.24 (0.04)	13.03 (0.05)
California halibut	0.0025	0.0004	0.0005	30.9100	4.45	84.97 (0.34)	12.24 (0.05)	16.99 (0.07)
Cancer megalops	0.0107	0.0026	0.0037	26.5015	4.45	311.81 (1.26)	76.06 (0.31)	108.99 (0.44)
Average for Coastal Taxa					Average =	206.39 (0.84)	41.85 (0.17)	59.31 (0.24)

September 25,2006

Hand-Carried
Mr. Terry O'Brien, Deputy Director
Systems Assessment & Facilities Siting Division
California Energy Commission
1516 Ninth Street, MS-16
Sacramento, CA 95814

Transmitted Via Facsimile (714) 374-1495 & U.S. Mail
Mr. Eric Pendergraft, Plant Manager
AES Huntington Beach
21370 Newland Street
Huntington Beach, CA 92646-7612

Other Interested Parties

Dear Messrs. O'Brien and Pendergraft:

After consideration of the recent proposals from AES concerning appropriate mitigation for the Huntington Beach project and the rest of the record in this case, I am writing to request that the parties in this proceeding discuss at today's staff workshop, and be prepared to comment at the California Energy Commission's Wednesday, September 27, 2006, Business Meeting on a mitigation package that would be based on the actual operating history for the first five years of the project, and the full permitted level of operation for the five year extension of the license that is under consideration.

Sincerely,

JEFFREY D. BYRON, Commissioner
Associate Member of the Siting Committee

Cc: Commissioners
Jackalyne Pfannenstiel
James D. Boyd
John L. Geesman
Arthur H. Rosenfeld

Desalination Plant Intake Technology Review

October 30, 2011

Prepared for:
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Introduction

This report provides an overview of intake technologies for ocean desalination plants in coastal areas of California. Unlike coastal power plants that have alternatives to ocean water for cooling, desalination plants need to withdraw ocean water either directly through an intake located in the ocean or indirectly through the seabed (**Figure 1**). The intake technology selected for each facility will depend on numerous factors but most importantly, each plant requires a reliable source of seawater. Other important factors related to the design and location of the intake and discharge include minimizing environmental impacts and management of the concentrated seawater discharge, while considerations for the siting of the plant include other factors such as access to an adequate source of energy and access to a water distribution system. Due to the considerations of these and other factors, the final intake design for each project should be based on a site-specific assessment as recommended by the State Desalination Taskforce.[1]

This report summarizes information from several sources but primarily two technical reports available from the WateReuse Association website (WateReuse Association 2011a and 2011b). These two reports provide an overview of the issues related to desalination plant intake systems as well as the various intake system options. Both reports are provided as attachments to this report. Also attached is an assessment of alternative intake technologies for the Poseidon Resources Carlsbad Desalination Project (Poseidon Resources 2004). While this document duplicates some of the information in the WateReuse report on intake technologies it provides additional information on the types of site-specific factors considered in selecting an appropriate intake technology at a single location.

[1] California Department of Water Resources. Findings and Recommendations of the California Water Desalination Taskforce. October 2003.

This report will provide a brief overview of desalination plant operations followed by a brief review of the various intake technologies that will rely on the more detailed information provided in the attached reports.

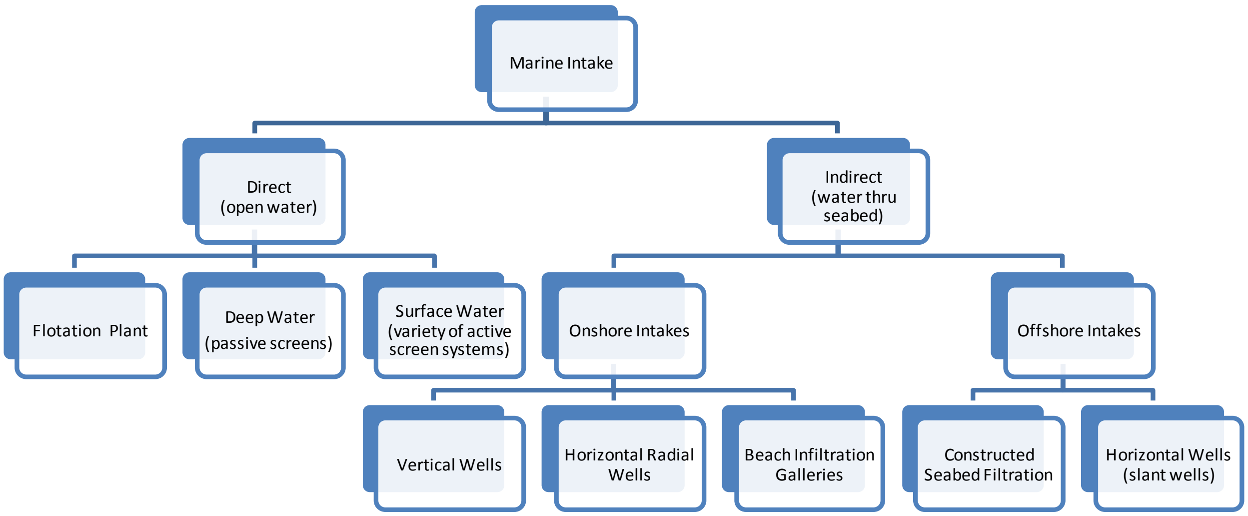


Figure 1. Flow chart showing various options for desalination plant ocean intakes. Adapted from presentation by Tom Pankratz, Global Overview of Seawater Desalination Intake Issues at Alden Desalination Intake Solutions Workshop, 16 October 2008.

Desalination Plant Operations

The most common desalination technology in plants being proposed in California is membrane reverse osmosis where pressure is used to force seawater through a membrane removing contaminants, particles, and salt. The percent of seawater converted to fresh water during the desalination process is known as plant recovery. Typically, seawater desalination plants are designed to recover 45 to 55% of the seawater collected by the intake. In addition to the seawater used for the production of fresh water, additional intake water may be needed as backwash for source water pretreatment systems and to dilute the concentrated seawater generated during the salt separation process down to acceptable salinity levels before it is discharged to the ocean.

The amount of additional intake seawater required depends on the type of intake and discharge system and the quality of the intake water. Most desalination plants increase their intake volume an additional 4 to 10% relative to the combined production and membrane reject volumes to wash their pretreatment filtration systems and discharge the filter backwash water back to the ocean. This volume can be reduced if the intake water has very low levels of suspended solids that need to be removed prior to entering the reverse osmosis process. Plants with low quality intake water may require multiple levels of pretreatment and greater volumes of intake water.

Collecting additional seawater for dilution of the concentrated seawater from the reverse osmosis process may be needed when the existing outfall volume is not sufficient to produce adequate dilution of the discharge. This additional intake flow could be eliminated by designing discharge diffuser systems that allow for rapid mixing and dilution of the discharge in the ocean and by co-locating desalination plants at locations with existing discharges such as power plants with warm water discharges and public-owned treatment facilities.

Desalination Plant Intake Systems

Desalination plants using both direct and indirect intake systems (**Figure 1**) have been proposed and are operating in California. In general, larger capacity desalination plants have been designed to use direct open ocean intakes with several of these plants being proposed for co-location at power plants with operating intake and discharge systems that would also be utilized by the desalination plant, although the recent California State Policy on the use of ocean and estuarine waters for power plant cooling[2] make co-location unlikely to be proposed on future plants. The intakes for power plants use active screening technology that largely is designed to remove debris that could clog the plants' condenser tubes. Therefore, new intake technologies that use passive screening systems such as cylindrical wedgewire screen (WWS) have only recently undergone testing in California in a few locations. Flotation plant intakes will not be discussed as these are not relevant to the types of desalination plants proposed for California (**Figure 1**).

Direct Open Water Intake Systems

Passive Screening Intake Systems

Passive screening systems could, by definition, include any intake screen that does not incorporate rotation or other movement to remove accumulated debris and includes many technologies that have been used at other intake locations but not necessarily at desalination plants. Passive screening system include the following technologies:

- Aquatic filter barriers (e.g., Gunderboom);
- Barrier nets;
- Porous dikes;
- Filtrex candles;
- Cylindrical wedgewire screen modules; and
- Wedgewire or other screen panels.

[2] Statewide Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling. California Water Resources Control Board, October 1, 2010.

A thorough review of all of these technologies is beyond the scope of this report, but information on some of these technologies is provided in the proceedings from a symposium sponsored by the EPA in 2003.[3] While several new intake designs based on wedgewire screens (WWS) have been used in many locations, including the Sacramento – San Joaquin Delta[4], the following text describes testing and analysis of cylindrical WWS that has been proposed for use at several locations in California. Desalination plants using WWS are in operation in other parts of the world such as the Beckton SWRO Plant in London, England with an intake volume of 150,000 m^3 per d (40 mgd).

Pilot-scale testing of WWS was conducted in 2005–2006 for the Marin Water District in San Francisco Bay and also in 2009–2010 for a proposed desalination plant for the Santa Cruz and Soquel Creek Water Districts. The following results of the Santa Cruz studies demonstrated the feasibility of using WWS for open coastal intakes:

- The turbulence in the shallow nearshore environment where the intake was located seemed to eliminate the need for an air burst or other system to remove impinged material from the surface of the screen;
- The smooth surface of the screen, turbulence, and low intake velocity through the screen slots (less than 0.15 mps [0.5 fps]) reduced or eliminated impingement on the screen; and
- The copper-nickel alloy used in the construction of the screen was effective at almost eliminating any biofouling growth on the screen.

The efficiency of the 2 mm (0.8 in) WWS module (**Figure 2**) at reducing entrainment was evaluated by sampling monthly over a 13-month period from April 2009 through May 2010. During most of these 24-hour surveys, four plankton samples were collected from the screened intake and four from the unscreened intake with half of the samples collected during the day and half at night. The WWS intake module was sized to ensure a maximum through-screen velocity of 0.1 mps (0.33 fps).

The study results did not detect any difference in entrainment concentrations between the screened and unscreened intakes. The statistical power to detect any differences that may have existed was very low due to the small numbers of samples collected, the low concentrations of fish larvae, and the variability in species composition and length of time between monthly sampling events. Also the sampling was not done at the same time from both intakes and as a result the samples from the screened and unscreened intakes had to be averaged for each sampling period further increasing the variability and decreasing the ability to detect any differences. The sampling should have been designed to take samples simultaneously from both intakes allowing them to be treated as paired samples.

[3] U.S. Environmental Protection Agency. 2005. Proceedings Report: A Symposium on Cooling Water Intake Technologies to Protect Aquatic Organisms. May 6-7, 2003, Arlington, Virginia. EPA 625-C-05-002, March 2005. Available at http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/symposium_index.cfm#who.

[4] See examples at http://intakescreensinc.com/projects/.

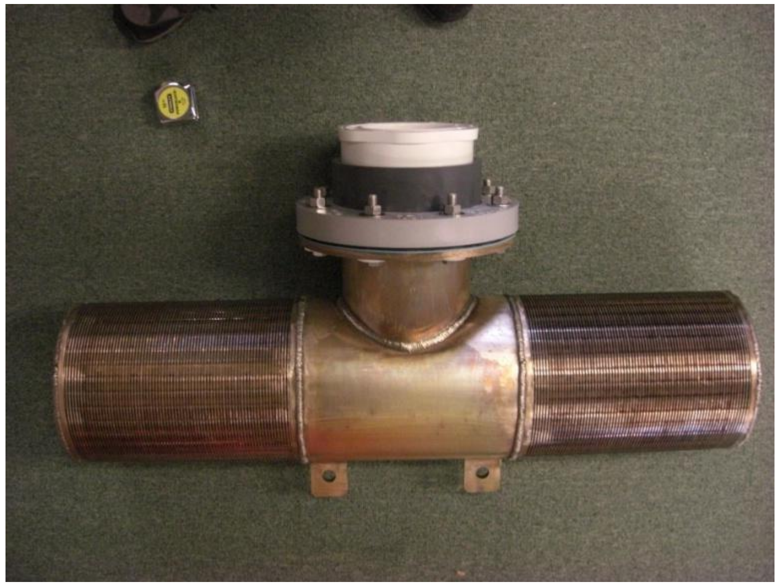
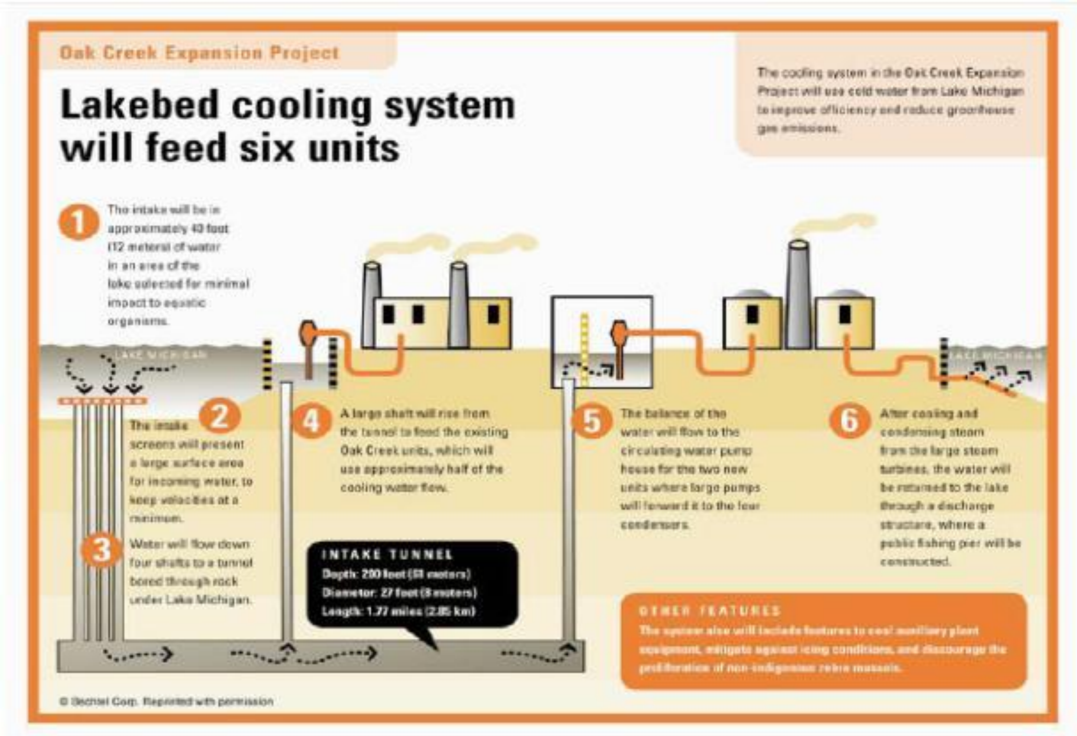


Figure 2. Wedgewire screen module used in testing during studies for Santa Cruz and Soquel Creek Water Districts in 2009 and 2010. The screen had a slot width of 2 mm (0.8 in) and was sized to ensure a maximum through screen velocity of 0.1 mps (0.33 fps).

Although there were not any differences detected between the WWS and the unscreened intake, results did show the potential for WWS as a technology that could potentially eliminate impingement of larger juvenile and adult fishes. This characteristic of WWS has been recognized and has been used to justify its installation for projects such as the Wisconsin Energy Oak Creek Power Plant Expansion Project where an intake equipped with WWS was located at a depth of 12 m (40 ft) in Lake Michigan (**Figure 3**). The rationale for the intake relocation was largely based on the reduction in impingement at depth relative to the previous surface water intake system as the 9 mm (0.35 in) slot width on the screens resulted in very limited levels of entrainment reduction. Examples such as Oak Creek show that the most important rationale for the use of WWS is to reduce or eliminate impingement of larger juvenile and adult fishes that have much greater value to fish populations than early stage larvae that experience very high rates of natural mortality. These larger fishes have greater value since they are either at or near the stage where they are reproductive and directly contributing to the population.

The same logic used for the Oak Creek facility for using WWS to reduce or eliminate impingement of juvenile and adult fishes will also need to be applied in the evaluation of WWS in California since even slot openings as small as 1.0 mm (0.04 in) will only screen out larger larvae. Although the eggs (**Table 1**) and newly hatched larvae of most species will still be entrained, WWS has the potential to reduce entrainment effects to older, larger larvae that have a higher probability of reaching maturity.

a)



b)

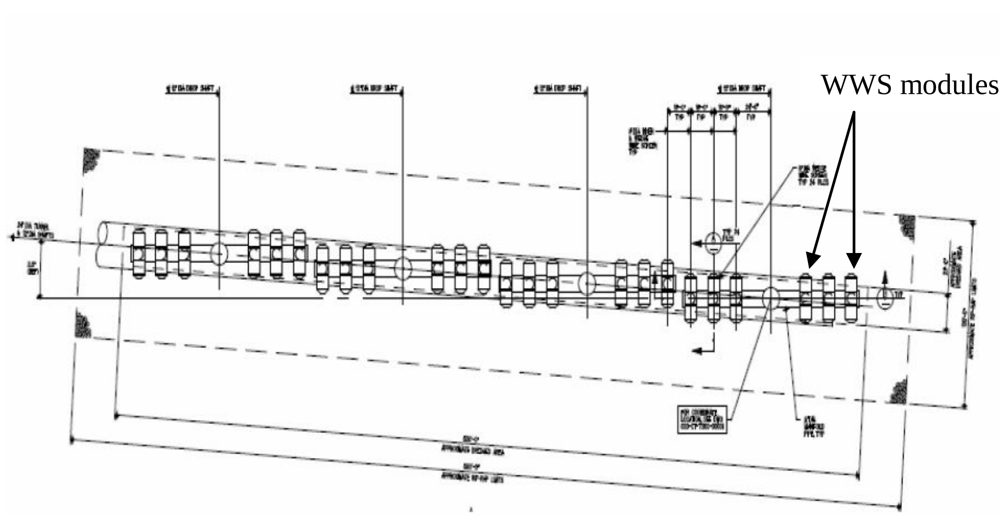


Figure 3. Diagrams of a) intake system at Oak Creek Power Plant, a 1,230 MW coal-fueled plant on the Wisconsin shoreline of Lake Michigan with a total intake capacity of 1,560,000 gpm or 2.2 billion gallons per day, and b) layout of 24-8 ft (2.4 m) diameter by 35 ft (10.7 m) long WWS modules using a slot width of 0.35 in (9mm). From Lee, D. 2008. Oak Creek Power Plant Expansion Project Offshore Wedge-wire Screen Intake, Presentation at Alden Desalination Intake Solutions Workshop, 16 October 2008.

Modeling of the theoretical reduction in entrainment of fish larvae for WWS based on the dimensions of the head capsule was done using data from recent 316(b) studies in southern California. Statistical relationships between body length and the width and depth of the head capsule for several of the most abundant species of fish larvae were determined and used to estimate the proportion of larvae potentially protected from being entrained based on the distribution of the lengths of fish larvae collected. Results varied by species depending on the size of the larvae for each species, the sizes collected (all small or across a broader range of lengths), and the differences in head dimensions. Results for northern anchovy and CIQ goby-complex (a species group comprised of *Clevelandia, Ilypnus,* and *Quietula*) are presented as they are two of the most abundant larvae collected in California (**Table 2**). Based on head capsule dimensions, all of the northern anchovy less than 8 mm (0.32 in) in length (74.5 % of the total) and all the CIQ gobies less than 6 mm (0.24 in) (92.2% of the total) would be entrained. While only 13.5 and 3.1% of the northern anchovy and CIQ goby larvae, respectively, were estimated to be excluded from entrainment by a 1.0 mm (0.04 in) WWS, the overall effect of reducing the entrainment of the larger larvae would have still resulted in 74.8 and 39.9%, respectively, of the age-1 equivalents that would have survived if no entrainment of larvae had occurred.

As the results for northern anchovy and CIQ gobies show, it is only necessary to eliminate entrainment of the larger larvae to provide substantial benefits to the population. The results of the modeling exercise likely underestimate the actual efficiency of cylindrical WWS modules which will have flow across the surface of the screen that should substantially reduce entrainment of larvae that may pass through the slot openings if they approached the screen surface either head or tail first. The studies described below that are currently underway at the West Basin Municipal Water District's (WBMWD) pilot desalination plant in Redondo Beach should help determine the operating efficiency of WWS screens. The number of WWS screen modules used for a facility would ensure that the flow through the slot openings is less than 0.15 mps (0.5 fps) to reduce impingement and help organisms move along the screen surface.

As mentioned above, the other evaluation of WWS currently underway in California is the intake for the WBMWD pilot desalination plant in Redondo Beach. The design of this study separates the modeling of entrainment impacts from the testing of WWS efficiency. As the pilot testing at Santa Cruz showed, variability in composition and abundance of fish larvae with the monthly sampling used for modeling of entrainment impacts effects makes it very difficult to detect differences due to the WWS. As the modeling of WWS efficiency indicates, the differences between screened and unscreened intakes may be less than 10%, which is a very small effect to detect even under controlled laboratory conditions. As a result, the study in Redondo Beach incorporates a separate sampling effort to test the efficiency of the 1 mm (0.04 in) and 2 mm (0.08 in) WWS modules used as intakes for the desalination plant. During the spring of 2012 when larval concentrations are at their highest, 40 to 60 paired samples will be collected from the WWS modules and compared with samples collected from an unscreened intake.

The results of the West Basin studies should provide the information necessary to more fully evaluate the effectiveness of WWS and its potential as a technology to reduce the effects of water withdrawals by desalination plant intakes. The potential for WWS to eliminate the effects of impingement of juvenile and adult fishes and the entrainment of larger, older larvae would provide substantial benefits to fish populations when compared with existing power plant intakes that result in impingement and entrainment of all life stages of fish.

Table 1. Diameter (mm) of entrained fish eggs at southern California power plants. Information largely from Moser (1996).

Family	Taxa	Common Name	Egg Diameter Range (mm)
Clupeidae	*Sardinops sagax*	Pacific sardine	1.3 - 2.1
Engraulidae	Engraulidae unid.	anchovies	0.7 - 0.8 x 1.2 - 1.5
Serranidae	*Paralabrax* spp.	sand and kelp basses	0.8 - 1.0
Haemulidae	*Xenistius californiensis*	salema	0.7 - 1.0
Sciaenidae	Sciaenidae unid.	croakers	0.7 - 1.3
Sciaenidae	*Atractoscion nobilis*	white seabass	1.2 - 1.3
Sciaenidae	*Cheilotrema saturnum*	black croaker	0.8 - 0.9
Sciaenidae	*Genyonemus lineatus*	white croaker	0.8 - 0.9
Sciaenidae	*Roncador stearnsi*	spotfin croaker	0.7 - 0.8
Sciaenidae	*Seriphus politus*	queenfish	0.7 - 0.8
Sciaenidae	*Umbrina roncador*	yellowfin croaker	0.7 - 0.8
Kyphosidae	*Girella nigricans*	opaleye	1.0 - 1.1
Labridae	*Oxyjulis californica*	senorita	0.7 - 0.8
Labridae	*Semicossyphus pulcher*	California sheephead	0.8
Sphyraenidae	*Sphyraena argentea*	Pacific barracuda	1.0 - 1.4
Scombridae	*Scomber japonicus*	Pacific mackerel	0.8 - 1.3
Pleuronectiformes	Pleuronectiformes unid.	flatfishes	0.6 - 3.1
Paralichthyidae	Paralichthyidae unid.	sand flounders	0.6 - 0.9; 1.2 - 1.4
Paralichthyidae	*Citharichthys* spp.	sanddabs	0.6 - 0.8
Paralichthyidae	*Paralichthys californicus*	California halibut	0.7 - 0.8
Pleuronectidae	*Microstomus pacificus*	Dover sole	2.1 - 2.7
Pleuronectidae	*Parophrys vetulus*	English sole	0.8 - 1.1
Pleuronectidae	*Pleuronichthys* spp.	turbots	0.8 - 2.1
Pleuronectidae	*Pleuronichthys guttulatus*	diamond turbot	0.8 - 0.9

Table 2. Theoretical reductions in entrainment by a 1 mm (0.04 in) WWS screen for different lengths of a) northern anchovy, and b) CIQ-complex (*Clevelandia*, *Ilypnus*, and *Quietula*) larvae based on head capsule dimensions. The proportions within each length category are based on the distribution of larvae collected at power plants in the southern California bight. The age-1 equivalents resulting from each length category were calculated using an adult equivalent model using stage specific survivals from Butler et al. (1993) for northern anchovy and Brothers (1975) for CIQ gobies.

a) northern anchovy

Length (mm)	Proportion Entrainment by Length	Estimated Entrainment by Length	Age 1 Equivalents	Age 1 Equivalents per larva	Proportion Excluded by 1.0 mm Mesh	Entrainment w 1.0 mm Mesh	Larvae Protected By Size Class	Percentage Protected	Resulting Age 1 Equivalents
<8	0.7451	74,512,535	8,085	0.0001	0.0000	74,512,535	0	0.0%	0
8-9	0.0237	2,367,688	2,971	0.0013	0.0201	2,320,204	47,484	2.0%	60
9-10	0.0334	3,342,618	7,432	0.0022	0.0790	3,078,521	264,097	7.9%	587
10-11	0.0348	3,481,894	13,717	0.0039	0.2012	2,781,255	700,639	20.1%	2,760
11-12	0.0265	2,646,240	18,471	0.0070	0.3758	1,651,885	994,355	37.6%	6,941
12-13	0.0209	2,089,136	16,838	0.0081	0.5633	912,311	1,176,825	56.3%	9,485
13-14	0.0306	3,064,067	28,515	0.0093	0.7250	842,612	2,221,455	72.5%	20,673
14-15	0.0153	1,532,033	16,462	0.0107	0.8423	241,550	1,290,483	84.2%	13,867
15-16	0.0084	835,655	10,368	0.0124	0.9166	69,673	765,981	91.7%	9,504
16-17	0.0153	1,532,033	21,948	0.0143	0.9588	63,086	1,468,947	95.9%	21,044
17-18	0.0097	974,930	16,127	0.0165	0.9808	18,727	956,203	98.1%	15,817
18-19	0.0056	557,103	10,641	0.0191	0.9915	4,761	552,342	99.1%	10,550
>=19	0.0306	3,064,067	67,574	0.0221	1.0000	0	3,064,067	100.0%	67,574
Totals	**1.0000**	**100,000,000**	**239,149**			**86,497,121**	**13,502,879**		**178,861**
							Total Reduction		**74.8%**

b) CIQ goby complex

Length (mm)	Proportion Entrainment by Length	Estimated Entrainment by Length	Age 1 Equivalents	Age 1 Equivalents per larva	Proportion Excluded by 1.0 mm Mesh	Entrainment w 1.0 mm Mesh	Larvae Protected By Size Class	Percentage Protected	Resulting Age 1 Equivalents
<6	0.9220	92,199,517	441,962	0.0048	0.00	92,199,517	0	0.0%	0
6-7	0.0277	2,768,622	36,031	0.0130	0.03	2,689,858	78,765	2.8%	1,025
7-8	0.0134	1,340,365	28,742	0.0214	0.16	1,123,309	217,056	16.2%	4,654
8-9	0.0103	1,032,740	33,976	0.0329	0.43	587,503	445,237	43.1%	14,648
9-10	0.0070	703,142	35,491	0.0505	0.71	203,202	499,940	71.1%	25,235
10-11	0.0048	483,410	40,204	0.0832	0.89	53,911	429,499	88.8%	35,720
11-12	0.0035	351,571	44,860	0.1276	0.97	11,969	339,602	96.6%	43,333
12-13	0.0044	439,464	86,033	0.1958	0.99	3,774	435,690	99.1%	85,295
>=13	0.0068	681,169	146,921	0.2157	1.00	0	681,169	100.0%	146,921
Totals		**100,000,000**	**894,221**			**96,873,043**	**3,126,957**		**356,831**
							Total Reduction		**39.9%**

Active Screening Intake Systems

Due to the development of new regulations for 316(b) issues in the U.S. a large variety of active screening systems are available and several have undergone testing. Some of the systems available include the following:

- Traveling screens fitted with fine mesh and Ristroph fish return trays;
- Beaudrey fine mesh WIP screens with fish return;
- Passavant-Geiger multi-disc screens;
- Eicher screens;
- Dual-flow traveling screens systems;
- Modular inclined screens;
- Drum screens; and
- Other modified screens and hybrid technologies.

Reviews of some of these technologies are provided in the proceedings from a symposium sponsored by the EPA in 2003.[5] Several of these active screening systems have been thoroughly reviewed as alternative intake designs for power plants as a means to reduce the effects of impingement and entrainment. All of the coastal power plants in California utilize active screening systems, which are conventional rotating traveling screens with a mesh size of 0.95 to 1.3 cm ($^3/_8$ to $^1/_2$ in). None of the plants have screens that are fitted with a fish return system, although the San Onofre Nuclear Generating Station (SONGS) does have a fish elevator that lifts fish out of the plant's forebay before they become impinged.

A thorough review of these systems is beyond the scope of this report, but the technology reviews conducted as part of the considerations for compliance at the coastal power plants in California provide information on the site-specific issues affecting the use of a specific technology at a facility.

Indirect Intake Systems

Several different indirect or subsurface intake systems (vertical and horizontal directionally drilled [HDD] wells, slant wells, and infiltration galleries) have been proposed and used for desalination plants. An overview of these intake technologies is presented in the attached WateReuse report (2011b). Although subsurface intakes are considered a low-impact technology in terms of impingement and entrainment, there have been no studies that document the actual level of entrainment reduction that can be achieved by these types of intakes. In addition, the potential application of a subsurface intake is very site specific and highly dependent on the

[5] U.S. Environmental Protection Agency. 2005. Proceedings Report: A Symposium on Cooling Water Intake Technologies to Protect Aquatic Organisms. May 6-7, 2003, Arlington, Virginia. EPA 625-C-05-002, March 2005. Available at http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/symposium_index.cfm#who.

project size, the coastal aquifer geology (aquifer soils, depth, transmissivity, water quality, capacity, etc.), the intensity of the natural beach erosion in the vicinity of the intake site, and many other environmental and socioeconomic factors. The consideration of these factors related to a specific project are described in detail in the attached alternatives intake analysis prepared as part of the permitting of the Poseidon Resources Carlsbad Seawater Desalination Project (Poseidon Resources 2004).

Because optimal conditions for subsurface intakes are often impossible to find in the vicinity of the desalination plant site, the application of this type of intake technology to date worldwide has been limited to plants of relatively small capacity. As indicated in WateReuse report (2011b), the largest seawater desalination facility with a subsurface intake in operation at present is the Pedro Del Pinatar (Cartagena) desalination plant in Spain where the first 64,000 m^3 per d (17 mgd) phase of the project used subsurface HDD wells. Site-specific hydrogeological constraints made it impossible to use similar intake wells for plant expansion, and the second 64,000 m^3 per d (17 mgd) phase of this project was constructed with an open intake. Another example of a larger facility with an indirect intake is the Fukuoka plant in Japan that has an intake volume of 103,000 m^3 per d (27.2 mgd) and uses a large constructed infiltration gallery with an area of 20,000 m^2 (4.9 acres) in the shallow nearshore ocean waters at a depth of 11.5 m (38 ft). There have been challenges in operating this intake system.

The use of indirect or subsurface intake systems will likely be restricted to very site-specific application or low volume plants due to the high construction and maintenance costs, operational challenges, and uncertainty in using these intake designs for larger capacity desalination plants. The potential environmental effects of these intakes are largely unknown. There are likely to be impacts on later stage fish larvae for species that settle to the bottom to complete development (Jahn and Lavenberg 1986).

Summary

A large variety of intake technologies are available for desalination plants. The selection of a specific technology will require the consideration of numerous factors and a site-specific assessment, as recommended by the State Desalination Taskforce.[6]

Literature Cited

Brothers, E. B. 1975. The comparative ecology and behavior of three sympatric California gobies. Ph.D. Dissertation, Univ. Calif. San Diego. 370 p.

[6] California Department of Water Resources. Findings and Recommendations of the California Water Desalination Taskforce. October 2003.

Butler, J. L., P.E. Smith, and N. C. H. Lo. 1993. The effect of natural variability of life-history parameters on anchovy and sardine population growth. CalCOFI Rep. 37:152−159.

Poseidon Resources. 2004. Carlsbad Seawater Desalination Project Alternatives to the Proposed Intake. Appendix C of Final EIR to the California Coastal Commission, March 2, 2004.

WateReuse Association. 2011a. Desalination Plant Intakes: Impingement and Entrainment Impacts and Solutions. Electronic copy available at www.watereuse.org/information-resources/desalination/resources.

WateReuse Association. 2011b. Overview of Desalination Plant Intakes Alternatives. Electronic copy available at www.watereuse.org/information-resources/desalination/resources.

Attachments

Attachment 1: WateReuse Association. 2011a. Desalination Plant Intakes: Impingement and Entrainment Impacts and Solutions. Electronic copy available at www.watereuse.org/information-resources/desalination/resources.

Attachment 2: WateReuse Association. 2011b. Overview of Desalination Plant Intakes Alternatives. Electronic copy available at www.watereuse.org/information-resources/desalination/resources.

Attachment 3: Poseidon Resources. 2004. Carlsbad Seawater Desalination Project Alternatives to the Proposed Intake. Appendix C of Final EIR to the California Coastal Commission, March 2, 2004.

Attachment 1: WateReuse Association. 2011. Desalination Plant Intakes: Impingement and Entrainment Impacts and Solutions.

WATEREUSE ASSOCIATION

Sustainable Solutions for a Thirsty Planet™

Desalination Plant Intakes

Impingement and Entrainment Impacts and Solutions

White Paper

The WateReuse Desalination Committee's White Papers are living documents. The intent of the Committee is to enhance the content of the papers periodically as new and pertinent information on the topics becomes available. Members of the desalination stakeholder community are encouraged to submit their constructive comments to Josh Dickinson at jdickinson@watereuse.org and share their experience and/or case studies for consideration for inclusion in the next issuance of the white papers.

WATEREUSE ASSOCIATION
DESALINATION COMMITTEE

Desalination Plant Intakes – Impingement and Entrainment Impacts and Solutions

White Paper

INTRODUCTION

Seawater intakes are an integral part of every seawater desalination plant. The purpose of this white paper is to provide an overview of potential impingement and entrainment (I&E) impacts associated with the operation of open ocean intakes for seawater desalination plants and to discuss alternative solutions for efficient and cost effective I&E reduction. For information on alternative intakes for seawater desalination plants, refer to the WateReuse Association's white paper titled "Overview of Desalination Plant Intake Alternatives."

WHAT IS IMPINGEMENT AND ENTRAINMENT?

As with any other natural surface water source currently used for fresh water supply around the globe, seawater contains aquatic organisms (algae, plankton, fish, bacteria, etc.). *Impingement* occurs when organisms sufficiently large to avoid going through the screens are trapped against them by the force of the flowing source water – i.e., algae, plankton and bacteria are not exposed to impingement. On the other hand *entrainment* occurs when marine organisms enter the desalination plant intake, are drawn into the intake system, and pass through to the treatment facilities.

Impingement typically involves adult aquatic organisms (fish, crabs, etc.) that are large enough to actually be retained by the intake screens, while entrainment mainly affects aquatic species small enough to pass through the particular size and shape of intake screen mesh. Impingement and entrainment of aquatic organisms are not unique to open intakes of seawater desalination plants only. Conventional open freshwater intakes from surface water sources (i.e., rivers, lakes, estuaries) may also cause measurable impingement and entrainment.

A third term, "*entrapment*," is then used when describing impacts associated with offshore intake structures connected to an on-shore intake screen and pump station via long conveyance pipeline or tunnel. Organisms that enter the offshore intake and cannot swim back out of it are often referred to as entrapped[1]. Such marine organisms could either be impinged on the intake screens or entrained if they pass through the screens and enter the downstream facilities of the desalination plant.

[1] http://www.waterlink-international.com/download/whitepaper_uploadfile_21.pdf

Attention to seawater intake impingement and entrainment issues is partially prompted by the Section 316(b) of the 1972 Clean Water Act that regulates cooling water intake of the steam electric industry by the environmental scrutiny associated with the public review process of desalination projects in California.

MAGNITUDE OF ENVIRONMENTAL IMPACTS

The magnitude of environmental impacts on marine organisms caused by impingement and entrainment of seawater intakes is site specific and varies significantly from one project to another. Open ocean intakes are typically equipped with coarse bar screens (Figure 1), which typically have openings between the bars of 20 mm to 150 mm followed by smaller-size ("fine") screens with openings of 1 mm to 10 mm (Figure 2), which preclude the majority of the adult and juvenile marine organisms (fish, crabs, etc.) from entering the desalination plants. While coarse screens are always stationary, fine screens could be two types – stationary (passive) and periodically moving (i.e., rotating) screens. Figure 2 depicts a 3-mm rotating fine screen. Most marine organisms collected with the source seawater used for production of desalinated water are removed by screening and downstream filtration before this seawater enters the reverse osmosis desalination membranes for salt separation. After screening, the water is typically processed by finer filters for pretreatment of seawater, which typically have sizes of the filtration media openings (pores) between 0.01 microns to 0.2 microns for membrane ultra- and micro-filters and 0.25 to 0.9 mm for granular media filters.

Source: GHD

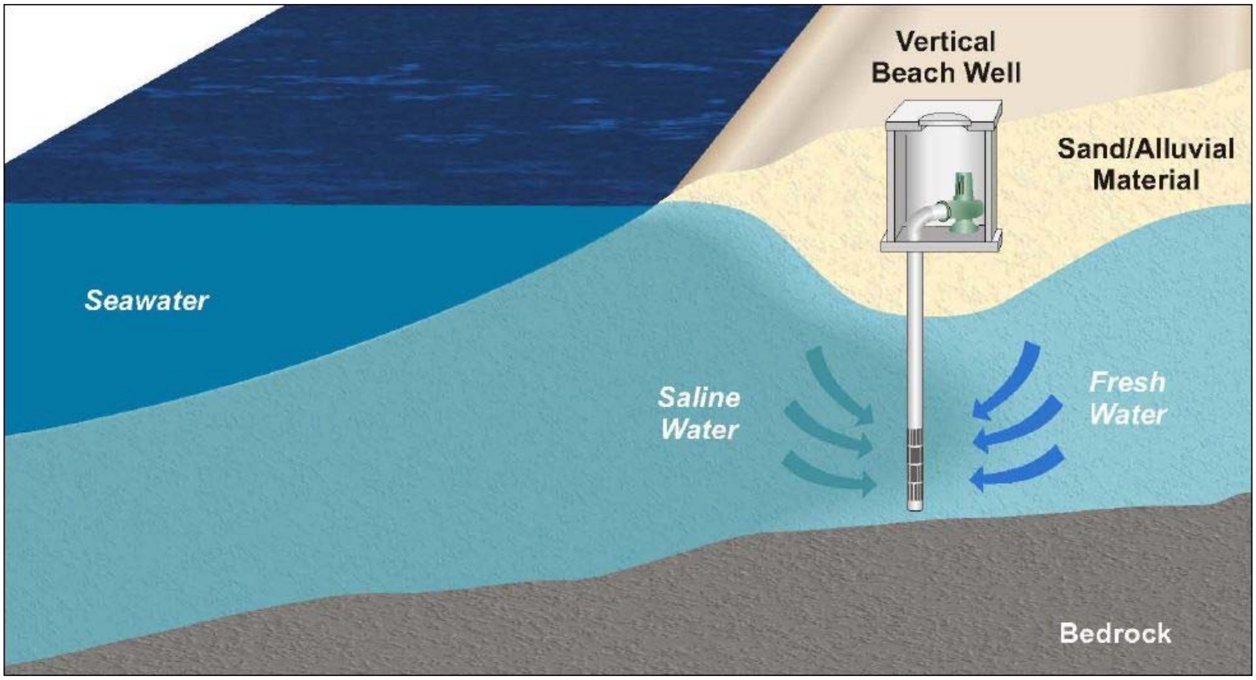
Figure 1 – Intake Bar Screen

Source: Water Globe Consulting

Figure 2 – Fine Intake Screen

By comparison, intake wells and infiltration galleries pre-filter aquatic life through the ocean bottom sediments. In this case, the ocean bottom provides a natural separation barrier for adult and juvenile marine organisms. Since subsurface intakes collect source seawater through the ocean bottom and coastal aquifer sediments (see Figure 3), they are not expected to exert an impingement type of impact on the marine species contained in the source seawater. However, the magnitude of potential entrainment of marine species into the bottom sediments caused by continuous subsurface intake operations is not well known and has not been systematically and scientifically studied to date. An ongoing side-by-side study of the I&E effects of a subsurface intake and an open ocean intake equipped with a passive wedgewire screen at the West Basin Municipal Water District's desalination demonstration plant is expected to provide more detailed information on this topic[2].

[2] http://www.watereuse.org/node/978



Source: Kennedy/Jenks Consultants

Figure 3 – Subsurface Intake Schematic

A comprehensive multi-year impingement and entrainment assessment study of the open ocean intakes of 19 power generation plants using seawater for once-through cooling completed by the California State Water Resources Control Board in 2010 provides important insight into the magnitude of these intake-related environmental impacts[3]. Based on this study, the estimated total average annual impingement of fish caused by the seawater intakes varied between 0.31 pounds (lbs.) per million gallons a day (MGD) of collected seawater (Diablo Canyon Power Plant) and 52.29 lbs./MGD (Harbor Generating Station); and for all 19 plants it averaged 6.63 lbs./MGD. Taking into consideration that this amount is the total annual impact, the average daily impingement rate is estimated to be 0.018 lbs./MGD of intake flow (6.63 lbs./365 days = 0.018 lbs./MGD).

Using the California State Water Resources Control Board impingement and entrainment study results as a baseline, for a large desalination plant of 50 MGD production capacity collecting 110 MGD of intake flow, the daily **impingement impact** is projected to be **2 lbs. per day** (0.018 lbs./MGD x 110 MGD = 2 lbs./day). This impingement impact is less than the daily food intake of **one pelican** – up to 4.0 lbs./day[4]. The comparison illustrates the fact that the impingement impact of seawater desalination plants with open ocean intakes is not significant and would not have measurable impact on natural aquatic resources (Figure 4).

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[3] http://www.watereuse.org/sites/default/files/u8/Quote 3.pdf
[4] http://www.sandiegozoo.org/animalbytes/t-pelican.html

Source: US Fish and Wildlife Service

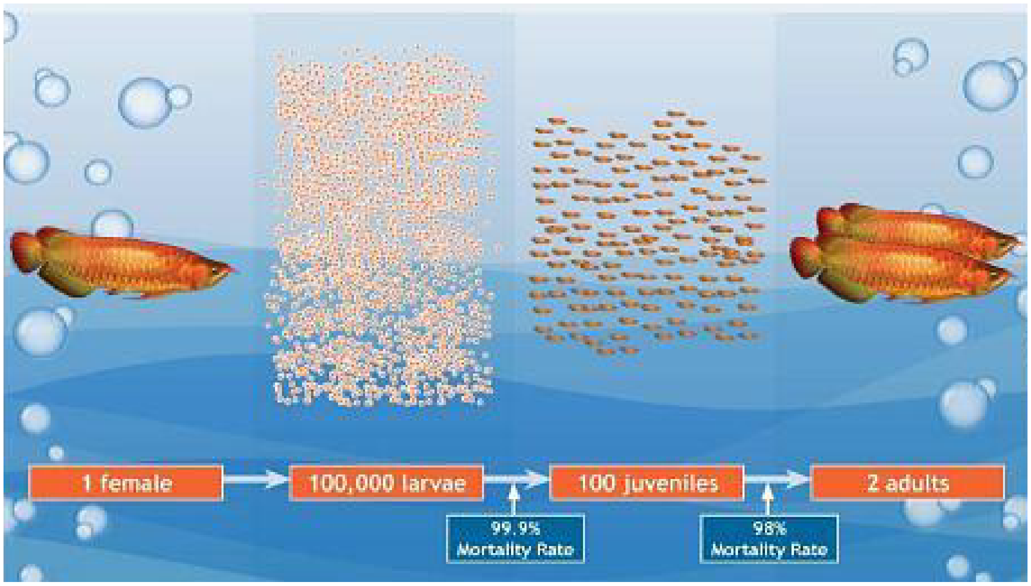
Figure 4 – Average Daily Desalination Intake Impingement Impact Is Less than the Daily Fish Intake of One Pelican

The California State Water Resources Control Board report mentioned earlier also gives a baseline for assessment of the entrainment impact of seawater intakes. The study indicates that the magnitude of such annual impact on larval fish can vary in a wide range – from 0.08 million (MM)/MGD (Contra Costa Power Plant) to 5.8 MM/MGD (Encina Power Plant) and illustrates the fact that the entrainment impact is very site-specific.

As per the same report, the average annual entrainment is estimated at 2.14 million of fish larvae per MGD of intake flow. Prorated for a 110 MGD intake of a 50 MGD seawater desalination plant, this annual entrainment impact is 235.4 MM of larval fish/yr. While this number seems large, based on expert evaluation and research, large entrainment numbers do not necessarily equate to a measurable impact to adult fish populations because of the enormous amount of eggs, fish larvae and other zooplankton in seawater[5]. Due to the large natural attrition of larval fish, very few larval fish actually develop to juvenile and adult stages in the natural environment (see Figure 5)[6]. The majority of larvae are lost to predation, exposure to destructive forces of nature such as wind and wave action, and the inability to find appropriately-sized pray during the

[5]http://www.swrcb.ca.gov/water_issues/programs/ocean/cwa316/docs/workshop_oakland2005/pres_tenera.pdf
[6] http://www.scwd2desal.org/documents/Presentations/Nov_10_2010/02_Tenera_nov10_web.pdf

critical period of their development (i.e., after their yolk sack is empty). All of these forces have several orders of magnitude higher impact on fish populations than seawater intakes.



Source: Tenera Environmental

Figure 5 – Typical Reproduction and Survival of Larval Producing Organisms

For example, a single female halibut produces as many as 50 million eggs per year for as long as 20 years, or one billion eggs over a lifetime[7]. In simple terms, the annual entrainment impact of one **50 MGD** desalination plant would be comparable to the annual bio-productivity of **five adult female halibut fish** (i.e., the "environmental impact" which five fishermen can cause with their daily halibut catch quota of one fish each).

The environmental impact of desalination plant operations should be assessed in the context of the environmental impacts of water supply alternatives that may be used instead of desalination. Desalination projects are typically driven by the limited availability of alternative lower-cost water supply resources such as groundwater or fresh surface water (rivers, lakes, etc.). However, damaging long-term environmental impacts may also result from continued over-depletion of those conventional water supplies, including inter-basin water transfers. For example, over-pumping of fresh water aquifers over the years in a number of areas worldwide (i.e., the San Francisco Bay Delta in Northern California; wetlands in the Tampa Bay region of Florida; and fresh water aquifers, and rivers and lakes in northern Israel and Spain, which supply water to sustain agricultural and urban centers in the southern regions of these countries), has resulted in substantial environmental impacts to the traditional fresh water resources in these regions. One

[7] http://www.watereuse.org/sites/default/files/u8/Quote%207%20-%20Presentation.pdf

such specific example of dramatic environmental impact is the reduction of the habitat of delta smelt as a result of over-pumping caused by California State Water Project's intake facilities.[8]

Such long-term fresh water transfers have affected the ecological stability in the fresh water habitats to the extent that the long-term continuation of current water supply practices may result in significant and irreversible damage of the ecosystems of traditional fresh water supply sources and even the intrusion of saline water into the freshwater aquifers, such as the case in Salinas Valley, Monterey County, California. In such instances, the environmental impacts of construction and operation of new seawater desalination projects should be weighed against the environmentally damaging consequences from the continued expansion of the existing fresh-water supply practices.

A responsible approach to water supply management must ensure that sustainable and drought-proof local supplies are available, and long-term reliance on conventional water supply sources (i.e., surface water, groundwater) is reconsidered in favor of a well-balanced and diversified water supply portfolio which combines surface water, groundwater, recycled water, water conservation, and desalination. For example, this type of reliability-driven, balanced water supply program is currently implemented by West Basin Municipal Water District (www.westbasin.org), the Texas Water Development Board, Tampa Bay Water, and other agencies in the United States.

IMPINGEMENT AND ENTRAINMENT SOLUTIONS

While impingement and entrainment associated with seawater intake operations are not expected to create biologically significant impacts under most circumstances, best available ***site***, ***design***, ***technology***, and when needed, ***mitigation measures***, are prudent for minimizing loss of marine life and maintaining the productivity and vitality of the aquatic environment in the vicinity of the intake.

Prudent Open Intake Design

Installation of Intake Inlet Structure Outside of the Littoral Zone

Intakes in the littoral zone (i.e., the near-shore zone encompassed by low and high tide levels) have the greatest potential to cause elevated impingement and entrainment impacts. The US EPA considers extending intakes 125 meters (410 feet) outside of the littoral zone a good engineering practice aimed at reduced impingement and entrainment[9]. According to the Office of Naval Research, the littoral zone extends 600 feet from the shore[10]. Thus, intakes with an inlet structure located at least 1100 feet from the shore could result in reduced environmental impacts. In addition, installing the intake to depths where there is a lower concentration of living organisms

[8] http://www.science.calwater.ca.gov/pdf/eco_restor_delta_smelt.pdf
[9] http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/phase1/upload/2009_04_02_316b_phase1_support_contents.pdf
[10] http://www.onr.navy.mil/focus/ocean/regions/littoralzone1.htm

(i.e., at least 20 meters) is also expected to decrease environmental impacts associated with intake operations.

Low Through-Screen Velocity

Impingement occurs when the intake through-screen velocity is so high that species such as crab or fish cannot swim away and are retained against the screens. The US EPA has determined that if the intake velocity is lower or equal to 0.5 feet per second (fps), the intake facility is deemed to have met impingement mortality performance standards[11]. Therefore, designing intake screening facilities to always operate at or below this velocity would adequately address impingement impacts.

Small-Size Bar Screen Openings

Use of bar screens with a distance between the exclusion bars of no greater than 9 inches is recommended for preventing large organisms from entering the seawater intake[12].

Suitable Fine Screen Mesh Size

After entering the bar screen, the seawater has to pass through fine screens to prevent debris from interfering with the downstream desalination plant treatment processes. The fine screen mesh size is a very important design parameter and should be selected such that it is fitted to the size of a majority of the larval organisms it is targeting to protect. Typically, the openings of most fine screens are 3/8 inch (9.5 mm) or smaller because most adult and juvenile fish are larger than 10 mm in head size.

Design Enhancements for Collection of Minimum Intake Flow

Membrane reverse osmosis desalination plants typically collect seawater for one or more of the following three purposes: (1) to use it as a source water for fresh water production; (2) to apply it as a backwash water for the source water pretreatment system; and (3) to pre-dilute concentrate generated during the salt separation process down to environmentally safe salinity levels before it is discharged to the ocean.

The percent of source seawater converted to fresh water during the desalination process is known as plant recovery. Typically, seawater desalination plants are designed to recover 45 to 55% of the seawater collected by the intake. Designing the desalination plant to operate closer to the upper limits of recovery (i.e., 50 to 55%) would require collecting less water and therefore, would reduce impingement and entrainment associated with seawater intake operations. Long-term testing completed by the Affordable Desalination Collaboration, aimed to identify the most suitable operational conditions for low-energy SWRO desalination, indicates that optimum

[11] http://edocket.access.gpo.gov/cfr_2008/julqtr/pdf/40cfr125.94.pdf
[12] http://www.watereuse.org/sites/default/files/u8/Quote%2012%20-%20Policy.pdf

energy consumption is achieved at a membrane flux of 9.0 gallons per square feet per day (gfd) and RO system recovery of 48%[13].

Most desalination plants collect 4 to 10% of additional water to wash their pretreatment filtration systems and discharge the spent filter backwash water back to the ocean. A design approach which may allow reducing this water use significantly is treatment and reuse of the backwash water. Such a backwash treatment and reuse approach has cost implications but is a prudent design practice aimed at reducing overall plant seawater intake flow and associated impingement and entrainment.

Collecting additional seawater for concentrate pre-dilution may be needed when existing wastewater intake or power plant outfalls are used for concentrate discharge and the existing outfall volume is not sufficient to produce adequate dilution of the saline discharge. This additional flow intake could be eliminated by designing facilities for storing concentrate during periods of low outfall flows when adequate dilution is not available, or by installing a discharge diffuser system which allows enhancing concentrate dissipation into the ambient marine environment without additional dilution.

If the desalination plant production capacity has to vary diurnally, the design and installation of variable frequency drives on the intake pumps could also allow decreasing impingement and entrainment of the plant intake by closely matching collected source seawater volume to the plant production needs.

Use of Low-Impact Intake Technologies

Impingement and entrainment of marine organisms could be minimized by using various subsurface and open intake technologies. Currently, there are no federal and state regulations which specifically define requirements for reduction of impingement and entrainment caused by desalination plant intakes. However, the US EPA Section 316(b) of the Clean Water Act federal regulations have stipulated national performance standards for intake impacts from power generation plants which require 80 to 95% reduction of impingement and 60 to 90% reduction of entrainment as compared to those caused by uncontrolled intake conditions[14]. Technologies that can meet these impingement and entrainment performance standards are defined by US EPA as Best Technology Available (BTA).

Subsurface Intakes

Subsurface intakes (vertical and horizontal directionally drilled wells, slant wells and infiltration galleries) are considered a low-impact technology in terms of impingement and entrainment. However, to date there are no studies that document the actual level of entrainment reduction that

[13] http://www.affordabledesal.com/home/news/ADC%20Completes%20Profile%20of%20SWRO%203-28-08.pdf
[14] http://edocket.access.gpo.gov/cfr_2008/julqtr/pdf/40cfr125.94.pdf

can be achieved by these types of intakes. In addition, the potential application of a subsurface intake is very site specific and highly dependent on the project size; the coastal aquifer geology (aquifer soils, depth, transmissivity, water quality, capacity, etc.); the intensity of the natural beach erosion in the vicinity of the intake site; and on many other environmental and socio-economic factors.

Because optimal conditions for subsurface intakes are often impossible to find in the vicinity of the desalination plant site, the application of this type of intake technology to date worldwide has been limited to plants of relatively small capacity. As indicated in WateReuse Association's White Paper titled "Overview of Desalination Plant Intake Alternatives,"[15] the largest seawater desalination facility with a subsurface intake in operation at present is the first 17 MGD phase of the 34 MGD San Pedro Del Pinatar (Cartagena) desalination plant in Spain. For this project, site-specific hydrogeological constraints made it impossible to use intake wells for plant expansion, and the second 17 MGD phase of this project was constructed with an open intake.

Ongoing long-term studies of innovative subsurface intakes in Long Beach and Dana Point, California are expected to provide comprehensive data that would allow completing a scientifically-based analysis of the viability and performance benefits of subsurface intakes for larger-size applications. The tested subsurface intake technologies are currently under evaluation and do not yet have established performance, reliability, and environmental track records.

Wedgewire Screen Intakes

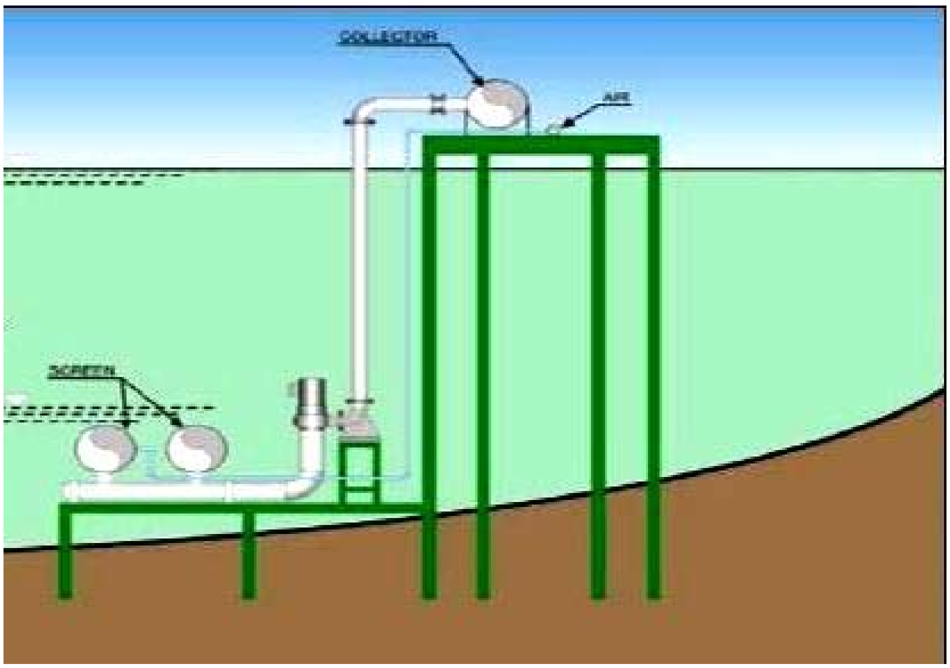
Wedgewire screens are cylindrical metal screens with trapezoidal-shaped "wedgewire" slots with openings of 0.5 to 10 mm. They combine very low flow-through velocities, small slot size, and naturally occurring high screen surface sweeping velocities to minimize impingement and entrainment. This is the only open intake technology approved by US EPA as Best Technology Available. Such approval, however, is granted provided that sufficient ambient conditions exist to promote cleaning of the screen face; the through screen design intake velocity is 0.5 feet/sec or less; and the slot size is appropriate for the size of eggs, larvae, and juveniles of any fish and shellfish to be protected at the plant intake site[16].

Wedgewire screens are designed to be placed in a water body where significant prevailing ambient cross flow current velocities (≥ 1 fps) exist. This high cross-flow velocity allows organisms that would otherwise be impinged on the wedgewire screen intake to be carried away with the flow.

[15] http://www.watereuse.org/node/1340
[16] http://edocket.access.gpo.gov/cfr_2006/julqtr/pdf/40cfr125.99.pdf

An integral part of a typical wedgewire screen system is an air burst back-flush system, which directs a charge of compressed air to each screen unit to blow-off debris back into the water body, where they are carried away from the screen unit by the ambient cross-flow currents.

Figure 6 presents a schematic of the wedgewire screen intake used at the 40 MGD Beckton desalination plant in London, England. The Beckton desalination plant is equipped with seven (7) 3-mm wedgewire screens installed on the suction pipe of each of the plant intake pumps. Total screen length is 11.55 ft. (3500 mm) and the screen diameter is 3.6 ft. (1100 mm). The plant intake is under significant influence of tidal exchange of river water and seawater. To capture the ebb tide and minimize entrainment, the intake adjusts as it also targets lower salinity waters.



Source: Acciona Agua

Figure 6 – Wedgewire Screen Intake of Beckton Desalination Plant

An I&E study of a cylindrical wedgewire screen (Figure 7) was conducted over a 13-month period from April 2009 through May 2010 by Tenera Environmental for a seawater desalination project currently under development by the City of Santa Cruz Water Department and Soquel Creek Water District in California[17]. The intake for the full-scale desalination project would be designed to collect of up to 7.0 MGD of source seawater in order to produce an average of 2.5 MGD of fresh drinking water.

[17] http://www.scwd2desal.org/documents/Reports/Open_Ocean_Intake_Effects/Open%20Ocean%20Intake%20Effects%20Study%20Final%20Dec%202010.pdf

The tested wedgewire screen had 2.0 mm of slot openings and was constructed of copper-nickel alloy. The diameter of the screen was 8-5/8 inches; the overall screen length was 35 inches; and the outer flange was 6-5/8 inches. Seawater was pumped from a depth of 15 to 20 feet beneath the sea surface.

Source: Tenera Environmental

Figure 7 – Wedgewire Screen Used in Santa Cruz I&E Study

The results of this comprehensive I&E study indicate that:

- No endangered, threatened, or listed species were entrained.
- At an average intake velocity of 0.33 fps, the screen was successful in completely eliminating impingement.
- The wedgewire prevented entrainment of adult and juvenile fish species.
- The greatest projected proportional mortality that could be attributed to the screen operation for the top 80% of the fish larvae in the source water area at 7.0 MGD intake flow was 0.06%.
- The greatest projected proportional mortality for the caridean shrimp and cancrid crab larvae in the source water area for 7.0 MGD intake flow was 0.02%.
- The extremely low proportional losses of fish, shrimp and crab populations indicate that the full-scale wedgewire intake screen operation at 7.0 MGD will not cause significant

environmental impact considering that the natural mortality rates of these species are over 99.9%.

- The absolute numbers of larvae projected to be entrained annually due to the collection of 7.0 MGD of source seawater for desalination plant operation are a very small fraction of the reproductive output of the source populations of marine organisms inhabiting the intake area. For example, for the white croaker – a fish frequently encountered in the intake area – the potential larval losses (fecundity losses) are 3.6 million larvae, which are comparable to the total lifetime fecundity (reproductive yield) of a single female fish.

To study the behavioral responses of different species swimming near or contacting the wedgewire screens, two underwater video cameras were installed to view the surface of the screens during operation. One camera was oriented to provide a lengthwise view of the screen's surface while a second camera videotaped a top view of the screen's surface. Videos were displayed and recorded to a digital video recorder (DVR) when the intake pump was operated. Figures 8, 9 and 10 present still photographs from the impingement video. The video footage shows that all fish, amphipods, and shrimps that encountered the screen were able to free themselves after contacting the screen. The video observations allow the conclusion that operating the wedgewire screen intake at a through-screen velocity of 0.33 fps eliminates impingement.

Source: Tenera Environmental

Figure 8 – Rockfish Sitting on Screen

Source: Tenera Environmental

Figure 9 – Shrimps Swimming Near Screen

Source: Tenera Environmental

Figure 10 – School of Juvenile Rockfish Swimming Near Screen

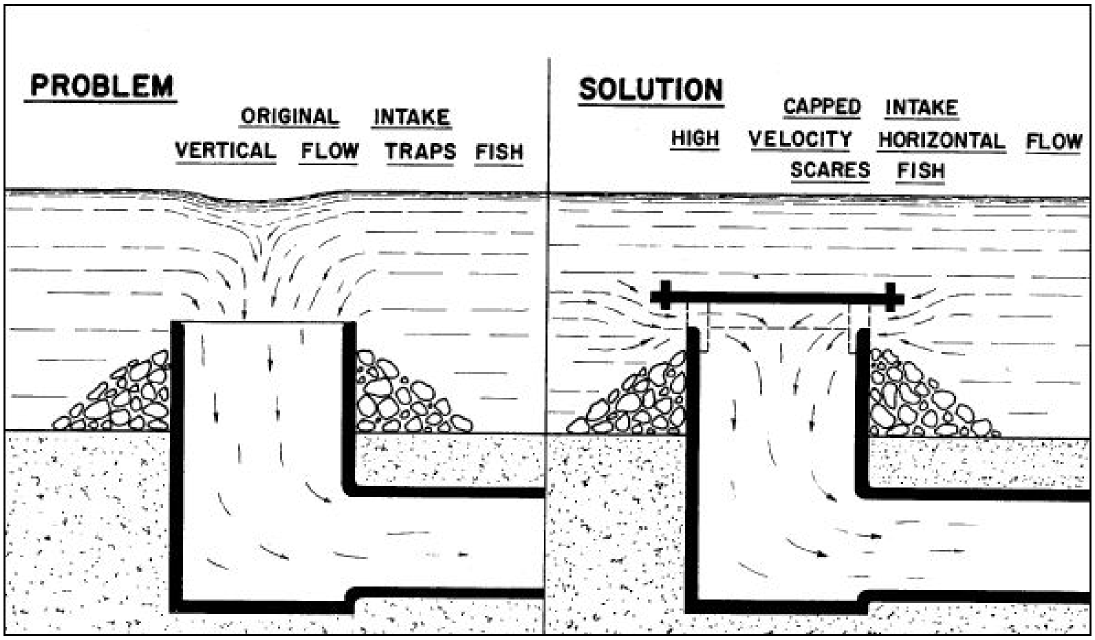
A wedgewire screen intake I&E study has also been completed at the Marin Municipal Water District SWRO pilot plant near San Francisco, CA[18]. The results of this study indicated that no impingement was observed and the larval entrainment losses were found to be less than 0.2% of the total larval population in the intake area of the desalination plant. The use of cylindrical wedgewire screens is also currently being tested at the West Basin Municipal Water District seawater desalination demonstration plant in California.

Offshore Intake Velocity Cap

A velocity cap is a configuration of the open intake structure that is designed to change the main direction of water withdrawal from vertical to horizontal (see Figure 11). This configuration is beneficial for two main reasons: (1) it eliminates vertical vortices and avoids withdrawal from the more productive aquatic habitat which usually is located closer to the surface of the water body; and (2) it creates a horizontal velocity pattern which gives juvenile and adult fish an indication for danger – most fish have receptors along the length of their bodies that sense horizontal movement because in nature such movement is associated with unusual conditions. This natural indication combined with maintaining low through-screen velocity (0.5 fps or less) provides fish in the area of the intake ample warning and opportunity to swim away from the intake.

The velocity cap intake configuration has a long track record and is widely used worldwide. This is the original configuration of many power plant intakes in Southern California and of all new large seawater desalination plants in Australia, Spain, and Israel constructed over the last five years. Based on a US EPA technology efficacy assessment, velocity caps could provide over 50% impingement reduction and can minimize entrainment and entrapment of marine species between the inlet structure and the fine plant screens[19].

[18] http://www.marinwater.org/controller?action=menuclick&id=446
[19] http://www.epa.gov/waterscience/316b/phase1/technical/ch5.pdf



Source: US EPA

Figure 11 – Velocity Cap for Entrainment Reduction

As indicated previously, open intakes may also exhibit an *entrapment* effect – fish and other marine organisms that are drawn into the offshore conduit cannot return back to the open ocean because they are stranded between the intake inlet structure and the downstream fine screens. The use of velocity caps and low velocity through both the coarse screen of the intake structure and the downstream fine screens could reduce this entrapment effect.

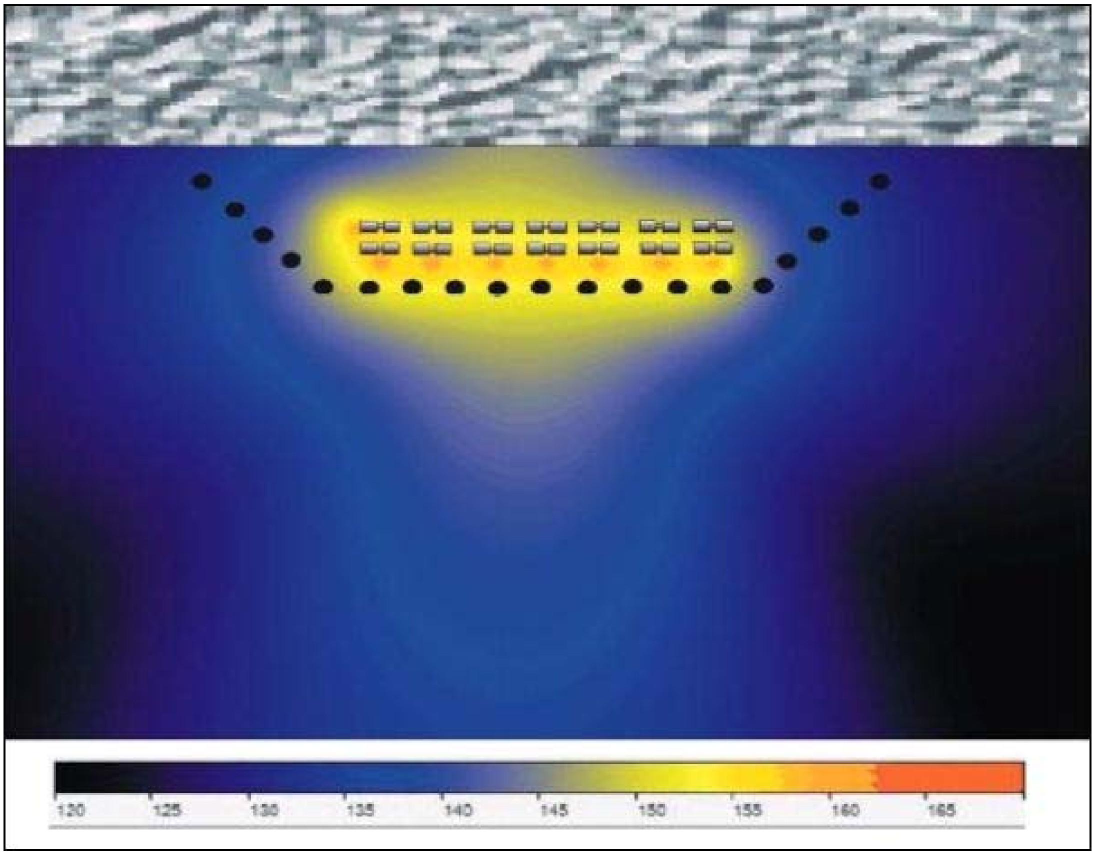
<u>Other Impingement and Entrainment Reduction Technologies</u>

In addition to the intake technologies described above, there are a number of other technologies which have been demonstrated to reduce the impingement and entrainment of open intake operations, mainly based on testing at existing power plant intakes. Table 1 below provides a summary of such technologies. Not all of the technologies listed in the table can meet the US EPA performance targets under all conditions and circumstances or deliver both impingement and entrainment benefits. However, if needed, these technologies could be used in synergistic combination to achieve project-specific environmental impact reduction targets. Some of the technologies listed in Table 1 (such as velocity caps, acoustic barriers, wedgewire screens and fine mesh travelling screens) have found full-scale applications for recently implemented seawater desalination projects. In mid-2011, the WateReuse Research Foundation initiated a research study to document and evaluate the impingement and entrainment reduction efficiency of these and other technologies (WateReuse-10-04).

Table 1 – Potential Open Intake Impingement and Entrainment Reduction Technologies

Type of I&E Reduction Measures	How Do They Work?	Technologies	Impact Reduction Potential	
			Impingement	Entrainment
Physical Barriers	By Blocking Fish Passage and Reducing Intake Velocity	• Wedgewire Screens • Fine Mesh Screens • Microscreening Systems • Barrier Nets • Aquatic Filter Barriers	Yes	Yes
Collection & Return Systems	Equipment is Installed on Fine Screens for Fish Collection and Return to the Ocean	• Ristroph Travelling Screens • Fine Mesh Travelling Screens	Yes	No
Diversion Systems	Devices Which Divert Fish from the Screens and Direct Back to the Ocean	• Angled Screens with Louvers • Inclined Screens	Yes	Yes
Behavioral Deterrent Devices	Repulsing Organisms from the Intake by Introducing Changes that Alert Them	• Velocity Caps • Acoustic Barriers • Strobe Lights • Air Bubble Curtains	Yes	No

An example of the synergistic use of I&E reduction technologies is the previously referenced 40 MGD Beckton desalination plant in London. Besides wedgewire screens, the intake structure of this plant is equipped with an acoustic fish deflection system. This system includes eight low frequency sound generation units that deflect fish movement away from the wedgewire intake structure (Figure 12). The scale at the bottom of this figure indicates the sound level of the acoustic fish deflection system in decibels (dB). The low frequency (25 – 400 Hz) sound level is maintained at a level of 150 dB or more, which gives a clear cue for danger to fish entering the area of the intake. This acoustic system is only operated for short periods, twice daily, during pump startup. At this time, no published data are available regarding the I&E reduction efficiency of this technology.



Source: Acciona Agua

Figure 12 – Beckton Desalination Plant Intake Acoustic Fish Deflection System

Fine mesh screens are one of the technologies equally popular for both seawater desalination and power plant intakes. One type of fine mesh screen associated with the operations of the 25 MGD Tampa Bay seawater desalination plant is shown on Figure 13. This desalination plant is collocated with the 1200 MW Big Bend Power Plant and uses cooling water from this plant as source seawater for desalination. The Tampa Bay desalination plant does not have a separate seawater intake. However, the intake of the power plant is equipped with 0.5-mm Ristroph fine-mesh screens, which have been proven to reduce impingement and entrainment of fish eggs and larvae through the downstream conventional bar and fine screens of the power plant intake by over 80%[20].

Unfortunately for the desalination plant, these screens are periodically bypassed (as allowed by permit) and/or screenings are conveyed to the power plant discharge outfall from where the desalination plant collects source seawater. As a result, the screenings can find their way to the desalination plant intake and impact desalination plant pretreatment system performance. This challenge necessitated the need for the remediated desalination plant to be equipped in 2005 with another set of fine screens located just upstream of the pretreatment facilities.

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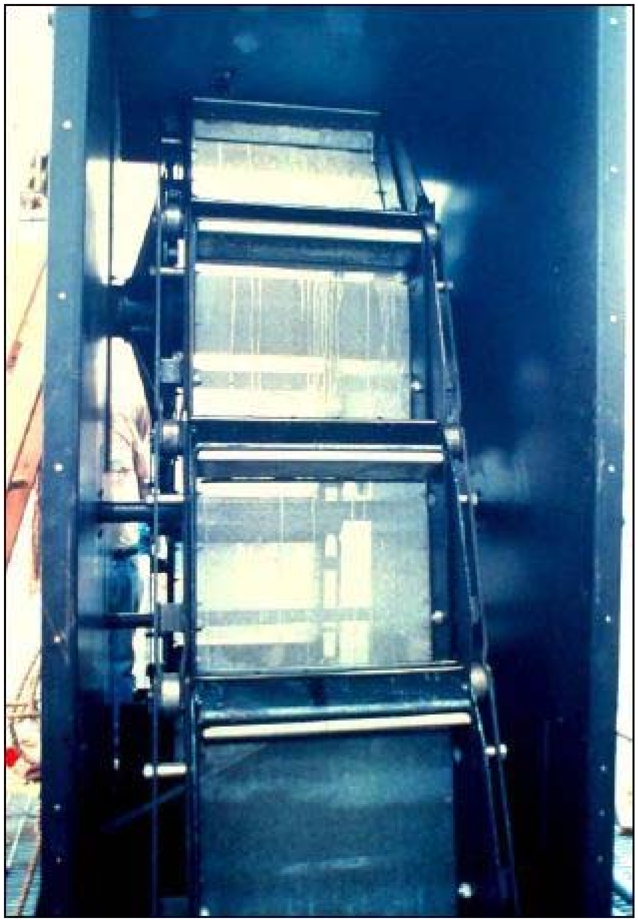
[20] http://www.epa.gov/waterscience/316b/phase1/technical/ch5.pdf



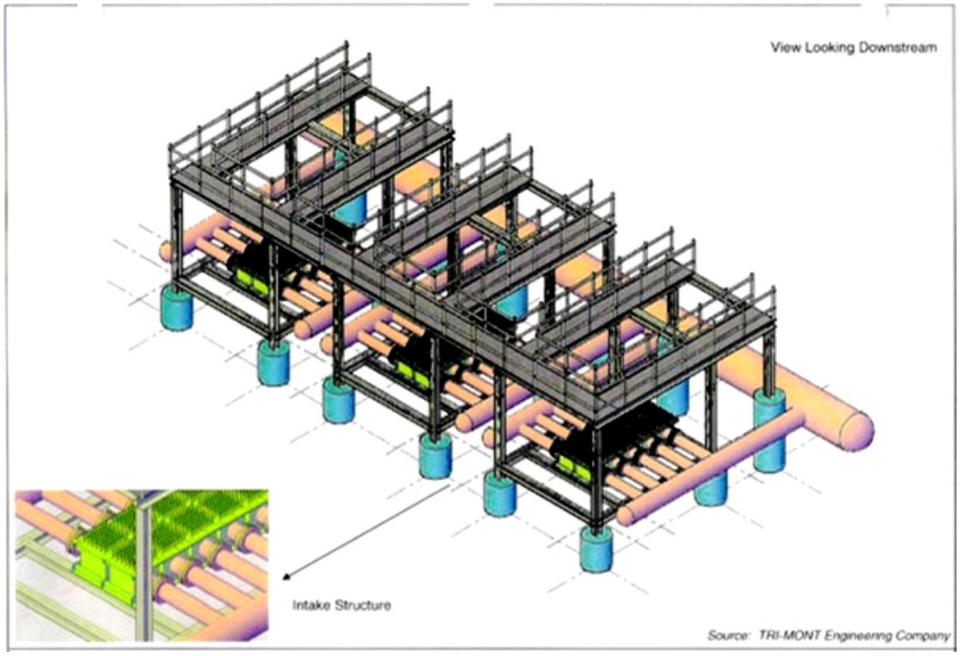
Source: Water Globe Consulting

Figure 13 – 0.5 mm Fine Mesh Screens of the Tampa Bay Power Plant Intake

Another example of a full-scale implementation of an intake with advanced impingement and entrainment reduction features is the Filtrex Filter Intake System of the 10 MGD Taunton River Desalination Plant in Dighton, Massachusetts (Figure 14). This plant is planned to be constructed in two 5 MGD phases. The 30 MGD intake system for this plant is comprised of 30 racks with 96, 4.6-inch long individual plastic filtration modules (candles) per rack, through which saline water is withdrawn.

The candles have a pore size of 0.04 mm (40 microns) and very low (0.2 feet/sec) through-pore velocity. These intake features allow complete avoidance of the impingement of adult fish; a reduction of impingement of fish eggs down to less than 15%; and a minimization of entrainment of larval organisms and fish eggs to less than 3% of the species in the intake area[21]. It should be pointed out that this type of screen has a limited track record because the plant began operation in November 2008 and has not been operating at its full 5 MGD production capacity as of yet.

[21] http://www.watereuse.org/sites/default/files/u8/Quote%2021.pdf



Source: TRI-MONT Engineering Company

Figure 14 – Taunton River Desalination Plant Intake

Environmental Impact Mitigation Measures

Environmental impact mitigation is typically applied if the site, design, and technology measures described above do not provide adequate impingement and entrainment reduction to sustain the biological balance of the marine habitat in the area of the intake. Examples of types of activities that may be implemented by desalination facilities to provide environmental impact mitigation include:

- Wetland Restoration;
- Coastal Lagoon Restoration;
- Restoration of Historic Sediment Elevations to Promote Reestablishment of Eelgrass Beds;
- Marine Fish Hatchery Enhancement;
- Contribution to a Marine Fish Hatchery Stocking Program;
- Artificial Reef Development; and
- Kelp Bed Enhancement.

The type and size of the mitigation alternative or combination of alternatives most suitable for a given project are typically selected to create a new habitat capable of sustaining types of species and levels of biological productivity comparable to those lost as a result of the intake operations.

Coastal wetlands are the nursery areas for many of the species impacted by desalination intakes. Wetland restoration is, therefore, a common mitigation measure for large seawater intake systems. For example, development of new coastal wetlands is the preferred impingement and entrainment mitigation alternative for the 50 MGD Carlsbad seawater desalination project in California.

The time and cost expenditures involved in the permitting, implementation, maintenance, and monitoring of such mitigation measures are significant, and such habitat restorative measures are typically used when the impingement and entrainment reduction measures described in the previous sections are not readily available or viable for a given project.

Some environmental groups do not consider mitigation as an acceptable I&E management alternative and have challenged the legality of the use of I&E mitigation measures for both power plant and desalination plant intakes. Court resolutions to recent legal challenges associated with the permitting of the 50 MGD Carlsbad and Huntington Beach SWRO projects, however, indicate that mitigation by environmental restoration is a viable method for supplementing the use of best technologies available and operational measures to address the potential environmental impacts associated with collecting seawater for desalination.

CONCLUDING REMARKS

In summary, appropriately sited, designed, and operated seawater desalination plant intakes can have minimal environmental impacts on the marine environment and resources. In fact, based on recent studies, impingement and entrainment resulting from well-planned and designed open ocean intakes would be minor: the equivalent of the daily food intake of one pelican and the loss of the annual bio-productivity of five adult female halibut, respectively. Ongoing developments in impingement and entrainment reduction technology, combined with the existing wealth of knowledge and experience in this field, both domestically and internationally, pave the way for maintaining sustainable and environmentally safe production of fresh water from the ocean. With over 20 years of successful operational experience at more than 8000 desalination plants worldwide, seawater desalination is currently a well-established drinking water production technology of proven performance which will play an increasingly prominent role in well balanced and sustainable water supply portfolios of coastal communities in the US and abroad.

Attachment 2: WateReuse Association. 2011b. Overview of Desalination Plant Intakes Alternatives.

Attachment 3: Poseidon Resources. 2004. Carlsbad Seawater Desalination Project Alternatives to the Proposed Intake. Appendix C of Final EIR to the California Coastal Commission, March 2, 2004.

CARLSBAD SEAWATER DESALINATION PROJECT
ALTERNATIVES TO THE PROPOSED INTAKE
Poseidon Resources Corporation
March 2, 2004

Alternative Project Intake Source Water Collection Systems – Beach Wells, Infiltration Galleries and Seabed Filtration Systems

Introduction

As described in section 3.0 of this EIR the proposed intake source water collection system includes a connection of the intake pipeline of the desalination plant to the existing cooling water discharge lines of the Encina power plant. The power plant collects cooling water directly from the ocean via the Agua Hedionda Lagoon intake structure, screens the seawater through 3-inch bar rack screens followed by 3/8-inch fine screens, and than pumps it through the power plant condensers for cooling. The cooling water is than conveyed via discharge canal to the power plant discharge structure from where it is directed to the ocean. Since the desalination plant intake is connected to the power plant discharge canal downstream from the condensers, the RO plant intake seawater is pre-screened by the power plant screening facilities. The desalination plant intake facility is equipped with microscreens located immediately downstream of the point of interconnection with the power plant discharge canal, which would effectively remove all particulates and marine organisms larger than 120 microns (0.005 inches) prior to the entrance of the seawater in the seawater desalination plant. This type of intake minimizes entrainment of organisms in the RO plant downstream treatment facilities.

Alternative Subsurface Systems

Since the proposed intake system for the Carlsbad desalination project is essentially an open ocean intake, alternative intake systems considered for the project are three most common subsurface type intake systems: beach wells, infiltration galleries and seabed filtration systems. The subsurface intake facilities provide the key advantage that the source water they collect is pretreated via slow filtration through the subsurface sand/seabed formations in the area of source water extraction. Therefore, source water collected using subsurface intake facilities is usually of better quality in terms of solids, slit, oil & grease, natural organic contamination and aquatic microorganisms, as compared to open surface water intakes.

The key factors that determine if the use of subsurface intake is practical or/and economical are: the transmissivity/productivity of the geological formation/aquifer; the thickness of the production aquifer deposits; and the existence of nearby fresh water source aquifers, which could be negatively impacted by the subsurface intake system operations or have measurable effect on beach well water quality.

Intake Wells. Intake wells are typically vertical or horizontal water collectors drilled in the source water aquifer. The type of horizontal collector wells most widely used for large subsurface intakes is referred to as Ranney wells.

Vertical Intake Wells. This type of wells consist of a non-metallic casting (typically, fiberglass reinforced pipe), well screen, and a stainless steel submersible or vertical turbine pump. The well casting diameter is between 6 inches and 18 inches, and well depth does not usually exceed 250 feet. The vertical intake wells are usually less costly than the horizontal wells but their yield is relatively small (typically, 0.1 to 1.0 MGD).

Vertical Intake Well Fatal Flaw Analysis. Because the amount of intake source water required for the Carlsbad seawater desalination plant is approximately 106 MGD, under best case scenario (vertical wells of 1.0 MGD capacity) the number of vertical wells needed exceeds 100. The construction and operation of such large number of vertical wells is not practical and feasible due to the significant number of pumps and control equipment associated with the operation of the vertical wells. Because of this fatal flaw, the use of vertical intake well facilities for this project is not further analyzed.

Horizontal (Ranney) intake wells consist of a caisson that extends below the ground surface with water well collector screens (laterals) projected out horizontally from inside the caisson into the surrounding aquifer (see Figure 1).

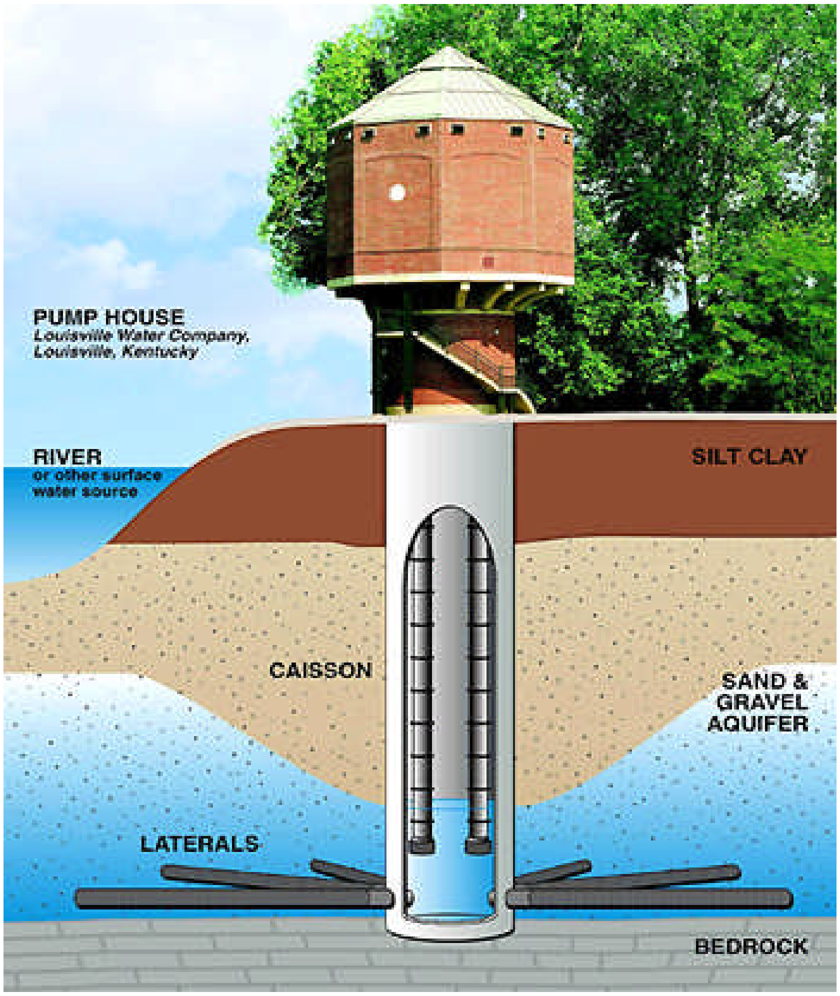


Figure 1 – Horizontal (Ranney) Beach Well

Since the well screens in the collector wells are placed horizontally, higher rate of source water collection is possible than with vertical wells. This allows the same intake water quantity to be collected with fewer wells. Individual horizontal intake wells are typically designed to collect between 0.5 MGD and 5.0 MGD of source water. The caisson is constructed of reinforced concrete that may be between 10 feet to 30 feet inside diameter with a wall thickness from approximately 1.5 to 3 feet. The caisson depth varies according to site-specific geologic conditions, ranging from approximately 30 feet to over 150 feet. The number, length and location of the horizontal laterals are determined based on a detailed hydrogeological investigation. Typically the diameter of the laterals ranges from 8 to 12 inches and their length extends up to 200 feet. The size of the lateral screens is selected to accommodate the grain-size of the underground soil formation. If necessary, an artificial gravel-pack filter is installed around the screen to suit finer-grained deposits.

In large intake applications, such as this shown on Figure 2, the horizontal beach wells are typically coupled with the intake pump station installed above the well caisson. Figure 2 shows one of the three 3.8 MGD horizontal (Ranney) intake beach wells for the largest existing seawater desalination plant located on the Pacific Ocean coast in North America – the 3.8 MGD water supply facility for the Pemex Salina Cruz refinery in Mexico.

Figure 2 – 3.8 MGD Horizontal Seawater Intake Beach Well

For the site specific conditions of the Carlsbad seawater desalination project, the minimum number of individual horizontal beach wells required is 25. This number is determined taking under consideration that the total intake capacity of the desalination plant is 106 MGD; the hydrogeological conditions are very favorable and therefore an individual well can yield 5 MGD of intake water; and that an additional 20 % well standby capacity is incorporated in the intake system design to account for well capacity decrease over the 30-year period of the useful life of the project and for well downtime due to routine maintenance ((106 MGD/5 MGD per well) x 1.2 = 25).

Horizontal Beach Well Fatal Flaw Analysis. The horizontal beach wells have to be located on the seashore, in close vicinity (usually within several hundred feet) of the ocean. Because of the high number of wells needed to supply adequate amount of water for the Carlsbad seawater desalination plant, construction of these facilities would result in disturbance of a significant amount of seashore beach area. Figure 3 shows the approximate size and configuration of a horizontal beach intake well system for a 10 MGD seawater desalination plant with 5 intake wells.

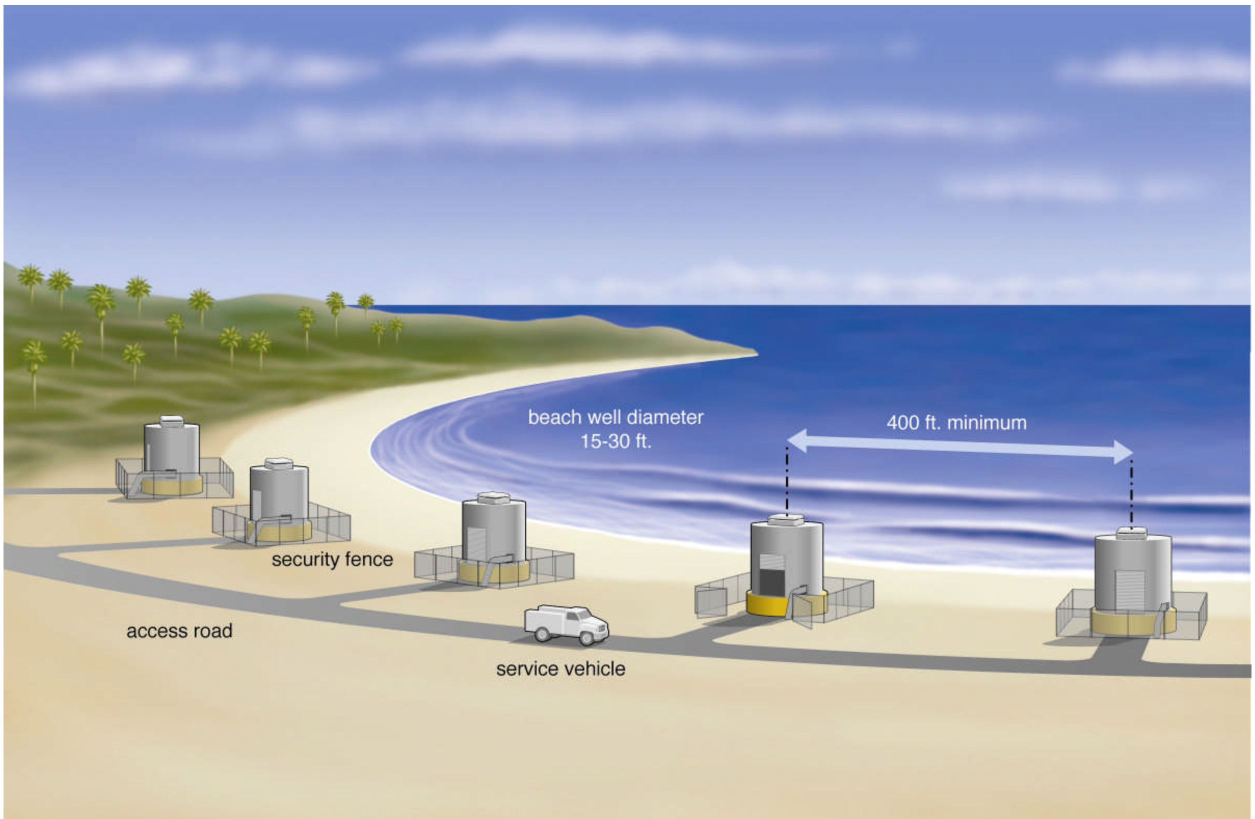


Figure 3 – A Horizontal Beach Well System for 10 MGD Desalination Plant

For 25 horizontal beach wells of individual capacity of 5 MGD, and a minimum distance between the individual wells of 400 ft, the footprint of the beach well impacted seashore area would be at least 100 ft wide by 10,000 feet long (400 ft x 25 wells = 10,000 feet (approx. 2 miles). Therefore, the minimum area of seashore impact as a result of construction of horizontal beach wells for the 50 MGD Carlsbad seawater desalination plant would be (100 ft x 10,000 ft = 1.0 MM sq ft (23 acres)). Figure 4 gives a general representation of the seashore area in front of the Encina power plant which would be impacted by the construction of a beach well intake system for the Carlsbad seawater desalination plant. The portion of the seashore shown on

Figure 4 is only approximately 3,000 feet long. As discussed previously, total length of the impacted seashore area will be 2 miles.

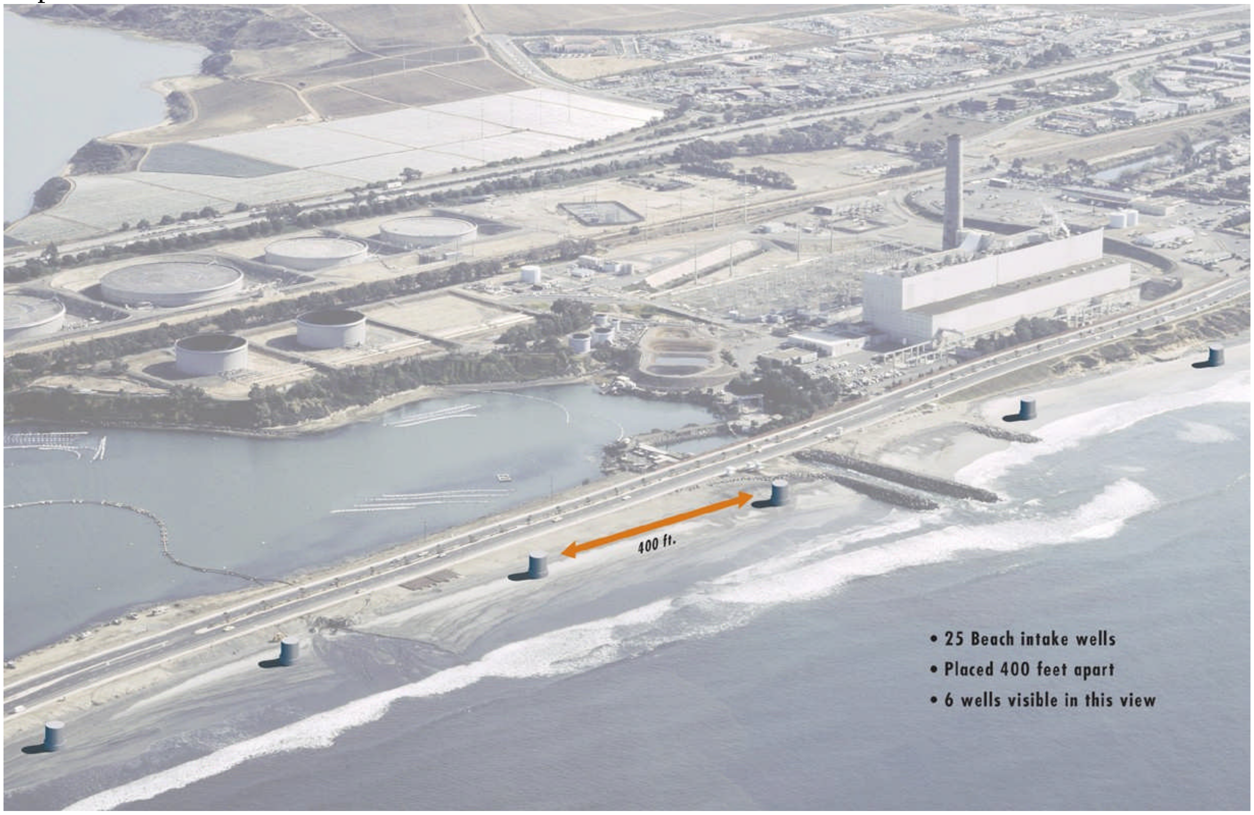


Figure 4 – Beach Well Intake Configuration for the Carlsbad Desalination Plant

Disturbing a two-mile strip of the City of Carlsbad seashore beach to install 25, 20 to 30-feet diameter intake wells for the Carlsbad Desalination Plant will have a measurable negative impact on the biological resources of the beach, which provides a habitat for marine organisms that a key food source for a number of seashore birds.

The intake beach wells for the Carlsbad seawater desalination plant will be constructed as large-diameter caissons and will be tall above-ground concrete structures that would have a visual and aesthetic impact on the shore line (see Figure 3). The pumps and service equipment conveying the water from a large-size beach wells would be located above the wet-well of the caisson. Taking under consideration that the beach wells are located in a close proximity of the ocean, the well intake pumps have to be installed at such an elevation that assures the protection of the well intake pumps and associated auxiliary equipment from flooding. Therefore, the height of the structures of the large plant intake wells with above-grade pump houses would exceed 10 feet above the beach ground level (see Figures 1 through and 3).

For a relatively small-size beach wells the caisson/vertical well collector can be build water-tight and located below grade to minimize visual impact. However, the size and servicing of the well pumps, piping, electrical, instrumentation and other auxiliary equipment of large-capacity wells in this case dictates the location of their pump house to be above grade. Although the above-grade pump house could be designed in virtually any architectural stile, this facility and its service roads and controlled access provisions would change the visual landscape of the seashore (see Figure 3). Taking under consideration that the desalination plant intake equipment and source water has to be protected from acts of vandalism and terrorism, the individual beach wells would have to be fenced-off or otherwise protected from unauthorized access. The large and tall fenced-off beach well concrete structures would have a limited visual and aesthetic appeal. Since the City of Carlsbad public beaches are visually sensitive areas, the installation of large beach wells will affect the recreational and tourism use and value of the City beaches, and will significantly alter beach appearance and character (see Figure 3).

The magnitude of the impact of a beach well intake system on the biological resources of the City beaches and the significant visual and aesthetic alteration of the beach appearance and aesthetic value are considered fatal flows for implementation of intake beach wells for the Carlsbad seawater desalination project.

For comparison, if the desalination plant is co-located with an existing power plant station, as proposed in the base project alternative, the City of Carlsbad coastal beach zone and environment would not be disturbed with the installation of additional structures, equipment and associated service infrastructure (access roads, fences, electrical supply equipment, etc.).

Infiltration Galleries. Infiltration galleries are typically implemented when conventional horizontal or vertical intake wells cannot be used due to unfavorable hydrogeological conditions. For example, they are suitable for intakes where the permeability of the underground soil formation is relatively low, or in the case of river or seashore bank filtration, where the thickness of the beach or the onshore sediments is insufficient to develop conventional intake wells. The infiltration galleries consist of an excavation trench which is filled up with filtration media of size and depth similar to that of the granular media filters used for conventional water treatment plants. Vertical or horizontal collector wells are installed in equidistance (usually 100 to 200 feet) inside the filter media. Typically the capacity of a single collection well is 0.2 to 2.0 MGD. The most common type of infiltration gallery is a horizontal well collection system with a single trench (Figure 5).

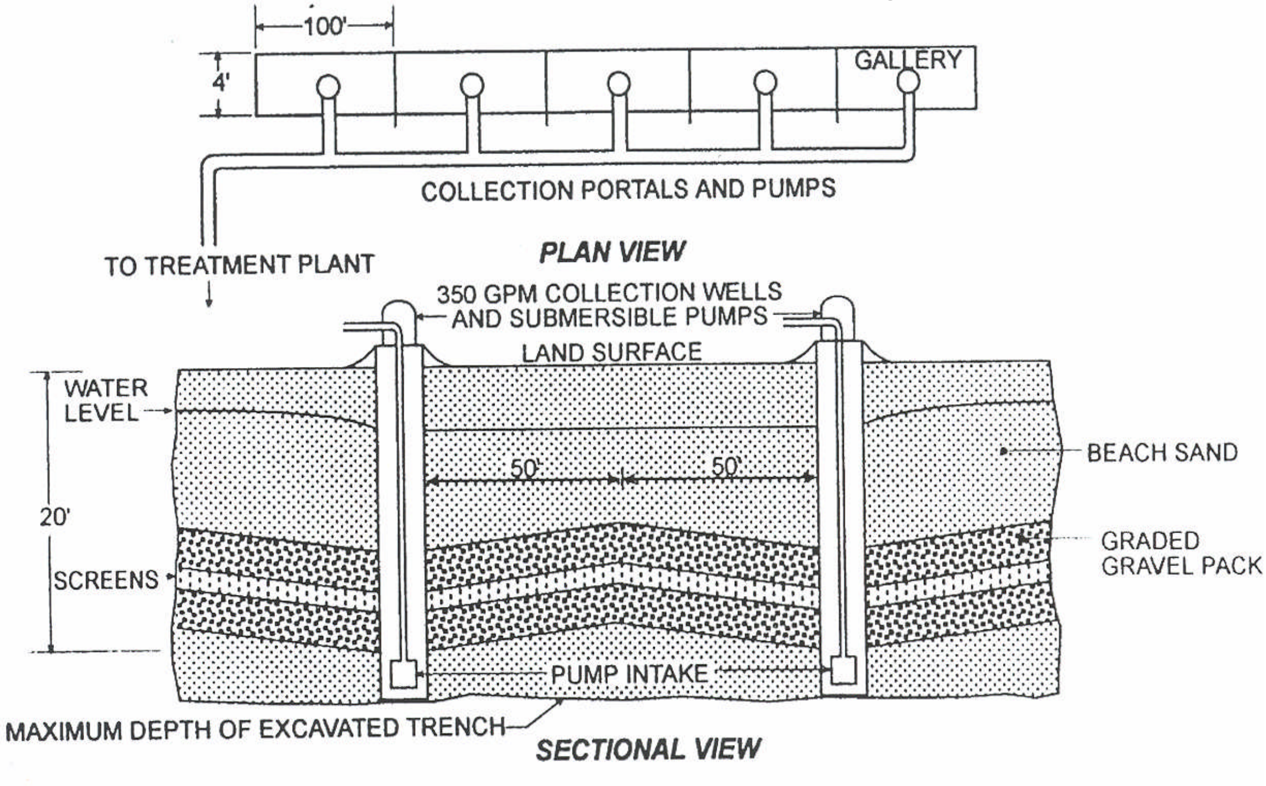


Figure 5 – Infiltration Gallery

The media in the infiltration gallery is configured in three distinctive layers: a bottom layer of sand media of approximately 3 to 6 feet, followed by a 4 to 6 feet layer of graded gravel pack surrounding the horizontal well collector screens; topped by a 20-foot to 30-foot layer of sand. The horizontal well collector screens are typically designed for inflow velocity of 0.1 ft/sec or less.

The infiltration galleries could be designed either similar to conventional rapid sand filters (if the natural ocean water wave motion can provide adequate backflushing of the infiltration gallery media) or could be constructed as slow sand filtration systems, which have at least a 30-feet layer of sand overlying the collection well screens. Infiltration galleries are usually 15 to 20 % more costly to construct than conventional intake wells and therefore, their use is warranted only when the hyrogeological conditions of the intake site are not suitable for intake wells.

The infiltration gallery shown on Figure 5 is 500 feet long, 4 feet wide and can deliver intake flow of 2.5 MGD, which is adequate to provide source water for 1 MGD seawater desalination plant. This system consists of four 0.5 MGD duty intake wells and one 0.5 MGD standby intake well. The infiltration gallery needed for the 50 MGD Carlsbad seawater desalination plant will be 50 times longer than that shown on Figure 5 and will have a total length of 25,000 feet (4.7 miles). In order to install this infiltration gallery on the City of Carlsbad shore, a beach strip 4-foot wide and 4.7-foot long has to be excavated at a depth of approximately 30 feet. This massive excavation work will yield 3 million cubic feet (approximately 14,000 cubic yards) of beach sand excavation debris, a portion (10 to 20 %) of which have to be transported and disposed off site.

Due to the large beach strip area that needs to be disturbed (4.7 miles) and excavated (at 30 feet depth), the impact of the installation of the infiltration gallery on the City beaches will be very significant. Disposal of over 0.3 to 0.6 million cubic feet of beach sand will also be a challenging task. In addition, the construction of this intake beach gallery will require the construction of 50 intake wells along the 4.7-mile long beach strip, which will cause measurable visual and aesthetic impact on the City beach. The significant environmental and other impacts of the construction of intake infiltration gallery for the Carlsbad desalination project render the use of infiltration galleries for this project fatally flawed.

Seabed Filtration Systems. These subsurface intake systems consist of a submerged slow sand media filtration system located at the bottom of the ocean in the near-shore surf zone, which is connected to a series of intake wells located on the shore (see Figure 6).

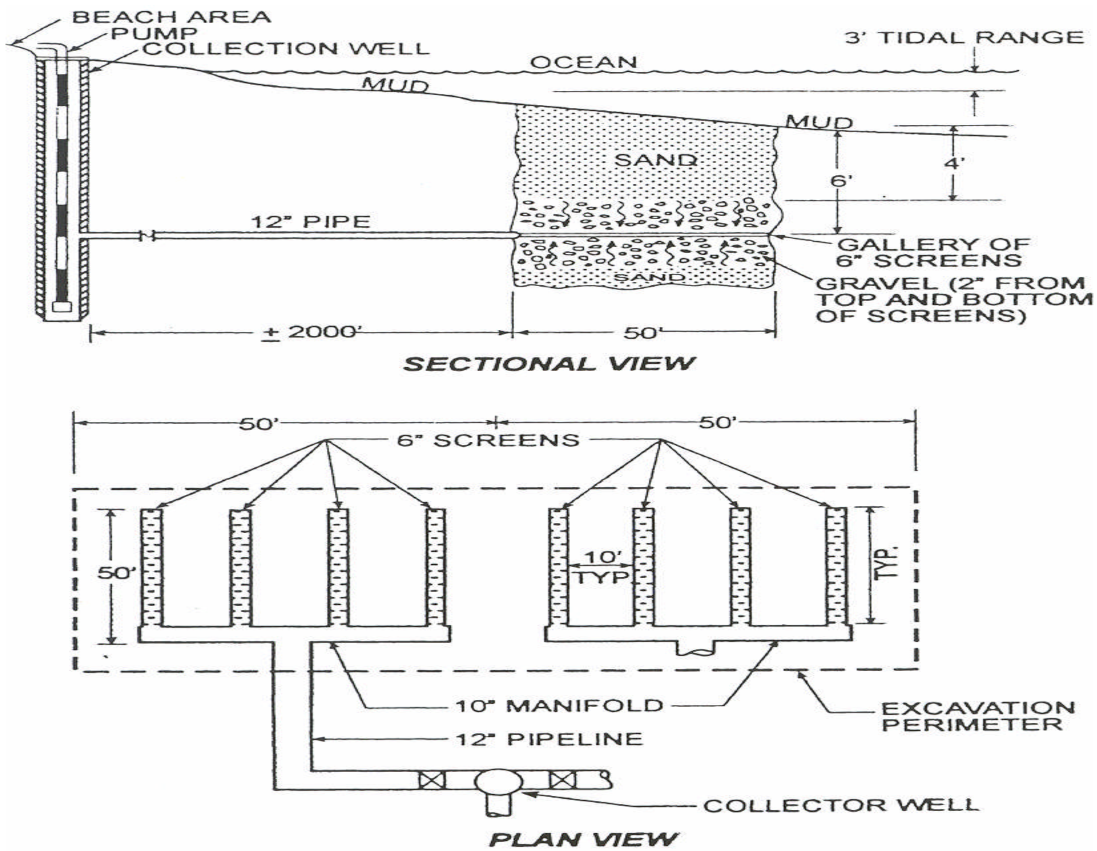


Figure 6 – Seabed Filtration System

As such, seabed filter beds are sized and configured using the same design criteria as slow sand filters. The design surface loading rate of the filter media is typically between 0.05 to 0.10 gpm/sq ft. Approximately 1 inch of sand is removed form the surface of the filter bed every 6 to 12 months for a period of three years, after which the removed sand is replaced with new sand to its original depth. Typically, seabed filtration systems are the costliest subsurface intake systems. Their construction costs are approximately 1.2 to 2.3 times higher than these of the conventional intake wells. In terms of overall cost of water (including both the capital and O&M components) the seabed filtration systems are usually more costly than any of the other type of subsurface intakes. As seen on figure 6, the ocean floor has to be excavated to install the intake piping of the wells. These pipes are buried at the bottom of the ocean floor excavation pit (see Figure 7).

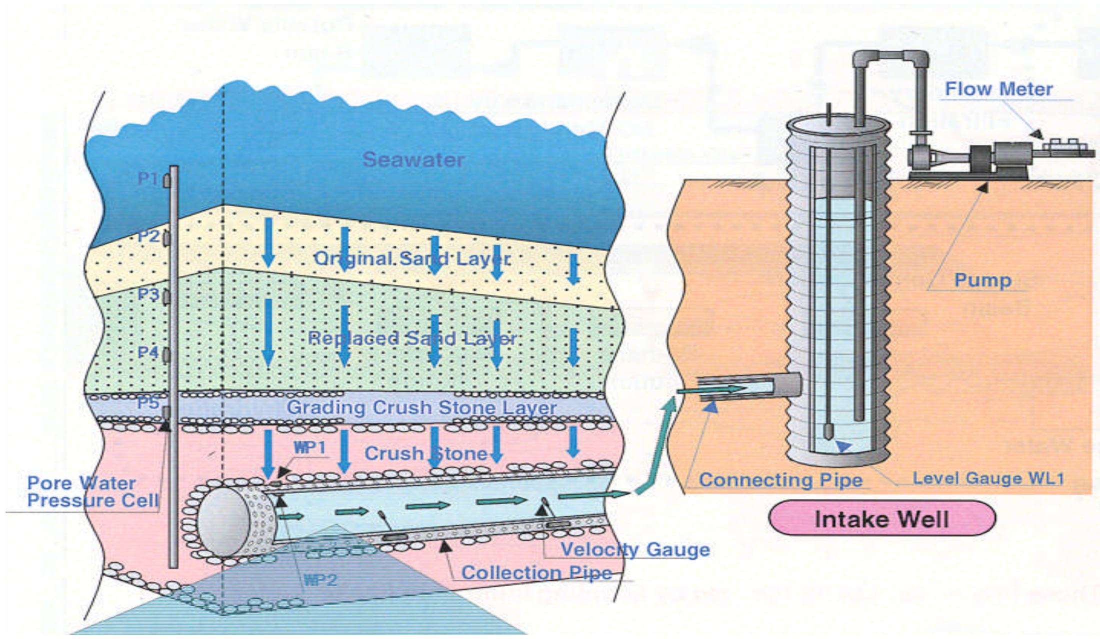


Figure 7 – A Cross-Section of a Seabed Intake System

For the source water intake feed rate of 106 MGD (74,000 gpm) needed for the Carlsbad seawater desalination project and a typical seabed design surface loading rate of 0.07 gpm/sqft, the total area of the ocean floor needed to be excavated to build a seabed intake system of adequate size is 24.3 acres (74,000 gpm/0.07 gpm.sq ft = 1,057,000 sq ft = 24.3 acres). Assuming that the seabed is 200 feet wide, this translates to impact of on the ocean floor of over one mile (1,057,000 sq ft /200 ft = 5,285 ft). The excavation of 24.3 acre/1-mile long strip of the ocean floor in the surf zone to install a seabed filter system of adequate size to supply the Carlsbad Desalination project, will result in a very significant impact on the benthic marine organisms in this location (see Figure 8). In addition, the use of this system will have a similar effect on the City beach, because the implementation of this intake system would also require installation of beach wells that collect the intake water prior to transferring it to the seawater desalination plant for further treatment.

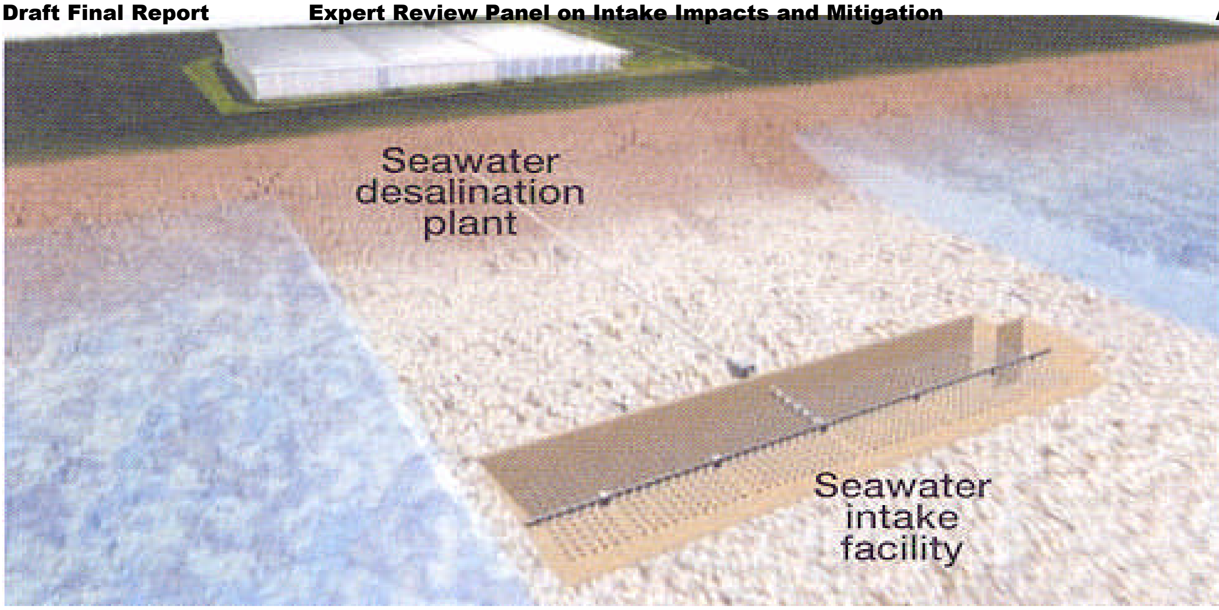


Figure 8 – Zone of Impact of the Seabed Intake System of the Ocean Floor

Currently, there are no existing large seawater desalination plants (with capacity over 5 MGD) using seabed intake systems. The largest seawater desalination plant with a seabed intake system currently under construction is the 13.2 MGD Fukuoka District RO facility in Japan. This plant is planned to be operational in late 2005. The Fukuoka seawater desalination plant seabed intake area is 312,000 sq ft. Taking under consideration that the Carlsbad seawater desalination plant is approximately 3.8 times larger in capacity, the corresponding surface are for this intake would be 1,185,600 sq ft. This comparison indicates that the estimated area of seafloor impact could actually be even higher than that presented in the estimates given above.

Seabed Intake Fatal Flaw Analysis. The significant environmental impacts on the benthic organisms of the 24.3 acre/1-mile long strip of the ocean floor in the surf zone along with the beach seashore impacts of installing intake collection wells that service the seabed intake are fatal flows for the practical implementation of this intake system for the Huntington Desalination Project. Additional issue that makes this system not viable is the fact that the seabed intake will be collecting seawater from the surf zone, which based on a number of third party studies (such as the Komex study) and the sanitary survey completed for this project, indicate that the level of coli bacteria in the surf zone is several orders of magnitude higher than that in the area of the power plant intake, which is approximately 1,400 feet away from the surf zone, i.e. co-location of the desalination plant intake with the power plant discharge under the proposed base scenario will likely yield much better quality source seawater in terms of bacterial content than the source water collected via the seabed intake.

Summary Comparison Between Base and Beach Well Intake Alternatives

The detailed analysis of common alternative subsurface intake systems (beach wells, infiltration galleries and seabed intakes) presented above clearly indicates that these systems are not viable for the site-specific conditions and size of the Carlsbad seawater desalination plant. Although beach wells have proven to be quite economic for desalination plants of capacity smaller than 1 MGD, open surface ocean intakes have found significantly wider application for large seawater reverse osmosis (SWRO) desalination plants. At present, worldwide there are only four operational SWRO facilities with capacity larger than 5.3 MGD using beach well intakes. The largest SWRO facility with beach wells is the 14.3 MGD Pembroke plant in Malta. This plant has been in operation since 1991. The 11 MGD Bay of Palma plant in Mallorca, Spain has beach wells with capacity of 1.5 MGD each. The third largest plant is the 6.3 MGD Ghar Lapsi SWRO in Malta. Source water for this facility is supplied by 15 vertical beach wells with unit capacity of 1.0 MGD.

As mentioned previously, the largest SWRO plant in North America which obtains source water from beach wells is the 3.8 MGD water supply facility for the Pemex Salina Cruz refinery in Mexico. This plant also has the largest existing seawater intake wells – three Raney-type radial collectors with capacity of 3.8 MGD, each. In addition, currently there are no operational large-scale (with capacity of 5 MGD or above) seawater desalination plants worldwide, which use infiltration galleries or seabed systems for collecting source water for seawater desalination plants.

In summary, the key factors that render the use of beach wells, infiltration galleries and seabed systems unfeasible for the Carlsbad desalination project are:

- Significant site impact of a large portion of the City beaches caused by the need for large excavation works.

- Measurable impact on the shore or benthic marine organisms in the area of the intake.

- Visual and aesthetic impacts that will change the character, appearance and recreational value of the City beaches.

- Lack of full-scale experience with seawater desalination plants of similar size to the Carlsbad desalination project, which use beach wells, infiltration galleries and seabed systems.

Additional factor which contribute to rendering these alternatives not feasible for this application is the oxygen concentration of the desalination plant discharge. Based on our previous experience, beach well water typically has a very low dissolved oxygen (DO) concentration. The DO concentration of this water is usually less than 2 mg/l, often it varies between 0.2 and 1.5 mg/L. The RO treatment process does not add appreciable amount of DO to the intake water. Therefore, the RO system product water and concentrate have the same or lower DO concentration. Low DO concentration of the product water will require either product water reaeration or will result in significant use of chlorine.

Since the low DO concentrate from the well intake desalination plant is to be discharged to the ocean, this discharge will not be in compliance with the United States Environmental Protection Agency's daily average and minimum DO concentration discharge requirements of 4 mg/L and 5 mg/L, respectively. Because this large desalination plant using intake wells would discharge a significant volume of low-DO concentrate, this discharge could cause oxygen depletion and significant stress to aquatic life. Therefore, this beach well desalination plant concentrate has to be re-aerated before surface water discharge. For this large desalination plant, the amount of air and energy to increase the DO concentration of the discharge from 1 mg/L to 4 mg/L is significant and would have a measurable effect on the potable water production costs. Discharge of this low DO concentrate to a wastewater treatment plant would also result in a significant additional power use to aerate this concentrate prior to discharge. For comparison the concentrate from RO plant with co-located intake (base EIR alternative) will have DO concentration of 5 to 8 mg/L, which is adequate for disposal to the ocean, without re-aeration.